IPF Batch PowerFlow (BPF) User’s Guide

User Documentation
Interactive Powerflow Program

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CHAPTER 1

INTRODUCTION

1.1 OVERVIEW

The *IPF Batch User's Guide*, derived from the manual developed by the Systems Engineering Branch of the Bonneville Power Administration, describes the usage of BPF, the batch form of WSCC's power flow analysis program, Interactive Power Flow (IPF). It also contains all the details of input data formats, internal modeling, and philosophies used by both the batch and interactive (GUI) versions of IPF.

1.2 PROGRAM HISTORY

Prior to the development of the Interactive Power flow program, BPA developed the Power F low program itself, and the Power System Analysis Package (PSAP). The Power Flow program is a collection of FORTRAN-coded computer programs permitting the analysis of the steady-state operation of an electric power network. This program is part of the Power System Analysis Package. PSAP was developed over a 20-year period and has added many features during this time. These programs were designed for character-based terminals connected to mainframes. However, recent years have seen the creation and maturation of graphical user interfaces (GUI) based on the mouse, windows, and menus. Studies have shown that GUIs are a generally more intuitive and easier-to-use interface than the older character/keyboard-based interface.

Starting in 1991, BPA began a two-way joint development of a GUI interface for the Power Flow program, based upon the X-Window System and the Motif GUI. The joint partners were EPRI and WSCC. The Power Flow program itself was also restructured and enhanced in the process, and a means provided for users to directly access Powerflow variables from an external CFLOW program.

1.3 PROGRAM AND FEATURES

The Interactive Power Flow (IPF) program essentially consists of the Power Flow program part of PSAP and a graphical user interface specially designed for power flow data input, output, and manipulation. These two halves of the IPF program are joined by interprocess communication (IPC) routines that shuttle data and instruction messages back and forth between the GUI and Powerflow program. The Power Flow program serves primarily as a solution and database engine that sends and receives data when requested by the user through the GUI.

The IPF user may choose to interact with the Power Flow program through the windows, menus, dialog boxes, keyboard, and mouse of the GUI. Many of the functions and features of the older batch Power Flow program are available through specially designed GUI features. The new Power Flow Control Language (PCL) is used by the GUI, and is directly available through the GUI Command Dialog and the IPFBAT program. See the IPF Advanced User's Guide for details. However, the BPF program preserves all the traditional "batch run" capabilities, using control files in the old PFC format.

IPF helps electric power system planning and design engineers investigate a given electric power network's various operating parameters, such as:

- Bus voltage distribution.
- Line real and reactive power flows.
- Line overloads.
- System reactive requirements.
- Area interchange control.
- Transformer tap settings.
- Remote-bus voltage controls.
- Effects of load shedding, generator dropping, line outages, etc.

In order to make more efficient use of computer memory space and computation time, the program uses advanced techniques of large-system analysis including the Newton-Raphson method of solution of algebraic equations and sparse-matrix computation techniques.

1.3.1 IPF Features

The IPF program offers many features. These include:

- Free-form structured program command languages (PCL or PFC).
- Extensive error messages for maximum aid to the user.
- Basic and extended power flow capabilities.
- User-selectable printed output reports.
- User-selectable microfiche reports on a fiche file.
- Easy-to-use graphical user interface.
- Easy-to-edit graphical display of coordinate file data.

1.4 CHAPTER SUMMARIES

Chapter 1 Provides a description of IPF, its history, and features.

Chapter 2 Provides a conceptual overview of the IPF package. The input/output model is described along with the program control language. How data flows and is transformed is described.

Chapter 3 Describes all record formats. How changes are made in the records is also presented.

Chapter 4 Describes all batch program control language commands. It also describes the syntax of the language.

Chapter 5 Describes advanced features. Currently, it shows how network reduction is accomplished in the program.

Appendix A Presents examples of batch program control language (PFC) files.

Appendix B Goes through some typical power flow uses.

Appendix C Shows how the Power Flow program models dc lines.

Appendix D Lists ownership codes and names.

Appendix E Lists global (default) voltage limits.

Appendix F Tells how to use the auxiliary batch programs IPFCUT and IPFNET.

Appendix G Describes differences between IPS and IPF input data, and the IPS2IPF data conversion program.

1.5 AUDIENCE

This guide introduces both experienced and inexperienced Power Flow program users to IPF's basic conceptual model, record formats, and program control language. All users need to use this manual; however, neither it nor the rest of the IPF documentation teach basic power flow network concepts. This guide is primarily a reference manual with enough background material to help less experienced Power Flow users accomplish their tasks with the program.

All users will benefit from reading Chapter 2, *IPF Overview*. From there, use the guide as a reference work to look up specific program control language commands and record formats. They are arranged alphabetically.

1.6 IPF DOCUMENTATION

The IPF documentation consists of four manuals:

- The *IPF Basic User's Guide* provides an introduction to the graphical user interface with special emphasis on the X Window System and OSF/Motif. A task-oriented chapter explains how to accomplish common IPF tasks. A reference-oriented chapter describes all the commands available in IPF along with some background conceptual information.
- The *IPF Batch User's Guide* is based on the previous *Power Flow Program User's Manual*. The treatment is mainly conceptual and reference-oriented. These topics are treated in detail: program input and database files, the PFC program control language, and record formats.
- The *IPF Advanced User's Guide* covers use of the PCL language from the GUI Command Dialog and the IPFBAT program, how to customize the XGUI file, and detailed information on plotting diagrams.
- The *CFLOW User's Guide* serves the needs of advanced IPF users who want to write special purpose programs in C, using the CFLOW library of C functions. Many of the functions of the batch user analysis programs may be more effectively accomplished with a C program using the CFLOW library. The manual consists of a reference-oriented section of the C library functions in alphabetical order. There are also example user-analysis programs to get you started.

1.7 A NOTE ON TYPOGRAPHICAL CONVENTIONS

Operating system commands, parameters, file names, etc., and any information that you type or that might appear on your screen all appear in the Courier plain font, for example, `ls -sF`.

CHAPTER 2
IPF OVERVIEW

2.1 IPF: A POWER FLOW ENGINEERING APPLICATION

Electric power system network design encompasses the following tasks:

- Determination of load centers (points) and generation patterns as well as sizes of loads and generation.
- Determination of available transmission corridors (rights-of-way) and assessment of the capacity of these corridors to accommodate transmission lines.
- Evaluation of existing or planned networks with regard to adequate power-carrying capability, voltage regulation, reliability of service, and operating economics.
- Determination of size and routing of new transmission lines, and size and location of terminal equipment for achieving efficient and economical reinforcements when needed.
- Evaluation of proposed reinforcements in light of power flow capability, ability to withstand transient disturbances, reliability of overall service, economics, impact on regional economy, environment, energy conservation and operational constraints such as construction lead times, coordination of various facility ownership interests, flexibility for future growth and compatibility with other long-range plans.

The dynamic nature of load growth, load distribution, and generation patterns make the problem of network design one of planning. To plan for the future, a design must look at the past and present. This makes the Interactive Power Flow program a key tool for the network design engineer. Thanks to a comprehensive, structured database, it permits a complex network structure to be modeled and evaluated at various points in time. IPF also incorporates most modern modeling and analysis concepts. In addition, IPF assists the engineer in documenting major design decisions and changes.

2.2 IPF FAMILY OF PROGRAMS

IPF can be thought of as a family of programs. BPF is the batch form of the Power Flow program. When the editing and displaying of buses and branches is being handled by GUI, the work of calculating solution voltages for a given power system network is done by IPFSRV, which is just the batch program in a different guise. Auxiliary programs allow you to do plots in batch mode, do a save of network data in batch mode, perform a “cut” of a solved base case, etc. These auxiliary programs complete the IPF family and are briefly described here.

> *Note:* There are two different program control languages, the “new style” PCL, and the “old style” PFC. These two sets of commands are *not* completely compatible even though the “new style” command set and syntax is closely modeled on the “old style.” This manual describes PFC only.

GUI — The X-based (X Window System) push button and menu-driven Graphical User Interface program that works in conjunction with the power flow server, IPFSRV. Documentation is in the *IPF Basic User’s Guide*

IPFSRV — The power flow server to the GUI. It executes power flow commands through Power Flow Control Language (PCL) scripts dispatched from the GUI.

IPFBAT — The batch version of IPFSRV. It accepts a “new style” Power Flow Control Language (PCL) script file. Plotting can be done with a control file; however, for most plots IPFPLOT is easier to use. Example of use: `ipfbat test.pcl`.

The “new style” PCL commands used with IPFSRV and IPFBAT (pseudo standard of `.pcl`) are described in the *IPF Advanced User’s Guide* and in Appendix A of the CFLOW User’s Guide. Many of the BPF commands from chapter 4 of this manual are supported, but not all, and there are many additional commands.

BPF — The updated version of the old BPA batch Power Flow program. It executes using the commands from an “old style” Power Flow Control (PFC) script file. Example of use: `bpf test.pfc`.

The PFC commands (pseudo standard of `.pfc`) used with BPF are scripts for a complete power flow run. Chapter 4 of the *IPF Batch User’s Guide* describes the commands available.

IPFPLOT — Batch plotting program to produce printed maps. The program accepts a coordinate file and a base case file on the command line, as well as an optional second base case file. When the second base case file is specified, a difference plot is produced. You can also use IPFPLOT to produce bubble diagrams. The same coordinate files are used for both GUI and IPFPLOT, but not all capabilities are available in GUI. Documentation is in the *IPF Advanced User’s Guide*.

IPFNET — The batch version of the “save netdata file” function built into the GUI/IPFSRV. This program generates a WSCC-formatted network data file in any of the following dialects: BPA, WSCC, or PTI. “Dialects” means that the file is still WSCC, but the data is generated with special processing or restrictions and is destined for use with other programs. In the case of the PTI dialect, that data is preprocessed by the PTI-proprietary conversion program WSCFOR. Documentation is in Appendix F of the *IPF Batch User’s Guide*.

IPFCUT — The stand-alone program that cuts out a subsystem from a solved base case file. Flows at the cut branches are converted into equivalent generation or load on specially formatted +A continuation bus records. An ensuing power flow run should solve with internal branch flows and bus voltages which are identical to those quantities in the original base case. Documentation is in Appendix F of the *IPF Batch User’s Guide*.

- Several methods are available to define the cut system: bus names, zones, base kVs, and individual branches.
- A pi-back feature replaces selected buses with a passive-node sequence (lines consisting of sections) with the original loads pi-backed in proportion to the line admittances.

IPS2IPF — The program that converts a network data file from IPS to IPF. Duplicate buses are renamed; LTC steps are converted to taps, shunt susceptance on slack and BQ buses are transferred to +A records; sectionalized lines containing a section 0 are renumbered 1, 2, . . . ; BX, X, and remote controlled bus data are converted to IPF format, etc. Documentation is in Appendix G of the *IPF Batch User’s Guide*, and Appendix D of the *IPF Basic User’s Guide*

2.3 IPF INTERACTION MODEL

The conceptual model of IPF is quite simple. You load power system network data into the IPF database and solution “engine” (PF); IPF performs the calculations for the solution, and then outputs this solution data.

IPF offers two different approaches to accomplish power system solutions.Their style of interaction and processing are quite different.

- The Graphical User Interface (GUI) approach. This is command oriented – you click a button or enter a command, and it is executed immediately.
- The traditional batch (BPF) approach. This is an Input-Process-Output approach. You put

into your PFC command file all of the ‘orders’ that you want filled, and the program performs the actions it determines are necessary to produce the ordered results.

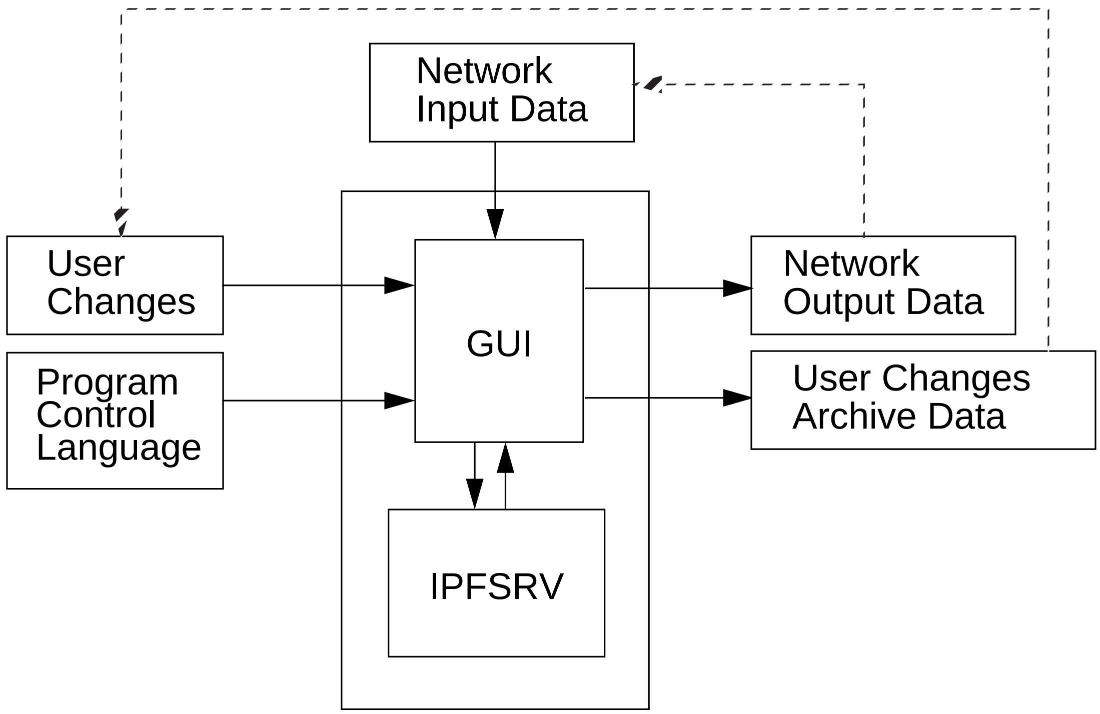


Figure 2-1 PCL Information Flow Model

2.3.1 The GUI Approach

When you use the GUI approach, you use the dialog boxes, menus, windows, etc., of the GUI. This makes data input, output, and manipulation easy. In addition to allowing basic case solution tasks to be accomplished, certain specialized tasks such as line impedance calculations are available. However, for more involved tasks, you need to use the BPF approach. For information about how to work with the GUI dialog boxes, menus, windows, etc., see the *IPF Basic User’s Guide*. This guide also has a tutorial to show you how to solve straightforward power system cases.

2.3.2 The IPFBAT Approach

IPFBAT allows you fine control over the database and solution “engine” (IPFSRV). You first create a PCL file with the appropriate commands, in the right order, to accomplish the solution task at hand. At runtime these commands are interpreted by IPFBAT. The PCL file commands are processed sequentially. Additional PCL command files may be specified by name, so that a "chain" of PCL files may be processed in one run. See the *IPF Advanced User's Guide* for details.

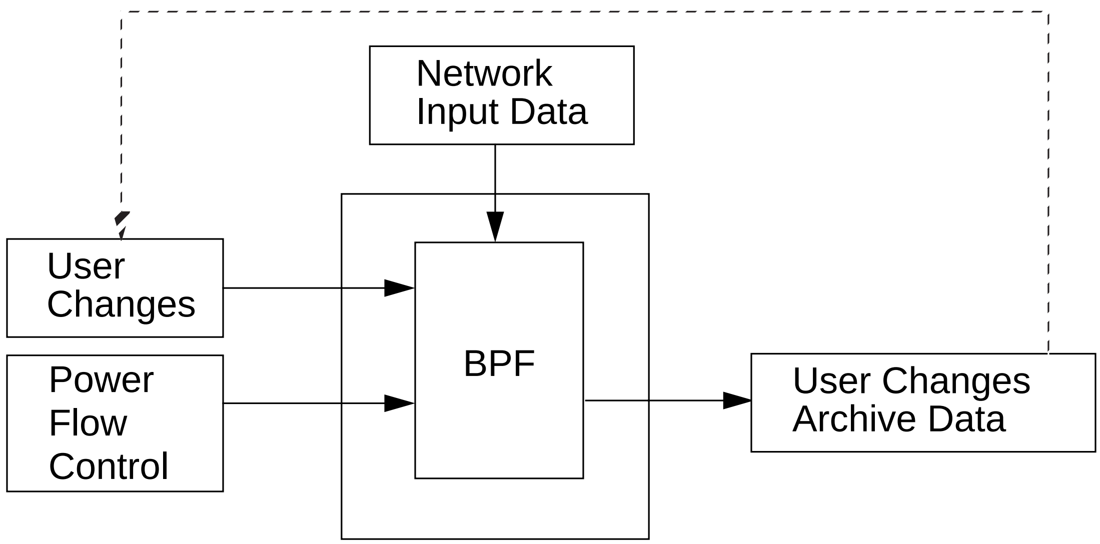


Figure 2-2 BPF Information Flow Model

2.3.3 The BPF Approach

When you use BPF, you must first create a PFC file with the appropriate commands to accomplish the solution task at hand. At runtime these commands are accepted by BPF and executed according to a logical processing order determined by the program. Hence you need not be concerned with the ordering of commands in your PFC file. Input commands will be processed first, and a solution done automatically before any output is produced. Finally, a new base file will be created, if you have requested one. See Appendix A for examples of PFC files.

2.4 NETWORK DATA

Network Data consists of various files of bus and branch record data. Most of the input files are ASCII text files. But one important file, the base case file, is in binary format. You can, of course, edit ASCII text files with any text editor. This is often done, but your data integrity is safer if you do all the editing you can in the dialog boxes of the GUI. The base case binary file cannot be edited with an ordinary text editor, but can in effect be edited via the GUI when you have a base case file loaded.

The following is a list of the various network input data files with descriptions. Additional information about the important `PFC`, `NETWORK_DATA`, and `NEW_BASE` files is found under individual headings below.

`PFC` This input file contains job control information for the BPF program. This file may contain a `NETWORK_DATA` file explicitly, but more often includes a name reference to an appropriate `NETWORK_DATA` file, `OLD_BASE` file, or other job control data to be described.

You can edit this file using any ASCII text editor to add, modify, and delete commands and data records.

`NETWORK_DATA` This ASCII text input file contains a series of records of bus and branch data. It must *not* contain modification records.

This file can be maintained by using an ASCII text editor. Or you can edit the records you want in the GUI through the various dialog boxes and then save a new `NETWORK_DATA` file.

In the file, data records may be in random order, but actual processing is done in the following order: (1) A and I records (area interchange); (2) B, +, and X records (bus); and (3) L, R, E, and T records (branch).

`BRANCH_DATA` This ASCII text input file contains the branch database of all branches coded with in-service date and out-of-service date. This file is searched for branches in service on the date requested. BPF selects the appropriate branches.

`NEW_BASE` This program-generated, binary output file contains complete base network data and steady-state operating values for the case being processed. This file is identical in format to the `OLD_BASE` file. `NEW_BASE` simply designates the file when it is produced as the output from a recently concluded case study.

`OLD_BASE` This program-generated, binary input file contains complete base network data and steady-state operating values. This file is identical in format to the `NEW_BASE` file. `OLD_BASE` simply designates the file when it functions as an already existing input file.

`CHANGE` This ASCII text input file contains changes (new and modification records) to the data input from any combination of `NETWORK_DATA`, `BRANCH_DATA`, and `OLD_BASE` files making up the case to be studied. These change records change the input data for the base case.

Printout File — This is an ASCII text output file that contains bus, branch, and solution data from a completed case study and is intended for ordinary, paper hardcopy output.

Microfiche file — This is a special format output file that contains bus, branch, and solution data from a completed case study and is intended for microfiche format.

Table 2-1 IPF Input/Output Files

File	Format	Input/Output	Created by	Editing	Information Contained
PFC	ASCII	BPF Input Only	User	Yes	Bus, Branch, Commands, File Names
PCL	ASCII	GUI/IPFBAT Input Only	User	Yes	Commands, File Names
NETWORK_DATA	ASCII	BPF - Input Only GUI/IPFBAT - Input or Output	User GUI IPFNET	Yes	Bus, Branch
BRANCH_DATA	ASCII	Input Only	User	Yes	Branch
OLD_BASE	Binary	Input Only	IPF	No	Bus, Branch, Solution Values
CHANGES	ASCII	Input or Output	User GUI	Yes	Bus, Branch, Modifications
NEW_BASE	Binary	Output Only	IPF	No	Bus, Branch, Solution Values
Printout file (<name>.PFO)	ASCII	Output Only	BPF	No	Input Data and Solution Reports, User Analysis
Microfiche file (<name>.PFF)	ASCII	Output Only	BPF	No	Input Data and Solution Reports, User Analysis
Debug file (<name>.PFD)	ASCII	Output Only	BPF	No	Solution arrays and iteration processing
Printout file (<logon>.PFO)	ASCII	Output Only	GUI	No	Messages, Iteration Summary
Debug file (<logon>.PFD)	ASCII	Output Only	GUI	No	Solution arrays and iteration processing

2.5 THE NETWORK_DATA FILE

This ASCII text data file consists of area, bus, and branch records in the format used by the Western Systems Coordinating Council (WSCC). However, note that IPF supports many record types which are not recognized by IPS, and in some cases the interpretation and application of the data values entered is different. See Appendix G for a list of IPS-IPF differences. This file must not contain modification records, only new data.

1. Area interchange records.

   Each area record identifies a composition of zones whose member (associated) buses define specific aggregate quantities that may be controlled to specified export values.

   A (Area interchange records)
   I (Area intertie records)

2. Bus data record group containing at least two records.

   Each bus data record identifies one bus in the network. Buses are uniquely identified by their bus name and base kV.

   B (Bus records)
   \+ (Continuation bus records)
   X (Continuation bus records)
   Q (PQ Curve data records)

3. Branch data record group containing at least one record.

   L (ac or dc Transmission line records)
   E (Equivalent Branch records)
   T (Transformer records)
   R (Regulators (Automatic or LTC transformer) records)

Branch data entered in any of the ASCII files is *single-entry* or one-way only. This means, for example, that a branch connecting buses A and B has a user-submitted entry (A,B) or (B,A) but not both. The program transposes the record internally as required during execution. Normally which way the branch is entered does not matter, but it does affect the default end metered on a tie line, and the physical position of line sections. See Chapter 3, *Record Formats*, for a discussion of this feature.

Branches are uniquely identified by three fields:

- Their terminal bus names and base kVs.
- Their circuit or parallel ID code.

- Their section code.

2.6 THE BASE FILE

This file, designated `OLD_BASE` if you are loading it, or `NEW_BASE` if you are saving it, is binary in format and contains the following data:

- The case identification , project ID, and two header records. (This corresponds to the IPS case title.)
- The date the case was generated.
- The program version used to generate the file (so future program versions can read the file if file structures change).
- Up to 100 comment records.

2.7 PROCESS SCENARIOS

In order to process a case, BPF requires a program control file and a valid set of base case data, which may be a composite of `NETWORK_DATA` and `BRANCH_DATA` formatted ASCII files or an `OLD_BASE` file from a previous power flow case, and a `CHANGE` file.

The PFC file either contains data used for the solution, or names files containing such data. The solution data is optionally saved on the file named in the `NEW_BASE` command.

Types of Processing

Input files used vary with the type of IPF processing, so it is important that you have a good understanding of the purpose of each type of file. Different program functions use the files to perform specific processes. Some major processes are:

- Basic Processing `(POWER FLOW)`
- Merge Base `/MERGE_BASE\`
- Network Reduction `/REDUCTION\`
- Outage Simulation `/OUTAGE_SIM\`

Sample PFC file setups for each of the following solution processes are given in Appendix A.

Creating a New Base Case

Figure 2-3 depicts the initial way an IPF case is processed and how the output is saved on a `NEW_-BASE` file, which may then become an `OLD_BASE` file for subsequent change studies. The contents of the print file (`PFO`) are defined by the `P_INPUT`, `P_OUTPUT`, and `P_ANALYSIS` commands. Likewise, the contents of the fiche file (`PFF`) are defined by the `F_INPUT`, `F_OUTPUT`, and

F_ANALYSIS commands.

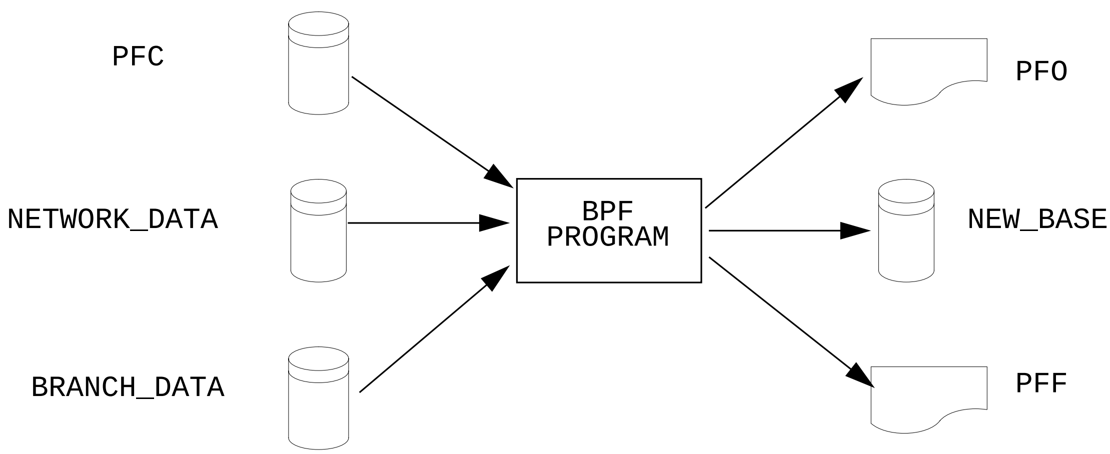


Figure 2-3 New Base Creation Process

Changing an Old Base Case

Figure 2-4 shows the most commonly used BPF process. A change case is created from an OLD_BASE file using a CHANGE file. The modified case data is saved on the NEW_BASE file. The output files PFO and PFF can be printed to paper or fiche or both.

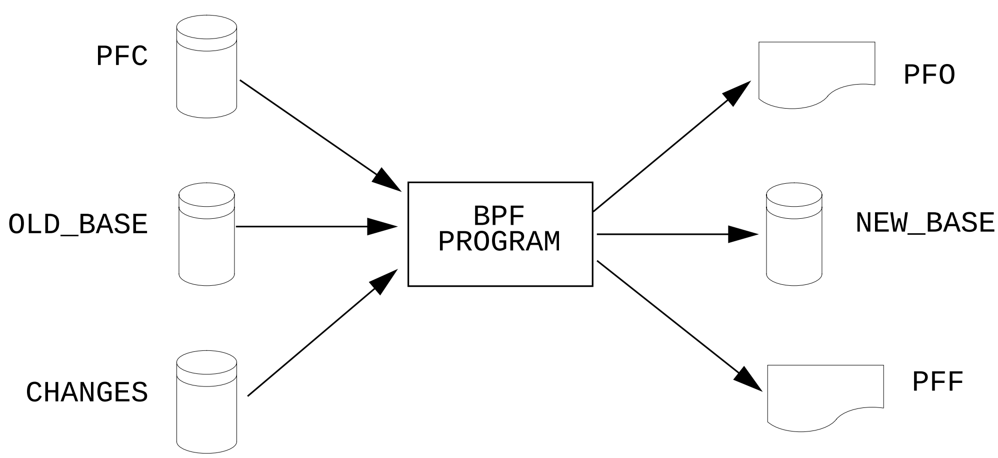


Figure 2-4 Old Base Case With Changes

Merging Subsystems

Figure 2-5 shows a `NEW_BASE` file being created by merging a subsystem from a case on an `OLD_BASE` file with another subsystem from either a second `OLD_BASE` or from a `BRANCH_DATA` and a `NETWORK_DATA` file. The output files `PFO` and `PFF` can be printed to paper and/or fiche.

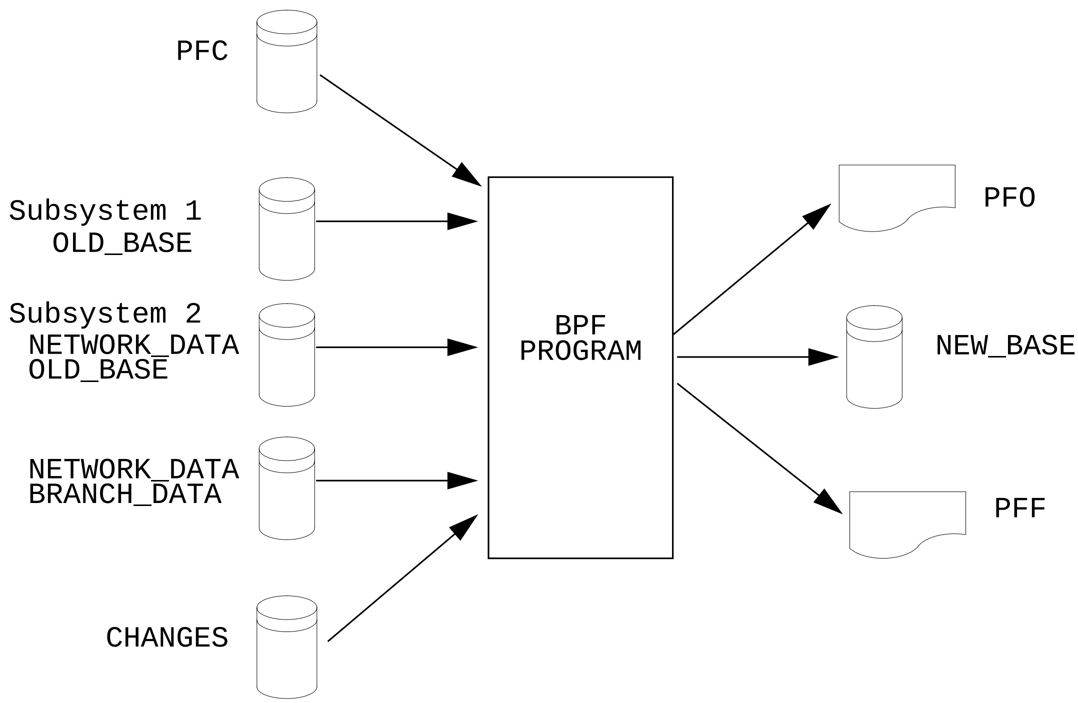


Figure 2-5 Merging Two or More Subsystems

Reducing a Network

In Figure 2-6, a network reduction is specified in the `PFC` file. Commands within this file define the retained system. The actual network reduction dynamically changes the base data in memory, and the reduced base case is saved on the `NEW_BASE` file. These output files (`.PFO` and `.PFF`) can be printed to paper and/or fiche.

For static reduction, you can use the IPFCUT program. It is described in Appendix F.

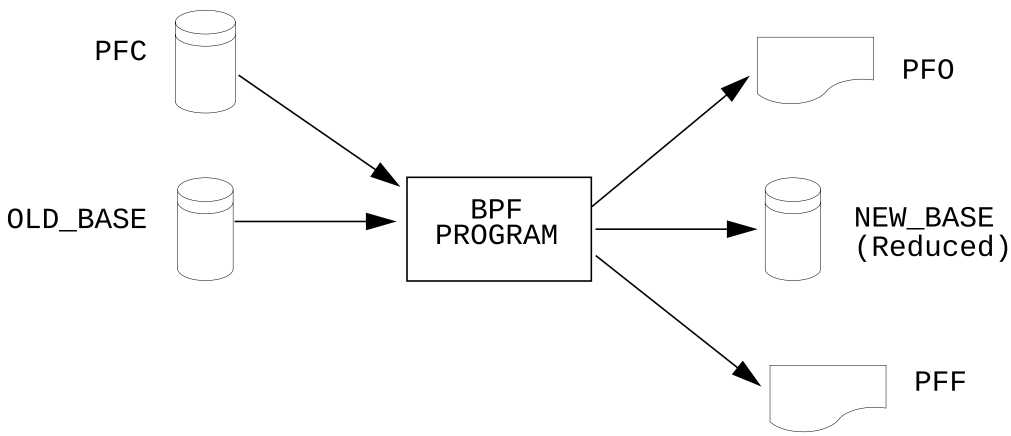


Figure 2-6 Reducing a Network

Simulating Outages

Figure 2-7 shows an outage simulation being processed directly from an `OLD_BASE` file. Only printed analysis is output; no data files are generated. This printed output can be directed to either fiche or paper. Simulating outages is a special power flow function that subjects a subsystem of interest to a series of single contingency branch outages and tabulates the consequences of each outage or the cause of each overload.

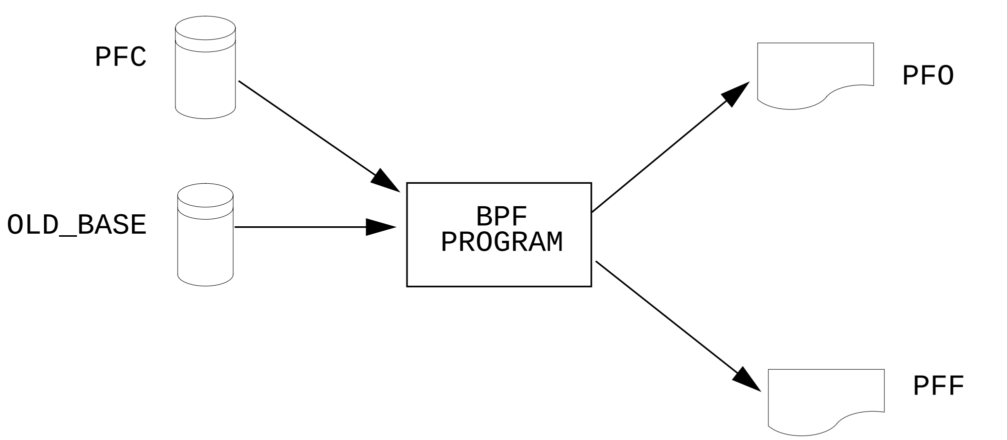


Figure 2-7 An Outage Simulation

CHAPTER 3
RECORD FORMATS

3.1 OVERVIEW

This chapter describes all data record formats recognized by BPF. Most, but not all of them are also available in the GUI interface. The record descriptions are organized alphabetically by record ID as you go through the chapter (except for the dc bus records which follow the ac bus records). Table 3-1 enables you to quickly locate a specific record format entry. The table also gives you a quick description of each record format.

Each entry has a card image that shows you where to put both identification and data information and where the implicit decimal point (if any) is located. Please note that all information must be in the correct columns; you will experience processing errors otherwise. Each card image has a legend showing whether data is required, optional, or ignored.

Each entry also has a table of column descriptions and data formats. This supplements the card image. Additional text accompanies any record formats that need extended discussion.

Some data are FORTRAN real numbers. For these fields, the implicit decimal point is shown as a black dot on the card image, just above the information entry row. Note that you can enter data with an explicit decimal point in any position within the field. A black dot that appears at the extreme right side of a field represents a decimal point at the right end (least significant digit) of a number. All other black dots appear above a line, indicating that the decimal point will fall between the digits on either side.

All IPF data record types are identified by the characters in columns 1 and 2. To fully specify a particular record, additional fields need to be filled in. These additional ID fields are usually the bus name and base kV. ID fields are called out in the column description tables.

Table 3-1 Record Types

Page	Record ID (columns 1-2)	Field Width	Description
3-7	Period (.)	120	Comment (not printed)
3-8	+	80	Bus continuation
3-14	A	80	Area interchange control
3-16	AO	80	Area output sort
3-18	-	-	General ac bus description
3-22	B	80	AC bus — load bus
3-25	BC	80	AC bus — voltage controlled by BG bus
3-28	BE	80	AC bus — constant voltage
3-31	BF	80	AC bus — special purpose bus for Newton--Raphson solution
3-32	BG	80	AC bus — generator
3-35	BQ	80	AC bus — constant voltage within Q limits
3-38	BS	80	AC bus — system slack bus
3-41	BT	80	AC bus — LTC transformer controlled ac bus
3-44	BV	80	AC bus — constant Q within V limits
3-47	BX	80	AC bus — attempts constant V using switched Q specified on X record
3-50	BD	80	Two-terminal dc bus
3-52	BM	80	Multi-terminal dc bus
3-55	DA	80	Delete buses by area
3-56	DZ	80	Delete buses by zones
3-57	E	88	Equivalent branch (has extended ratings)
3-60	I	80	Area intertie I record
3-62	L	88	Transmission line (has extended ratings)
3-66	LD	80	Two-terminal dc line
3-69	LM	80	Multi-terminal dc line

Table 3-1 Record Types (Continued)

Page	Record ID (columns 1-2)	Field Width	Description
3-72	PO, PZ, PN, PA, PB, PC, PD	80	Factor changes
3-78	QN, QP, QX	120	Reactive capability curve
3-82	R, RV, RQ, RP, RN, RM	80	Regulating transformer
3-86	RZ	80	VAR compensator model
3-88	T	92	Transformer (has extended ratings)
3-88	TP	92	Phase shifter (has extended ratings)
3-93	X	80	Switched reactance (BX record)
3-96	Z	80	Zone rename

3.2 SYSTEM CHANGES

After a base case has been established, it may be changed with the use of change records. The change records are identified as system data records which immediately follow the network-solution qualifier `/CHANGES` statement. See Chapter 4.

The change records are system data records with a change code in column 3. Each of the input data forms describe the permissible types of changes under the caption CHANGE CODES. In all, there are five types of changes.

- *Additions*: Change code = blank

  The data record identification must be unique to the system. The contents of the record must be complete as if it were being submitted to build a base case.

- *Deletions*: Change code = `D`

  Only existing data may be deleted, and only the identification fields are needed. Numerical data in any other field is ignored. Special conditions are given:

  - Deleting a bus automatically deletes all continuation bus data, switched reactance data and all branch data associated with that bus. Deleting all branches connected to a bus will result in an error. It is better to delete the bus. A bus should not be deleted and added back in the same case with the same name in a single change file.
  - Deleting all transformer banks between two buses will automatically delete any regulating transformer data.
  - A line composed of sections may be deleted in its entirety by deleting section 0 (zero) or blank. The alternative is to delete each section with a separate change record. If a section is deleted the line is reconnected without that section. Transformer sections cannot be deleted.
  - A branch composed of parallel lines between two buses may be deleted in its entirety by entering a `*` in place of CKT ID. This provides a means of disconnecting two directly connected buses from each other. The branches may also be deleted individually.
  - A blank branch ID is legitimate identification.
  - Changing a bus from type X to any other type will delete all switched-reactance data automatically. No separate X delete record should be included.

- *Elimination*: Change code = `E`

  This causes the elimination of all existing `A` (area interchange) records to make room for possible new `A` records. *The user should note that this change code works for* `A` *records only*.

- *Modifications*: Change code = `M`

  All currently existing system data may be modified, which means changing the value of some quantity of system data. Data in the identification field cannot be changed.

  Only the data to be changed is entered on the change record. Nonblank fields constitute data modification, while blank fields indicate that the quantity is not to be changed. A blank and a zero quantity on the change record are distinguishable. Often, it is necessary to change a quantity into a blank. Examples are the bus zone name and the bus subtype. To change these into blank quantities, a `00` or `0` must be entered in the appropriate respective column fields. Special recognition is conferred on these change quantities.

- *Restorations*: Change code = `R`

  Previously outaged system data may be reactivated with the use of restore change records. This type change permits data to be restored to the system with change records using the identification fields only. Any data fields on the restore record will be ignored, and the reactivated data assumes the same quantities it had prior to deletion. Restoring data is an option. Data could be re-entered with additional type change records as well. The operations and rules are similar to those for deletions. However, some important differences must be explained.

  - Restore changes are permissible only with data deleted in a previous change case but within the same base case. You cannot restore data outaged in a previous `OLD_BASE` case.
  - Area interchange records may not be restored.
  - Restoring a bus restores only branches which connect to a viable system base. In some cases, not all of the outaged branches can be restored.
  - Restoring all transformer banks between two buses will not automatically restore any regulating transformer data. If this is intended, the regulating `R` transformer data must be restored separately.
  - A restored branch record must match the branch code as well as the identification fields. For example, if the branch is type `L`, the restore record must match the type.

  The change records are read, interpreted and stored for further processing. As they are read the following are processed immediately:

  - Area Interchange (`A`-blank)
  - Zone Renames (`Z`-blank)
  - Area Deletes (`DA`)

  Processing of changes then continues in the following manner:

- Changes Percents (P)
- Deletes
- Adds/Restores
- Modifications

Note: If more than one modification for the same data item occurs, the changes will be made in the order encountered. In IPF, no message will be given the user.)

If fatal data errors are encountered in batch mode, switches are set and the processing continues only to discover additional errors, list all changes and exit. For changes to existing data, component identification must be specified exactly as in the base case file.

If fatal errors are encountered in interactive mode, appropriate diagnostics are issued so that the user can remedy the faulty command or data.

3.3 COMMENT (.)

This comment text is used to annotate the program control file, network data file, or change file. Its contents are not added to the output listings nor saved in the binary base case file.

Simply place a "." (period character) in the first column and the comment in the rest of the columns. This is also handy to temporarily deactivate a command or data line.

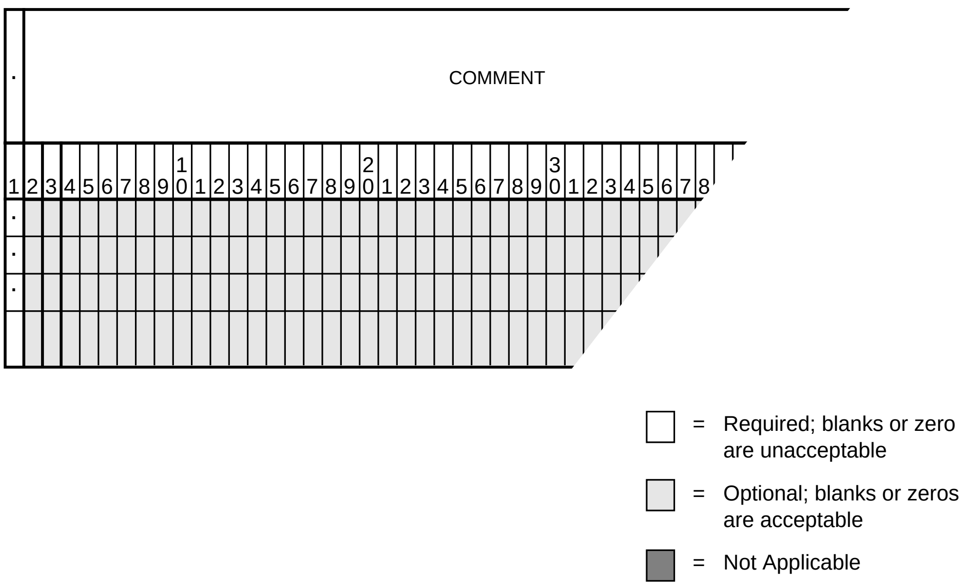


Figure 3-1 Comment Input Format

Table 3-2 Column Descriptions for Comment Format

Column	ID Field	Format	Content
1	yes	A1	. (period)
2-120	no	A119	Text string for record comment

3.4 CONTINUATION BUS DATA (+)

Continuation bus data is identified with a + in column 1 and supplements the data on any ac bus record. It specifies additional generation, load and shunt admittance at the bus and permits additional classification and utilization of data. Generally, it permits a more detailed analysis of data. Its most typical application is distinguishing loads represented by several different owners at the same bus. The following fields are for identification:

- Bus name and base kV
- Code and code year
- Ownership

Each bus may have more than one continuation record. However, some means of distinction must be made in the minor identification fields of `code year` or `owner`. See Figure 3-2, Table 3-3, and Table 3-5.

A sample coding sheet and column descriptions for continuation bus data follows.

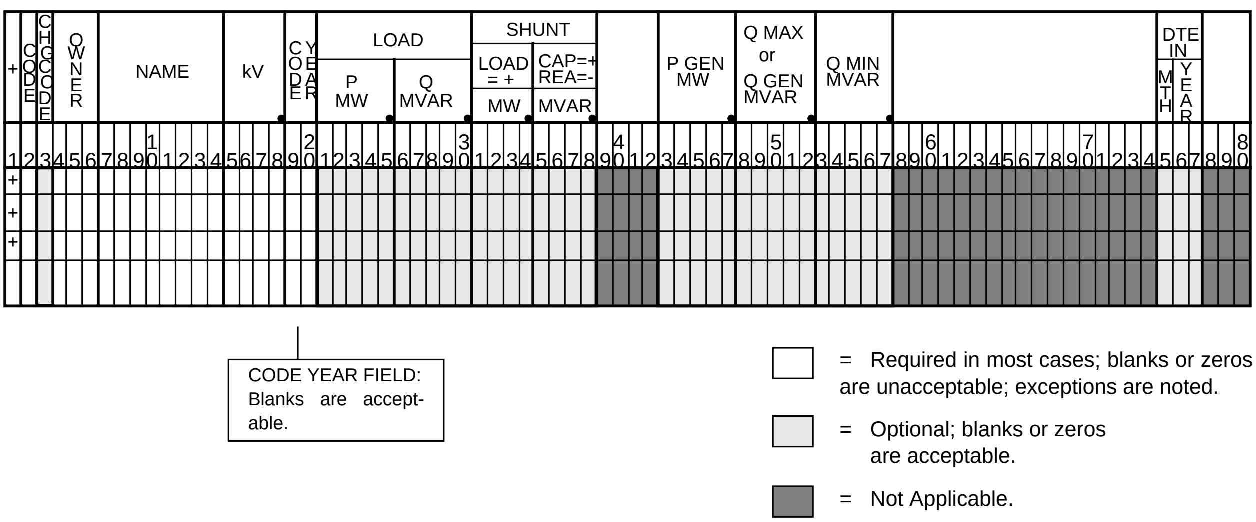


Figure 3-2 Continuation Bus Data Input Format

Table 3-3 Classification Codes

Code	Description
A	Equivalent injection data from network reduction. Note that data associated with this code is not subject to the effect of factor change (P) records.
C	Shunt MW or MVAR
F	Industrial firm load
I	Industrial interruptible load
N	Nonindustrial firm load (bus ownership differs from load ownership)
P	Industrial potential load
S	Nonindustrial secondary load
Blank	Nonindustrial firm load (bus ownership = load ownership)

In addition to the special classifications codes of column (2:2), the code year may convey special meaning or models to the continuation bus records. Table 3-4 summarizes the features.

Table 3-4 Special Constant Current and Constant Impedance Loads

Code	Code year	P_load	Q_load	G_shunt	B_shunt	Description
+A		Constant power MW load (generation if negative)	Constant power MVAR load (generation if negative)	Constant admittance MW evaluated at nominal voltage	Constant admittance MVAR evaluated at nominal voltage	Quantity generated by Network Data or Cutting routines
+A	00	Constant power MW load (generation if negative)	Constant power MVAR load (generation if negative)	Constant admittance MW evaluated at nominal voltage	Constant admittance MVAR evaluated at nominal voltage	Quantity generated by Network Data routine
+A	01	Distributed constant current MW load (generation if negative) evaluated at nominal voltage	Distributed constant current conjugate MVAR load (generation if negative) evaluated at nominal voltage	Equivalent MW shunt admittance	Equivalent MVAR shunt admittance	Quantity generated by Network Reduction routines
+A	02	Distributed MW load (generation if negative)	Distributed MVAR load (generation if negative)	Equivalent MW shunt admittance	Equivalent MVAR shunt admittance	Quantity generated by Network Reduction; denote equivalent shunt admittances
	*I	Constant current MW load (generation if negative) evaluated at nominal voltage	Constant current conjugate MVAR load (generation if negative) evaluated at nominal voltage	Not applicable	Not applicable	Quantity generated by %LOAD_DISTRIBUTION

Table 3-4 Special Constant Current and Constant Impedance Loads (Continued)

Code	Code year	P_load	Q_load	G_shunt	B_shunt	Description
	*Z	Constant power MW load (generation if negative)	Constant power MVAR load (generation if negative)	Constant admittance MW load (generation if negative) evaluated at nominal voltage	Constant admittance MVAR load (generation if negative) evaluated at nominal voltage	Quantity generated by %LOAD_DISTRIBUTION
	*P	Constant power MW load (generation if negative)	Constant power MVAR load (generation if negative)	Not applicable	Not applicable	Quantity generated by %LOAD_DISTRIBUTION

Table 3-5 Column Description for Continuation Bus Data

Column	ID Field	Format	Description
1	yes	A1	Record type; + for all continuation bus data
2	yes	A1	Code (See code types above.)
3	no	A1	Change code
4-6	yes	A3	Ownership
7-14	yes	A8	Bus name
15-18	yes	F4.0	Base kV
19-20	yes	A2	Code year—alphanumeric subtype of code
21-25[a]	no	F5.0	Load MW
26-30	no	F5.0	Load MVAR
31-34	no	F4.0	Shunt Admittance Load in MW at base kV
35-38	no	F4.0	Shunt Admittance in MVAR at base kV (+) = Capacitive (-) = Inductive
43-47	no	F5.0	P GEN MW
48-52	no	F5.0	Q GEN MVAR (or Q MAX) (+) = Capacitive (-) = Inductive
53-57	no	F5.0	Q MIN in MVAR
75-77	no	A1, A2	Energization date month and year {month = 1,2,3,4,5,6,7,8,9,O,N,D}

a. If the Code (column 2) is `A` and the Code year (column 19-20) is `01`, the load quantities are constant current-constant power factors and are:

1. interpreted as MW and MVAR evaluated at base kV
   (+) = Inductive
   (-) = Capacitive
2. evaluated as:
   P + jQ = (I*)|V|

Note: `Q_max` and `Q_min` represent inequality constraints (`Q_max > Q_min`). However special concerns apply for bus subtypes blank, C, T and V, where the Q is constrained. In order to assign appropriate values for scheduled Q, `Q_min` is first examined. If `Q_min < 0` and `Q_max > 0`, the limits are recognized as erroneous constraints and both are ignored. If `Q_min = 0`, then the schedule Q is always `Q_max`.

3.5 AREA INTERCHANGE CONTROL (A)

A network may be partitioned geographically by area. Similarly, areas may be partitioned by zones. The net power exported from each area can be specified with an area interchange record. Export power is controlled by varying the area slack bus generation. Interchange export is measured as the sum of the exported power on all area tie lines metered at the area boundaries. The total net export of all areas must add to zero; otherwise, the area interchange control is aborted. See Figure 3-3 and Table 3-6.

Valid subtypes are blank, 1, ..., 9, with 1, ..., 9 being continuation records. This allows up to 100 zones to be defined in an area.

In order for area interchange control to be activated, `A` records must be defined and the `/AI_CONTROL` option must be set to the default, `CON` (Control). Three slack bus restrictions pertain to each area.

- One area slack bus must be the system swing bus.
- Each area slack bus must be within the area it controls.
- For all slack buses the P generation is variable.

Note: Area Continuation records (A1, ..., A9) accept only area name and zones 1-10 fields.

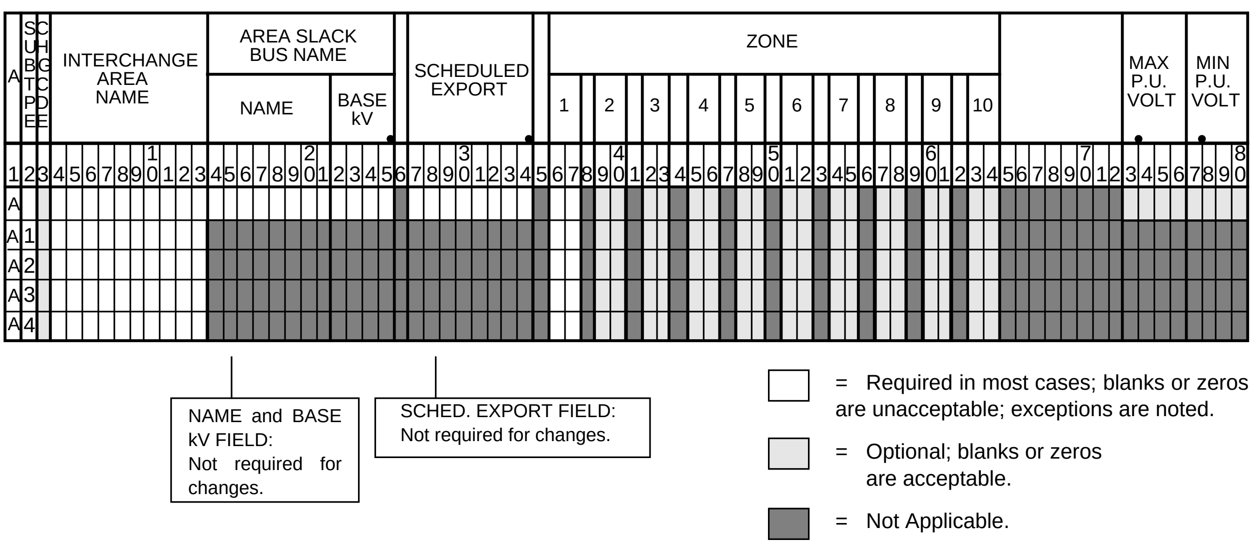


Figure 3-3 Area Interchange Control Input Format

Table 3-6 Column Description for Area Interchange

Column	ID Field	Format	Description
1	yes	A1	Record type — A
2	yes	A1	Subtype — blank, 1, ..., 9
3	no	A1	Change code — see System Changes
4-13	yes	A10	Interchange area name — Name of area consisting of one or more zones. Alphanumeric entries are permitted.
14-25	no	A8,F4.0	Area slack bus name and base kV. (Does not apply to subtypes A1, ..., A9.)
27-34	no	F8.0	Scheduled export — MW flow scheduled (+) out of area or (-) into area. If I (interchange) records are present for this area, the net schedule will be overwritten with the netting computed from the I records. (Does not apply to subtypes A1, ..., A9.)
36-64	no	10(A2,1X)	Zones to be included in the interchange area named in columns 4-13. A blank zone terminates the scan unless it is zone 1. All zones must be listed within some area, but no zone may be common to more than one area.
73-76	no	F4.3	Maximum per unit voltage. (Does not apply to subtypes A1, ..., A9.)
77-80	no	F4.3	Minimum per unit voltage. (Does not apply to subtypes A1, ..., A9.)

3.6 AREA OUTPUT SORT (AO)

The order of buses in the input and output listings may be grouped into areas with arbitrary zone configurations. The areas are sorted alphabetically and the buses within each area are then sorted alphabetically. See Figure 3-4 and Table 3-7.

These records permit an area to be defined independently of any area interchange. Once introduced, these records become a permanent part of the base case file. A coding sheet and description of the record columns follows:

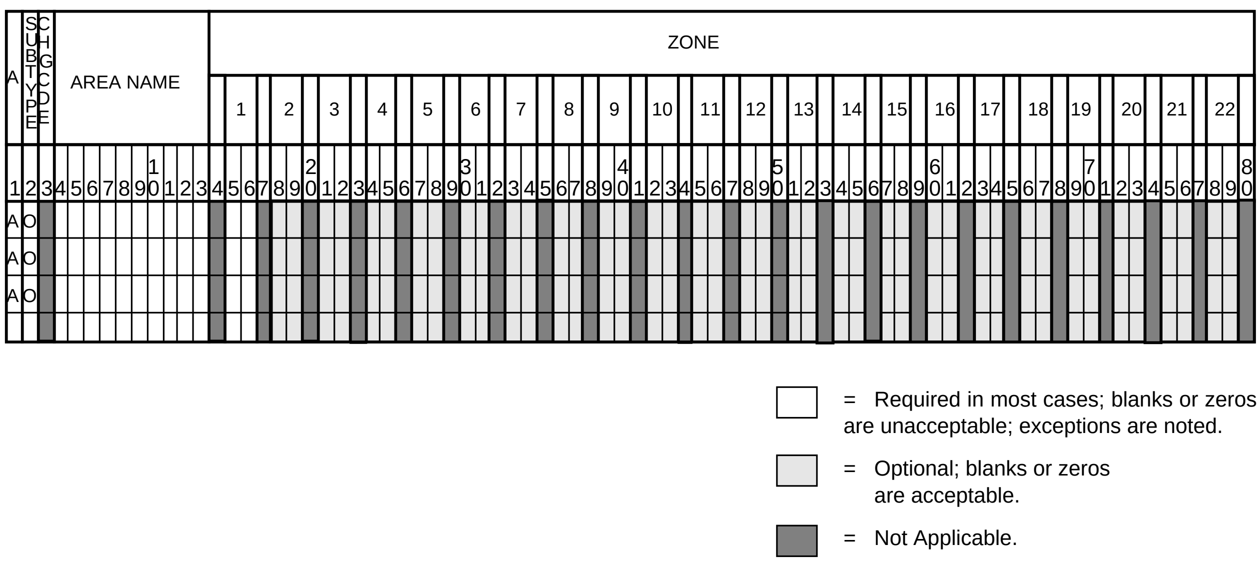


Figure 3-4 Listing by Sorted Areas Input Format

Table 3-7 Column Description for Area Output Sort

Column	ID Field	Format	Description
1	yes	A1	Record type — A
2	yes	A1	Subtype — O
3	no	A1	Change code — see System Changes
4-13	yes	A10	Area Name — These names are independent of area interchange names but may be identical.

Table 3-7 Column Description for Area Output Sort

Column	ID Field	Format	Description
15-79	no	22(A2,1X)	Zone composition list — a blank zone terminates the zone scan unless it is zone 1.
80	no	blank	

3.7 AC BUS DATA

Bus records identify nodes in the network. The following description applies to ac buses only; dc buses are identified by a subtype `D` or `M` and are described in Section 3.18 and Section 3.19. See Figure 3-5 and Figure 3-6.

Each ac bus consists of three attributes: generation, load, and shunt admittance. Various subtypes assign unique characteristics to these attributes. Some affect conditions in the solution; others affect only the allocation of quantities in the output listings.

The various subtypes permit different models to represent the operation of the system. Most buses have constant real injection. Exceptions are the system slack bus and any area interchange slack buses.

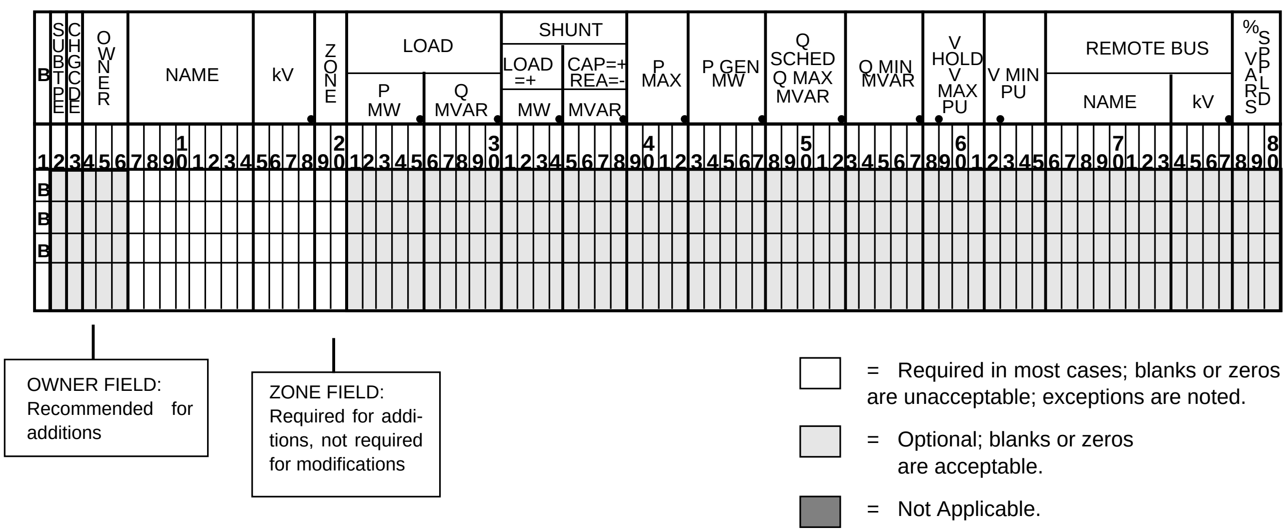


Figure 3-5 Bus Data Input Format

Table 3-8 Column Description for AC Bus Data

Column	ID Field	Format	Description
1	yes	A1	AC B type record
2	no	A1	Subtype
3	no	A1	Change code
4-6	no	A3	Ownership
7-14	yes	A8	Bus name
15-18	yes	F4.0	Base kV
19-20	no	A2	Zone
21-26	no	F5.0	Load MW
26-30	no	F5.0	Load MVAR
31-34	no	F4.0	Shunt Admittance Load in MW at base kV
35-38	no	F4.0	Shunt Admittance in MVAR at base kV (+) = Capacitive (-) = Inductive
43-47	no	F5.0	P GEN MW
48-52	no	F5.0	Q GEN MVAR (+) = Capacitive (-) = Inductive
53-57	no	F5.0	Q MIN MVAR
58-61	no	F4.3	V HOLD — V MAX (in per unit)
62-65	no	F4.3	V MIN (in per unit)
66-73	no	A8	Controlled bus name
74-77	no	F4.0	Base kV
78-80	no	F3.0	Percent of vars supplied for remote bus voltage control.

For all subtypes, the following diagram illustrates the reactive allocation scheme.

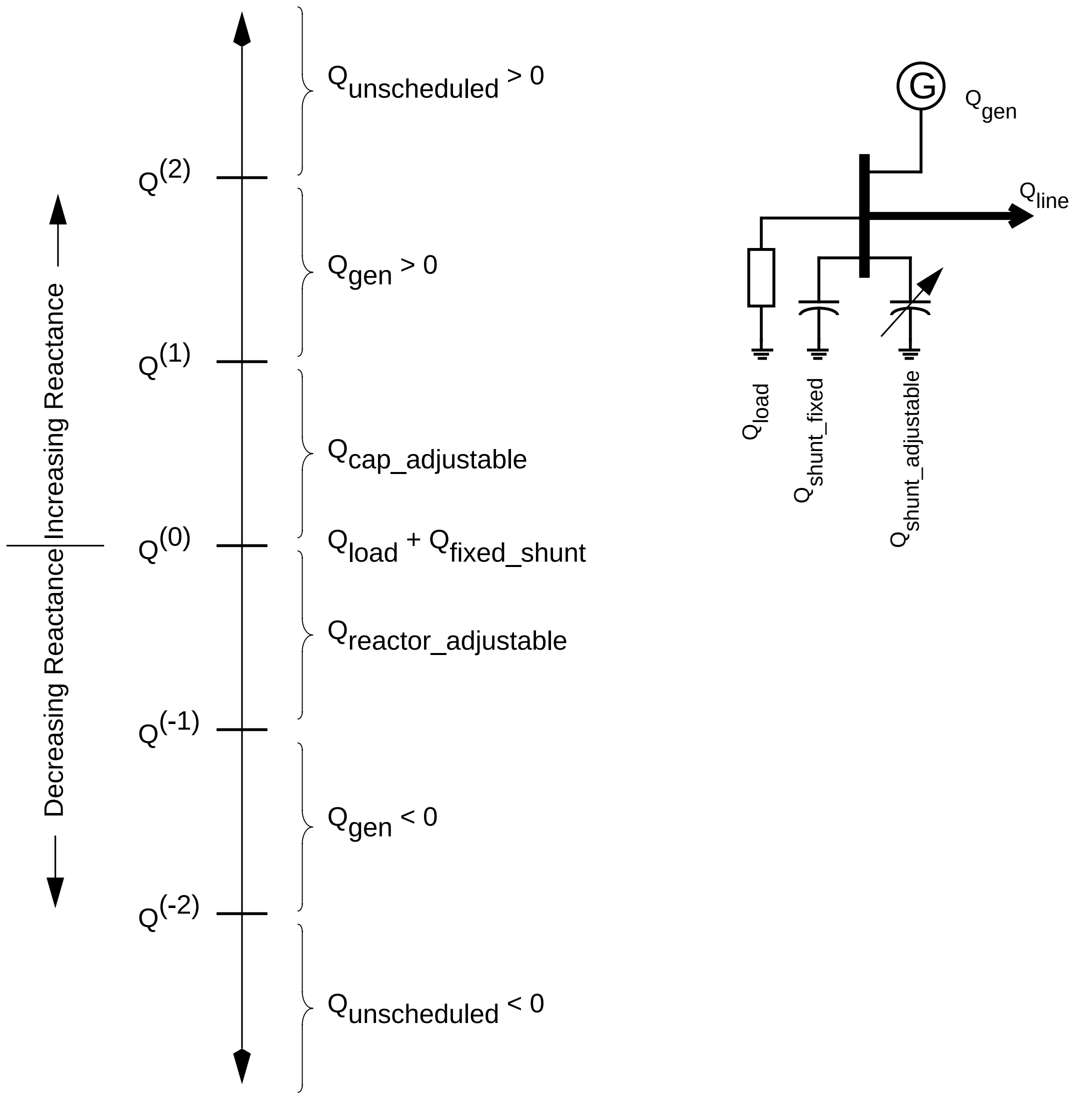


Figure 3-6 Reactive Allocation Scheme

Allocation of reactive facilities is complex. These may be allocated by equality constraints (Q_net is constant), inequality constraints (Q_net varies between a minimum and maximum value), or no constraints.

Let "NET" define the total line export. Then the following equation is always valid:

$$\text{NET = GENERATION - LOAD - } Y_{shunt} \text{ * VOLTAGE}^2$$

The equation is complex; the real and reactive components are balanced separately. The separate equations are:

$$P_{net} = P_{Gen} - P_{load} - G * V^2$$

$$Q_{net} = Q_{Gen} - Q_{load} + B * V^2$$

The shunt admittance is

$$Y = 1 / Z = G + jB$$

The equations above define the interrelationship between quantities and are valid for all bus types. The bus type determines which equations are also constraints.

The preceding diagram illustrates the following priority scheme. In applying the equation for Q, vars are allocated to generation and variable shunt components on a priority basis. If Q_net is less than Q_load + Q_shunt fixed, then vars are allocated first to variable shunt reactors and then, if necessary, to reactive generation. If, on the other hand, Q_net is higher than Q_load + Q_shunt fixed, then vars are allocated first to the variable shunt capacitors and then, if necessary, to reactive generation. If the limits of reactive generation are exceeded, then unscheduled reactive is allocated.

3.8 AC BUS DATA (B-blank)

Application

This bus subtype is passive in the sense that it cannot control the voltage of another bus. Its primary use is for modeling load buses. See Figure 3-7 and Figure 3-8.

Bus Characteristics

Both real (P) and reactive (Q) power are held constant throughout the entire solution. This applies to generators, load and shunt devices (capacitors/reactors).

A specific amount of reactive generation can be requested. This can be accomplished by entering a zero (0) in the Q MIN field and the desired amount of reactive generation in the Q SCHED field.

Since this bus normally has no voltage control, the voltage limits (V MAX, V MIN) serve two purposes.

- If the bus is remotely controlled by another bus (type BG or BX) or by an LTC transformer (which is not standard but is accepted), the limits specify the range of acceptable voltage.
- For accounting purposes, these limits can flag undervoltage or overvoltage situations in the analysis reports.

It must be recognized that every bus has voltage limits, whether they are explicitly specified through the V MIN, V MAX fields or implicitly specified through default global voltage limits. See Appendix E.

Reactive limits are not allowed for this type of bus. If reactive limits are entered in the Q MAX and Q MIN fields, they will be ignored. However, legitimate Q GEN can be entered if Q MIN is zero.

For this subtype, Q_{net} is constant; its Q-V characteristic is shown in Figure 3-7.

If this bus is controlled by an LTC transformer or by a BG or BX bus, a warning diagnostic will be issued to the effect that remotely controlled buses are typically type BC or type BT and the controlled voltage is a single value, V_{sched} and not a range $V_{min} < V_{controlled} < V_{max}$.

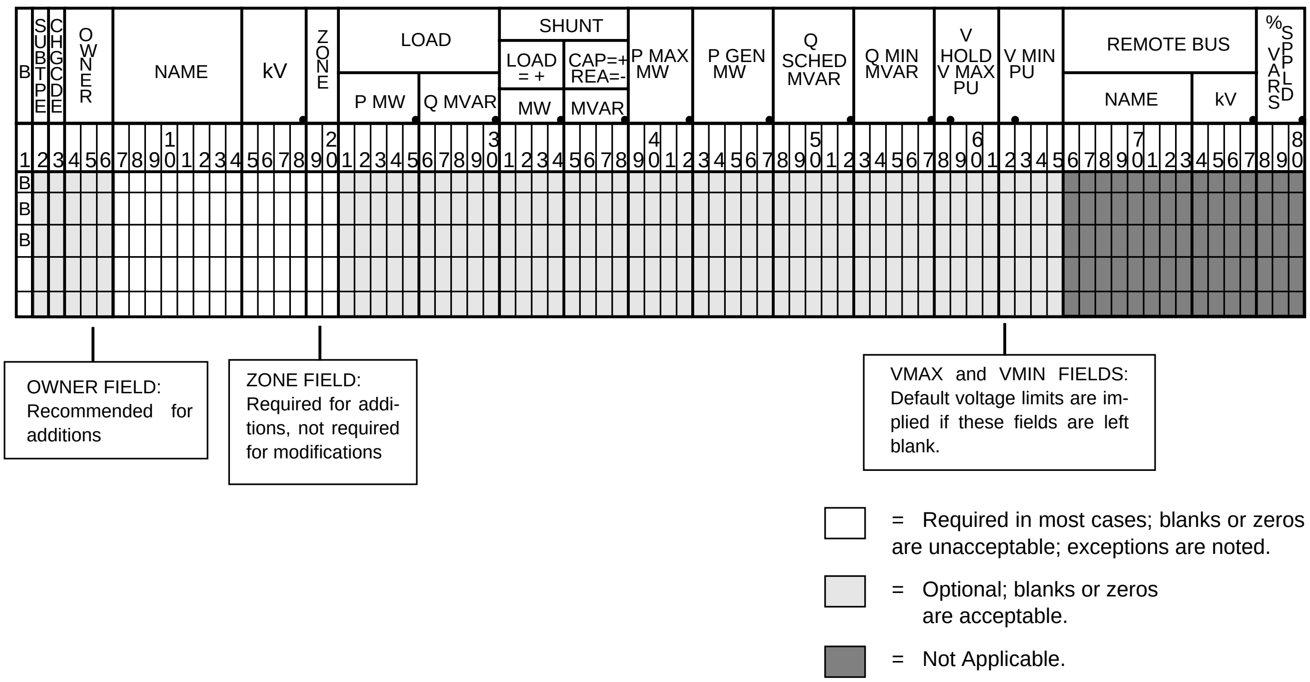


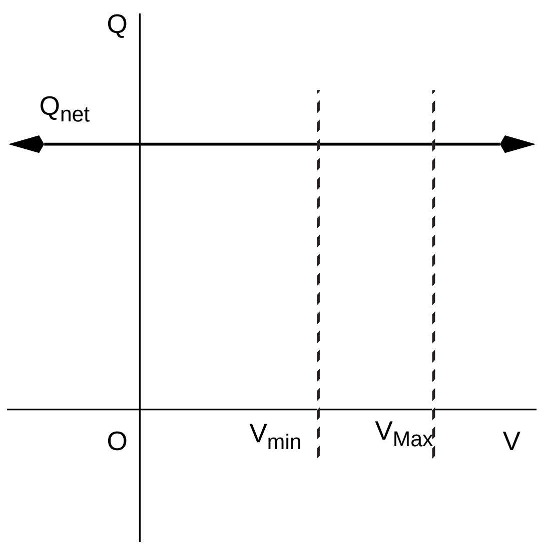
Figure 3-7 B-blank Subtype Format

Table 3-9 Column Description for B Bus Data

Column	ID Field	Format	Description
1-2	yes	A2	B — Generic load bus
3	no	A1	Change code
4-6	no	A3	Ownership
7-14	yes	A8	Bus name
15-18	yes	F4.0	Base kV
19-20	no	A2	Zone
21-25	no	F5.0	Load MW
26-30	no	F5.0	Load MVAR
31-34	no	F4.0	Shunt Admittance Load in MW at base kV
35-38	no	F4.0	Shunt Admittance in MVAR

Table 3-9 Column Description for B Bus Data (Continued)

Column	ID Field	Format	Description
39-42	no	F4.0	P MAX
43-47	no	F5.0	P GEN
48-52	no	F5.0	Q SCHED in MVAR
53-57	no	F5.0	Q MIN — Must be blank or zero for Q SCHED to apply
58-61	no	F4.3	VMAX. If blank, then limits default to global limits as outlined in Appendix E.
62-65	no	F4.3	VMIN. If blank, then limits default to global limits as outlined in Appendix E.
66-77	no	A8,F4.0	N/A
78-80	no	F3.0	N/A



Qnet is constant for all voltages.

Figure 3-8 Q-V Curve For B-blank Subtype

3.9 AC BUS DATA (BC)

Application

This bus type has its voltage maintained by a subtype BG bus. See Figure 3-9 and Figure 3-10.

Bus Characteristics

Both real (P) and reactive (Q) power are held constant throughout the entire solution. This applies to generators, loads, and shunt devices (capacitors/reactors).

A specific amount of reactive generation can be requested. This can be accomplished by entering a zero (0) in the Q MIN field and the desired amount of reactive generation in the Q SCHED field.

Reactive constraints are not allowed for this type of bus. If reactive limits are entered in the Q MAX and Q MIN fields, they will be ignored.

Since this bus type has its voltage maintained by a generator bus, a V HOLD entry is strongly recommended on the bus record. However, if that field is blank, the global default limits apply, in effect, using VMAX for the VHOLD. See Appendix E.

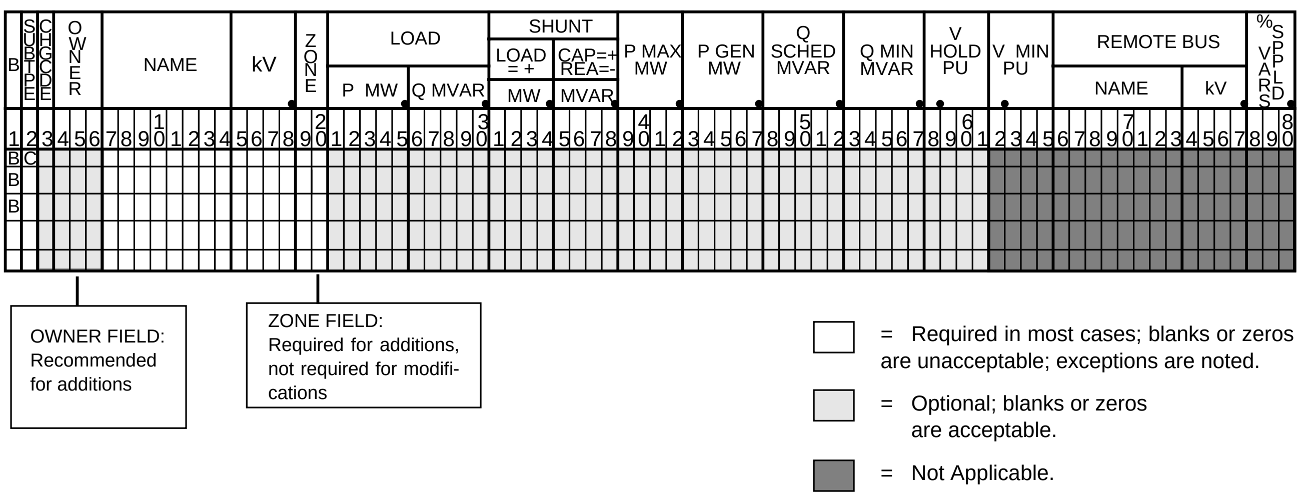
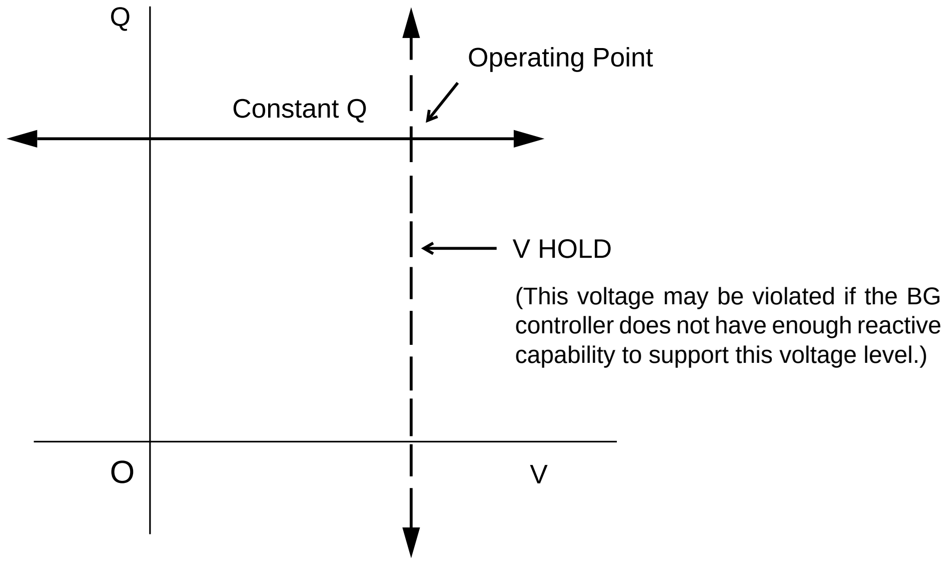


Figure 3-9 BC Subtype Format

Table 3-10 Column Description for BC Bus Data

Column	ID Field	Format	Description
1-2	yes	A2	BC — Voltage controlled by BG bus
3	no	A1	Change code
4-6	no	A3	Ownership
7-18	yes		Bus name and base kV
15-18	yes	F4.0	Base kV
19-20	no	A2	Zone
21-25	no	F5.0	Load MW
26-30	no	F5.0	Load MVAR
31-34	no	F4.0	Shunt Admittance Load in MW at base kV
35-38	no	F4.0	Shunt Admittance in MVAR
39-42	no	F4.0	P MAX
43-47	no	F5.0	P GEN
48-52	no	F5.0	Q SCHED in MVAR
53-57	no	F5.0	Q MIN — Must be blank or zero for Q SCHED to apply
58-61	no	F4.3	V HOLD in per unit
62-65	no	F4.3	N/A
66-77	no	A8,F4.0	N/A
78-80	no	F3.0	N/A



Bus voltage and Q are held constant. Voltage is maintained by a controlling subtype BG bus and is held independently of Q.

Figure 3-10 Q-V Curve for BC Subtype

3.10 AC BUS DATA (BE)

Application

This subtype is used to hold the bus voltage to a specified value, regardless of the amount of reactive required. See Figure 3-11 and Figure 3-12.

Bus Characteristics

Voltage magnitude (V) is held constant. Real (P) power is held constant. This applies to generators, load, and shunt devices. Reactive (Q) load is held constant for this bus type.

Reactive (Q) shunt is variable. The amount of shunt reactance added by the program can vary from 0 to Qshunt, depending upon the amount needed to maintain desired bus voltage.

Reactive (Q) generation is variable.

Reactive constraints are allowed for this bus type. These quantities are entered in the Q MAX and Q MIN fields. If reactive constraints are imposed, "unscheduled reactive" may be added by the program to hold the bus voltage.

A specific amount of reactive generation (Q SCHED) cannot be requested.

Since this bus type maintains its own voltage, a V HOLD entry is required on the record. The voltage is held fixed at this value, regardless of the amount of reactive required. Note that V HOLD is not required for type "M" changes.

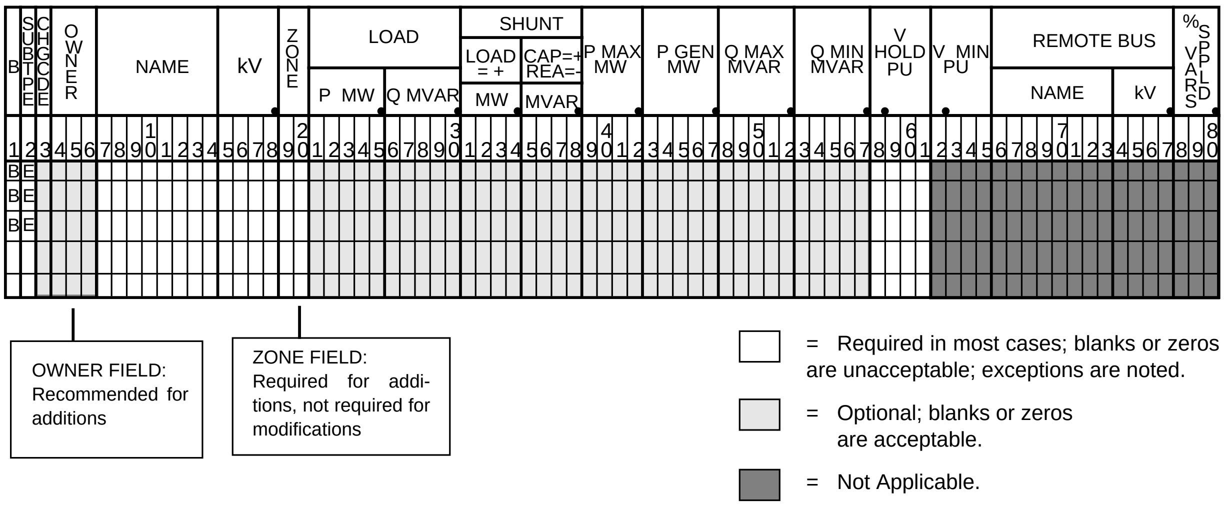


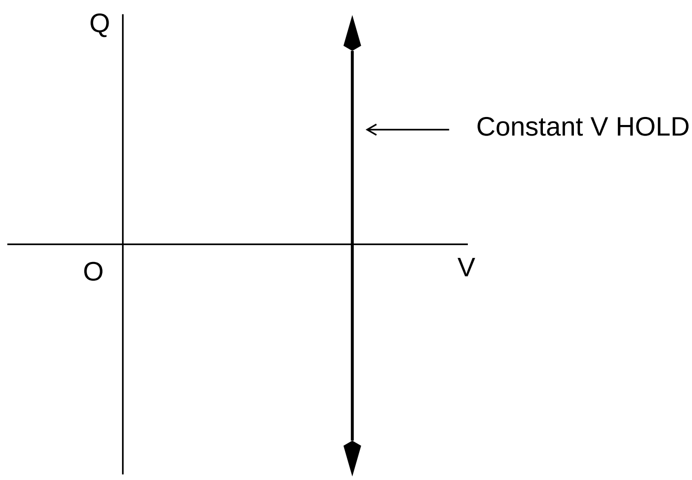
Figure 3-11 BE Subtype Format

Table 3-11 Column Description for BE Bus Data

Column	ID Field	Format	Description
1-2	yes	A2	BE — Constant voltage bus
3	no	A1	Change code
4-6	no	A3	Ownership
7-14	yes	A8	Bus name
15-18	yes	F4.0	Base kV
19-20	no	A2	Zone
21-25	no	F5.0	Load MW
26-30	no	F5.0	Load MVAR
31-34	no	F4.0	Shunt Admittance Load in MW at base kV
35-38	no	F4.0	Shunt Admittance in MVAR
39-42	no	F4.0	P MAX
43-47	no	F5.0	P GEN
48-52	no	F5.0	Q MAX in MVAR
53-57	no	F5.0	Q MIN in MVAR

Table 3-11 Column Description for BE Bus Data

Column	ID Field	Format	Description
58-61	no	F4.3	V HOLD in per unit
62-65	no	F4.3	N/A
66-77	no	A8,F4.0	N/A
78-80	no	F3.0	N/A



Bus voltage will be held at a constant value implying infinite Q resources.

Figure 3-12 Q-V Curve for BE Subtype

3.11 AC BUS DATA (BF)

This is a special purpose bus type used to assist the Newton-Raphson solution convergence. The BF type behaves as a BE bus until the P_net converges to the Newton-Raphson solution. Then it functions as a B- type. This feature is useful to bias a solution toward a more feasible voltage.

3.12 AC BUS DATA (BG)

Application

This bus type is typically used to maintain the voltage at a remote bus (subtype BC).

This subtype may also be used for local control. For this application, the bus would maintain its own voltage. In this case, it would differ from a BQ bus only by the voltage limit. BG has $V_{min} \leq V_{max}$; BQ has V_{hold}.

Bus Characteristics

Real (P) power is held constant. This applies to generators, load and shunt devices. However, it is not required to have generation (P GEN) at this bus.

Reactive (Q) load and shunt are held constant for this bus type.

Reactive (Q) generation is variable.

This bus type requires reactive limits to be entered in the Q MAX and Q MIN fields. The reactive limits on the subtype BG bus are used to maintain a specified voltage at a remote bus. If the remote bus voltage cannot be held with the available BG bus reactance, voltage control stops at either Q MAX or Q MIN.

A specific amount of reactive generation (Q SCHED) cannot be requested.

This bus type uses V MAX and V MIN limits. If these fields are blank, global voltages are used as defaults. The voltage on the BG bus must be between V MIN and V MAX when controlling a remote bus. If not, remote voltage control will be disabled.

If this bus type is being used to control another bus, the REMOTE BUS and % VARS SUPPLIED fields should be used. The REMOTE BUS may not be the system swing bus or another subtype BG bus. The % VARS SUPPLIED field is used to allow the voltage control of a remote bus, to be distributed among more than one BG bus.

If the % VARS SUPPLIED is left blank, the program computes these values based upon the percent of total VARS supplied by the bus.

If the bus is controlling itself, its own name must appear in the REMOTE bus field.

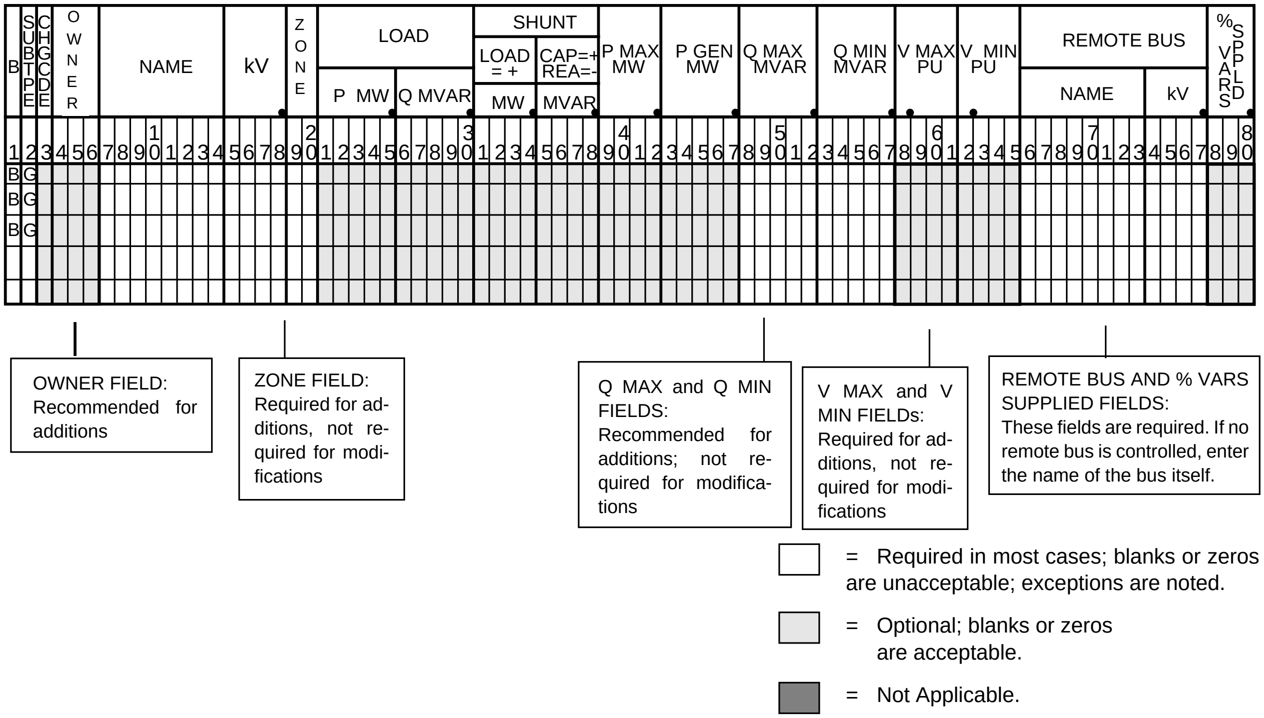


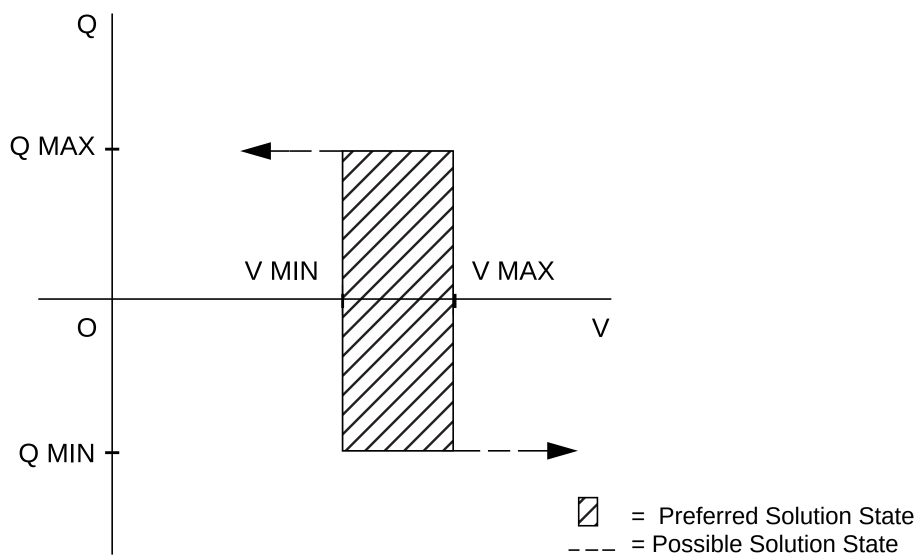
Figure 3-13 BG Subtype Format

Table 3-12 Column Description for BG Bus Data

Column	ID Field	Format	Description
1-2	yes	A2	BG — Maintains the voltage of a remote bus
3	no	A1	Change code
4-6	no	A3	Ownership
7-14	yes	A8	Bus name
15-18	yes	F4.0	Base kV
19-20	no	A2	Zone
21-25	no	F5.0	Load MW
26-30	no	F5.0	Load MVAR
31-34	no	F4.0	Shunt Admittance Load in MW at base kV

Table 3-12 Column Description for BG Bus Data

Column	ID Field	Format	Description
35-38	no	F4.0	Shunt Admittance in MVAR
39-42	no	F4.0	P MAX
43-47	no	F5.0	P GEN
48-52	no	F5.0	Q MAX in MVAR
53-57	no	F5.0	Q MIN — Must be blank or zero for Q SCHED to apply
58-61	no	F4.3	V MAX
62-65	no	F4.3	V MIN
66-77	no	A8,F4.0	Controlled bus name and base kV (self or remote)
78-80	no	F3.0	Percent of vars supplied for remote bus voltage control.



Shaded area depicts region of active control. Voltage and Q are variable within constraints shown.

Figure 3-14 Q-V Curve for BG Subtype

3.13 AC BUS DATA (BQ)

Application

This subtype is used to hold the bus voltage to a specified value within reactive limits. See Figure 3-15 and Figure 3-16.

Bus Characteristics

Real power (P GEN) is held constant. This applies to generators, load, and shunt devices.

Reactive load (Q MVAR) load is held constant for this bus type.

Reactive (SHUNT MVAR) shunt is variable. The amount of shunt reactance added by the program can vary from 0 to Qshunt, depending on the amount needed to maintain desired bus voltage.

Reactive (Q) generation is variable.

This bus type requires adjustable reactive generation or shunt to perform as intended. If neither is available, the bus functions as a bus type B-blank.

A specific amount of reactive generation (Q SCHED) cannot be requested.

Since this bus type is attempting to maintain its own voltage, a V HOLD entry is required on the record. If the voltage cannot be held at the desired level, using the reactive capability of the bus, the desired voltage will be violated and reactive will be held at the Q MAX or Q MIN limit. Note that V HOLD is not required for modifications.

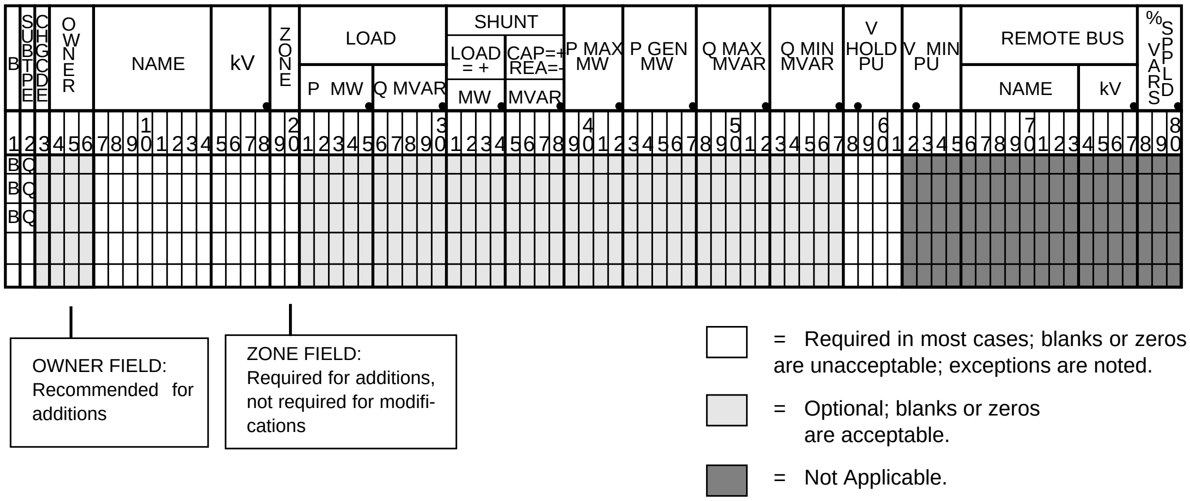


Figure 3-15 BQ Subtype Format

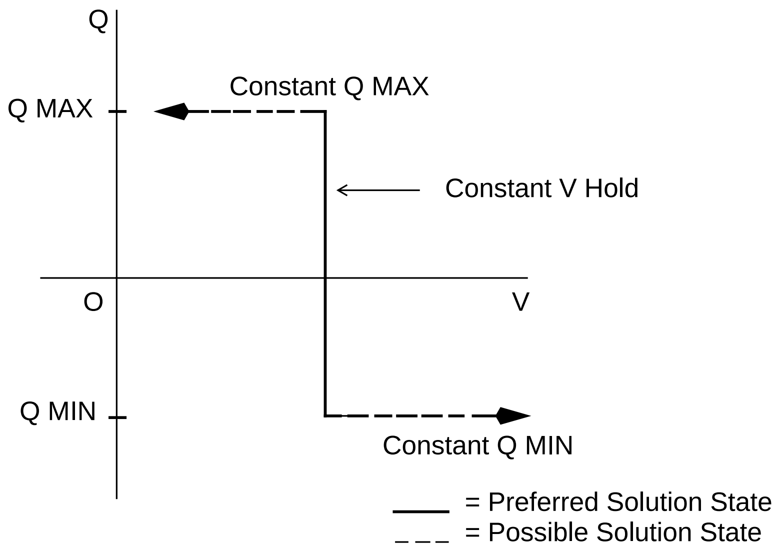
Note: For a type BQ bus to be viable, it needs a source of adjustable reactive. This may be the B_shunt field or the Q_{min}-Q_{max} fields. The necessary reactive component may be provided on the bus record, or it may be provided on an accompanying continuation (+) bus record or both.

Table 3-13 Column Description for BQ Bus Data

Column	ID Field	Format	Description
1-2	yes	A2	BQ — Constant voltage within Q limits
3	no	A1	Change code
4-6	no	A3	Ownership
7-14	yes	A8	Bus name
15-18	yes	F4.0	Base kV
19-20	no	A2	Zone
21-25	no	F5.0	Load MW
26-30	no	F5.0	Load MVAR
31-34	no	F4.0	Shunt Admittance Load in MW at base kV
35-38	no	F4.0	Shunt Admittance in MVAR

Table 3-13 Column Description for BQ Bus Data

Column	ID Field	Format	Description
39-42	no	F4.0	P MAX
43-47	no	F5.0	P GEN
48-52	no	F5.0	Q MAX
53-57	no	F5.0	Q MIN
58-61	no	F4.3	V HOLD
62-65	no	F4.3	N/A
66-77	no	A8,F4.0	N/A
78-80	no	F3.0	N/A



Preferred solution state is constant voltage. Solution voltage may differ if either Q constraint is violated.

Figure 3-16 Q-V curve for BQ Subtype

3.14 AC BUS DATA (BS)

Application

This subtype designates the system swing or slack bus. The generators at the swing bus supply the difference between the specified power flowing into the system at the other buses and the total system output plus losses. Thus, real and reactive power are determined as part of the solution for this subtype.

Every power flow case must have a minimum of one swing bus. In addition, each isolated ac system must have its own swing bus. The maximum numbers of swing buses allowed for a single power flow case is ten.

Bus Characteristics

Real (P) load is held constant.

Both real (P) generation and shunt are variable. The P GEN field is updated to the base case value. The P MAX field is used for reporting purposes only.

Reactive (Q) load is held constant for this bus type.

Reactive (Q) shunt is variable. The amount of shunt reactance added by the program can vary from 0 to Qshunt, depending on the amount needed to maintain desired bus voltage.

Reactive (Q) generation is variable.

Reactive constraints are allowed for this bus type. These quantities are entered in the Q MAX and Q MIN fields. If reactive constraints are imposed, "unscheduled reactive" may be added by the program to maintain the bus voltage.

A specific amount of reactive generation can be requested, in place of reactive constraints. This is implemented by entering a 0 in the Q MIN field and the desired amount of reactive generation in the Q SCHED field. Again, "unscheduled reactive" may be added by the program to maintain the bus voltage.

The BS bus record requires an entry in the V HOLD field.

The V MIN field is used to specify the angle of the swing bus for this application. It should be noted that an implied decimal point exists between columns 64 and 65. For example, an angle of 3.7 degrees can be specified with a 3 in column 64 and a 7 in column 65.

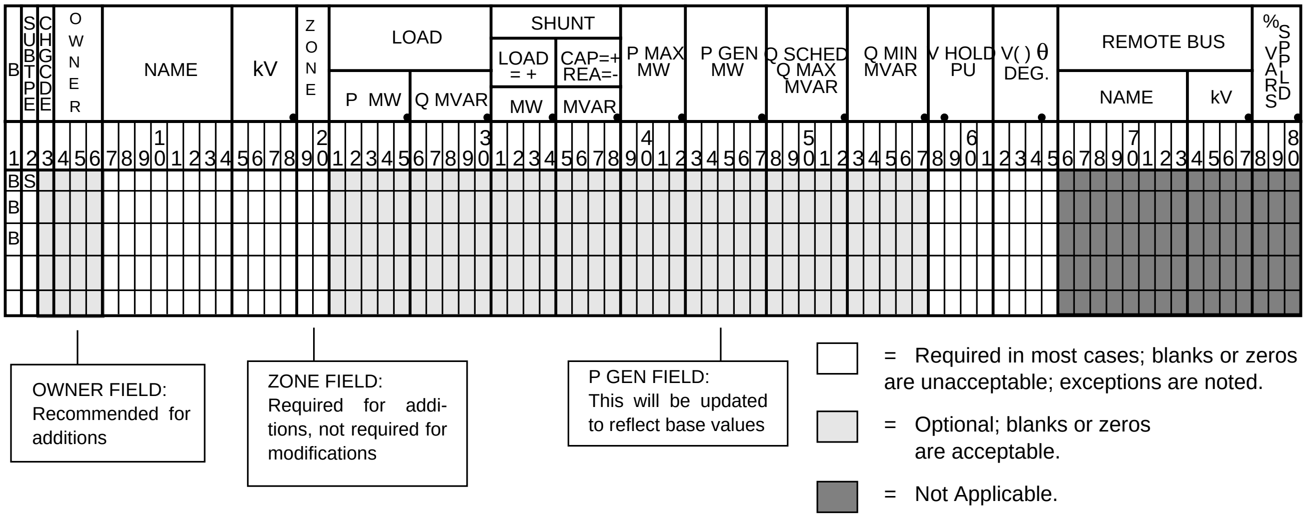


Figure 3-17 BS Subtype Format

Table 3-14 Column Description for BS Bus Data

Column	ID Field	Format	Description
1-2	yes	A2	BS — System swing or slack bus
3	no	A1	Change code
4-6	no	A3	Ownership
7-14	yes	A8	Bus name
15-18	yes	F4.0	Base kV
19-20	no	A2	Zone
21-25	no	F5.0	Load MW
26-30	no	F5.0	Load MVAR
31-34	no	F4.0	Shunt Admittance Load in MW at base kV
35-38	no	F4.0	Shunt Admittance in MVAR
39-42	no	F4.0	P MAX
43-47	no	F5.0	P GEN
48-52	no	F5.0	Q MAX
53-57	no	F5.0	Q MIN

Table 3-14 Column Description for BS Bus Data (Continued)

Column	ID Field	Format	Description
58-61	no	F4.3	V HOLD
62-65	no	F4.1	Voltage angle (blank implies zero degrees)
66-77	no	A8,F4.0	N/A
78-80	no	F3.0	N/A

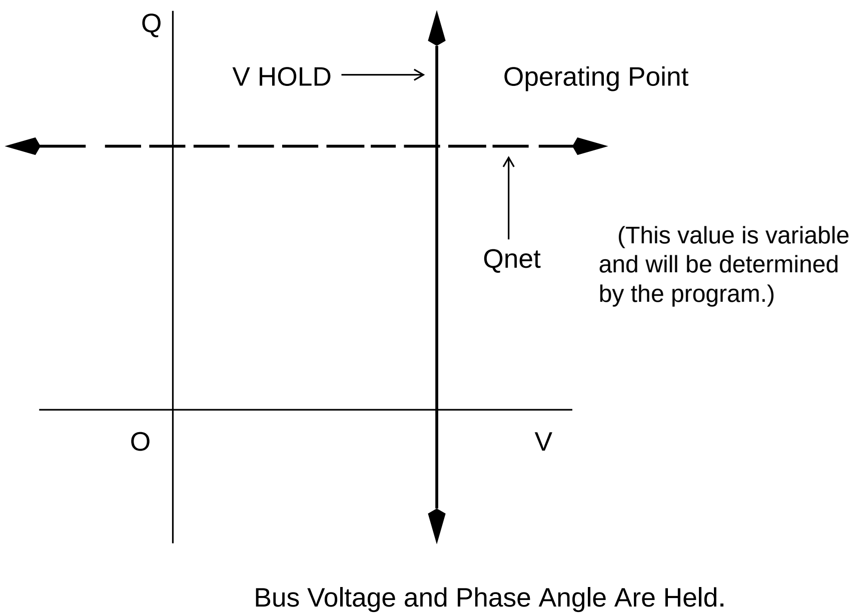


Figure 3-18 Q-V Curve for BS Subtype

3.15 AC BUS DATA (BT)

Application

This subtype has its voltage maintained by an LTC transformer. See Figure 3-19 and Figure 3-20.

Bus Characteristics

Both real (P) and reactive (Q) power are held constant throughout the entire solution. This applies to generators, load, and shunt devices (capacitors/reactors).

A specific amount of reactive generation can be requested. This can be accomplished by entering a zero (0) or blank in the Q MIN field and the desired amount of reactive generation in the Q SCHED field.

Reactive constraints are not allowed for this type of bus. If reactive limits are entered in the Q MAX and Q MIN fields, they will be ignored.

Since this bus type has its voltage maintained by an LTC transformer, a V HOLD entry is required.

This subtype requires an additional record, the R (Regulating Transformer) record.

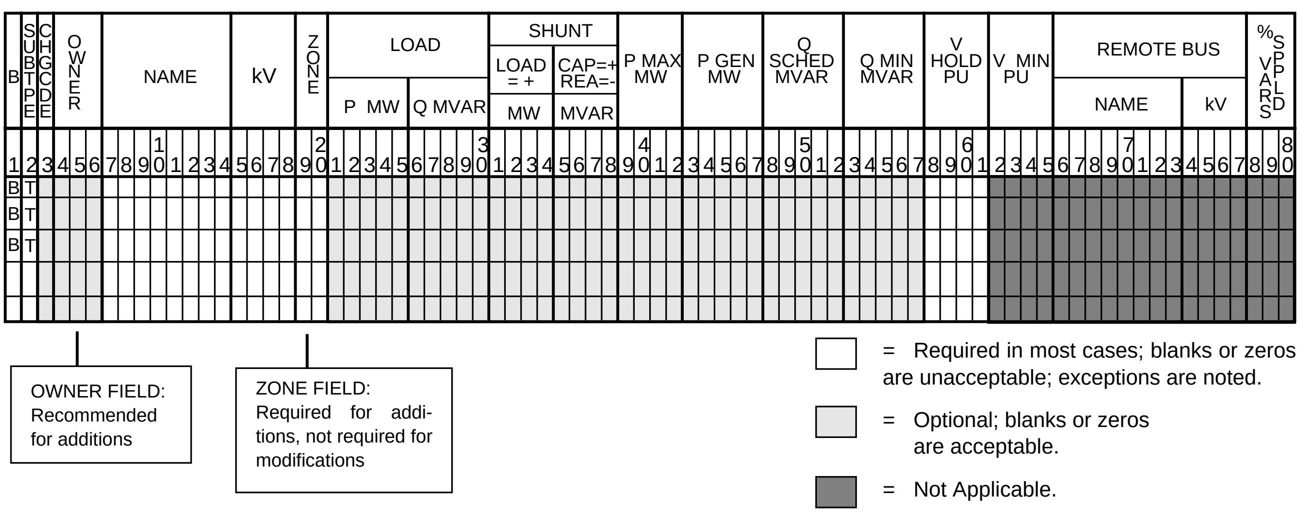
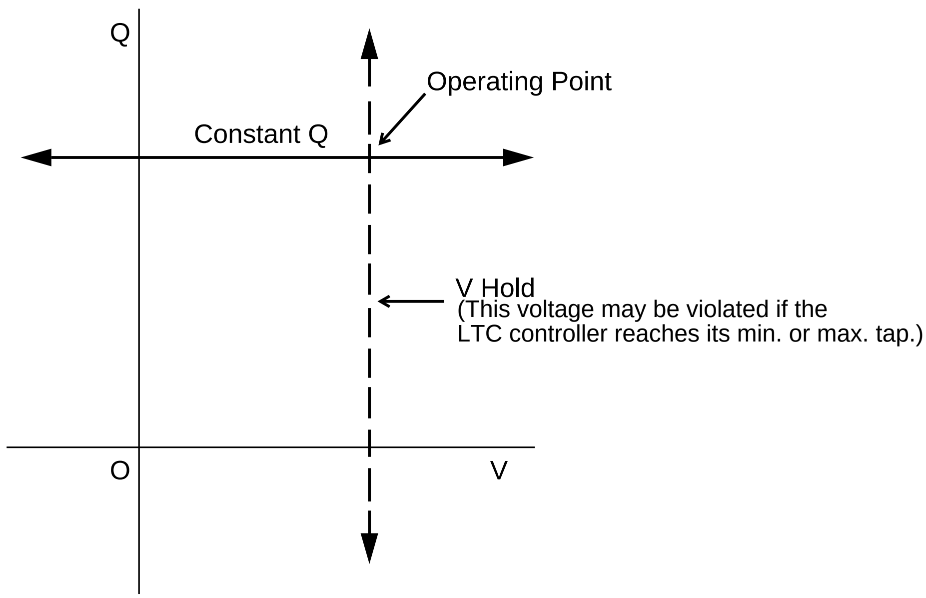


Figure 3-19 BT Subtype Format

Table 3-15 Column Description for BT Bus Data

Column	ID Field	Format	Description
1-2	yes	A2	BT — LTC transformer controlled bus
3	no	A1	Change code
4-6	no	A3	Ownership
7-14	yes	A8	Bus name
15-18	yes	F4.0	Base kV
19-20	no	A2	Zone
21-25	no	F5.0	Load MW
26-30	no	F5.0	Load MVAR
31-34	no	F4.0	Shunt Admittance Load in MW at base kV
35-38	no	F4.0	Shunt Admittance in MVAR
39-42	no	F4.0	P MAX
43-47	no	F5.0	P GEN
48-52	no	F5.0	Q SCHED
53-57	no	F5.0	QMIN must be blank or zero for QSCHED to apply
58-61	no	F4.3	V HOLD
62-65	no	F4.1	N/A
66-77	no	A8,F4.0	N/A
78-80	no	F3.0	N/A



Bus voltage and Q are held constant. Voltage is maintained by a controlling LTC transformer and is held independently of Q.

Figure 3-20 Q-V Curve for BT Subtype

3.16 AC BUS DATA (BV)

Application

This subtype maintains the bus's net reactive (Qnet) power flow as long as the bus voltage does not violate the user specified voltage range. See Figure 3-21 and Figure 3-22.

Bus Characteristics

Real (P) power is held constant throughout the entire solution. This applies to generators, load, and shunt devices.

Reactive (Q) load and shunt are also held constant.

Reactive (Q) generation is normally constant. Although this bus type actually has infinitely adjustable reactive limits, the program attempts to hold Qnet constant. However, if either of the voltage limits are violated, Qnet is changed to hold that limit. If any additional reactive generation is added by the program, it will be referred to as "unscheduled reactive" in the program output file.

A specific amount of reactive generation can be requested. This is accomplished by entering a zero (0) in the Q MIN field and the desired amount of reactive generation in the Q SCHED field.

Reactive constraints are not allowed for this type of bus. If reactive limits are entered in the Q MAX and Q MIN fields, they will be ignored.

The BV bus record requires entries in the V MAX and V MIN fields. The program's solution voltage will be within the range of V MAX to V MIN, regardless of how much reactive is required. If voltage attempts to rise above V MAX, additional negative reactive (-Q shunt) is added to bring the voltage down to V MAX. Also, if the voltage is below V MIN, additional reactive (+Q shunt) is added until the bus voltage has reached V MIN.

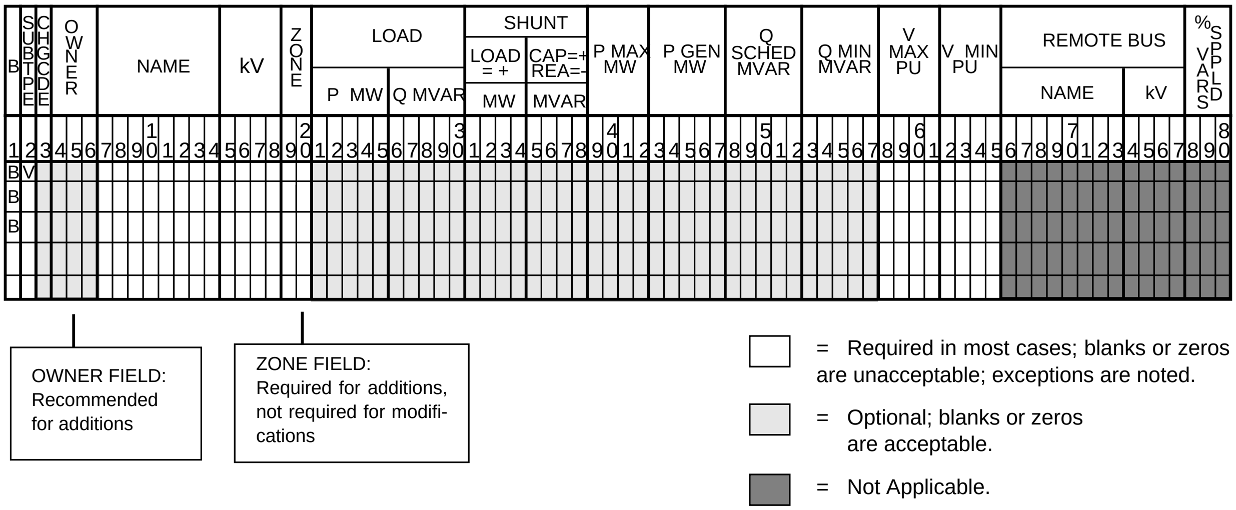


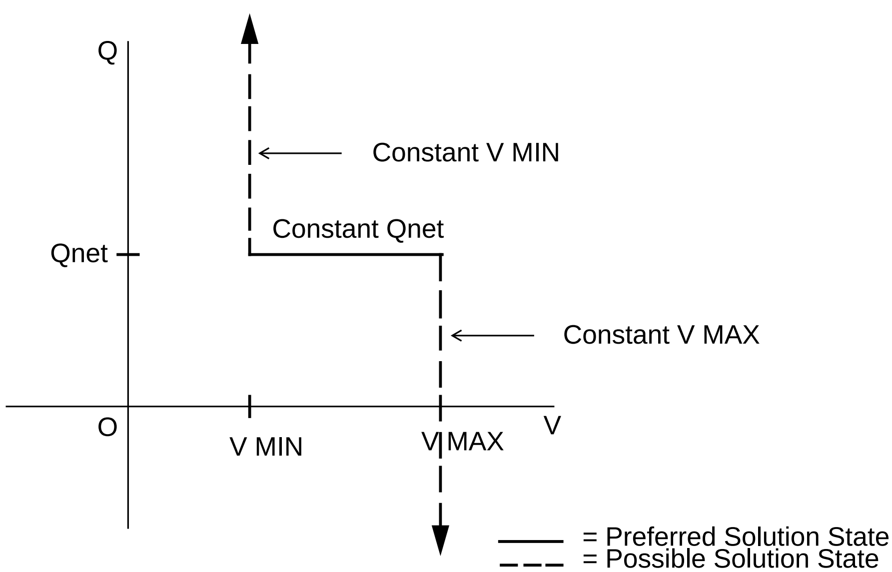
Figure 3-21 BV Subtype Format

Table 3-16 Column Description for BV Bus Data

Column	ID Field	Format	Description
1-2	yes	A2	BV — Constant Q within V limits
3	no	A1	Change code
4-6	no	A3	Ownership
7-14	yes	A8	Bus name
15-18	yes	F4.0	Base kV
19-20	no	A2	Zone
21-25	no	F5.0	Load MW
26-30	no	F5.0	Load MVAR
31-34	no	F4.0	Shunt Admittance Load in MW at base kV
35-38	no	F4.0	Shunt Admittance in MVAR
39-42	no	F4.0	P MAX
43-47	no	F5.0	P GEN
48-52	no	F5.0	Q SCHED or QMAX

Table 3-16 Column Description for BV Bus Data

Column	ID Field	Format	Description
53-57	no	F5.0	Q MIN
58-61	no	F4.3	V MAX in per unit
62-65	no	F4.1	V MIN in per unit
66-77	no	A8,F4.0	N/A
78-80	no	F3.0	N/A



The preferred solution state is constant Q, but may change if voltage constraints are violated.

Figure 3-22 Q-V Curve for BV Subtype

3.17 AC BUS DATA (BX)

Application

This subtype may be used for a truer representation of capacitors/reactors that are switched in discrete blocks to control bus voltages.

The BX subtype is most often used for local voltage control. Here, the bus would maintain its own voltage within a specified range of voltages. It is recommended, but is not mandatory, that for local control the bus name should be repeated in the REMOTE field.

This subtype may also be used for remote control, where the BX bus maintains a specified voltage level at another bus. Provide the remote bus name.

Bus Characteristics

The real (G) and reactive (B) shunt fields hold the base case values of discrete reactance. These values may be updated by the solution.

Real (P) power is held constant. This applies to generators and loads.

Reactive (Q) load is held constant.

Reactive (Q) generation is variable.

Reactive constraints are allowed for this bus type. These quantities are entered in the Q MAX and Q MIN fields. A specific amount of reactive generation (Q SCHED) is available only if QMAX = QMIN.

This bus type uses V MAX and V MIN limits. If these fields are blank, global voltages are used as defaults. The voltage on the BG bus must be between V MIN and V MAX when controlling a remote bus. If not, remote voltage control will be disabled.

Reactive shunt (± Q) is added in discrete blocks to maintain the desired bus voltage. The capacitive/inductive blocks of reactance are identified on the X (switched reactance) record. It should be noted that actual convergence is implemented with continuous susceptance control, then discretization occurs automatically. This means that exact voltage control may not be possible.

It should be noted that the program will attempt to select a discrete reactive step, which yields the highest voltage within the specified limits, so that losses can be minimized. This is the default (BPA) value, for the third level `>MISC_CNTRL` Program Control Statement, `X_BUS` option.

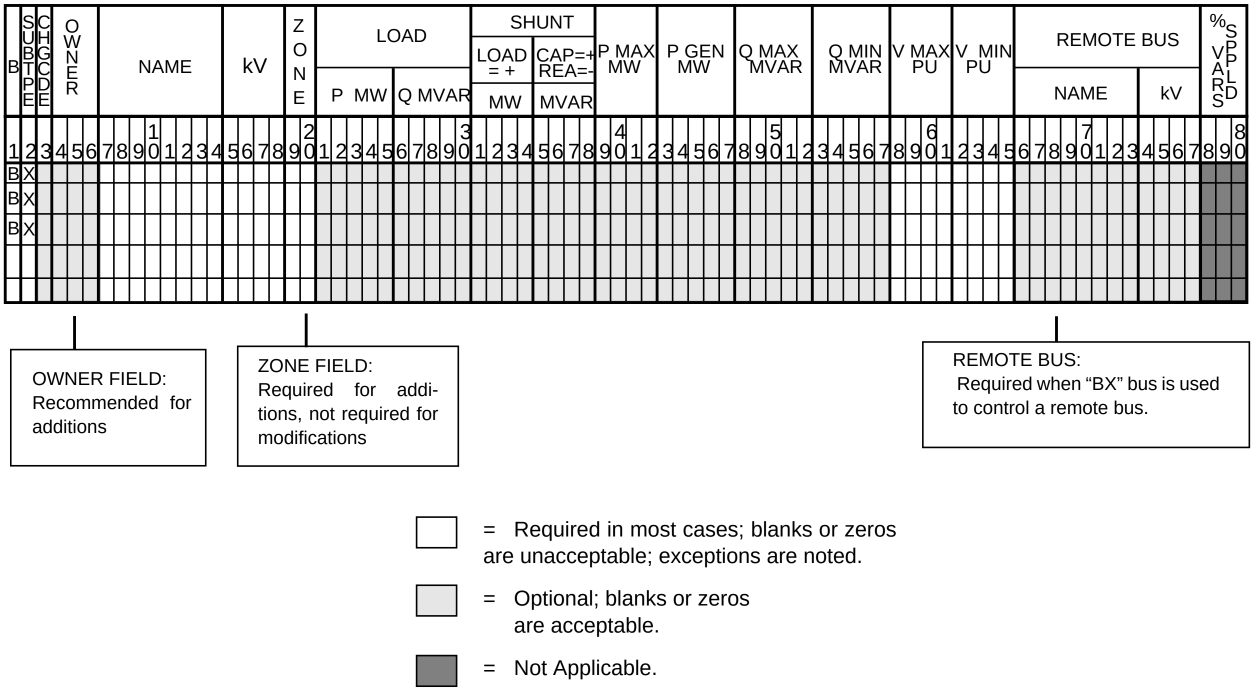


Figure 3-23 BX Subtype Format

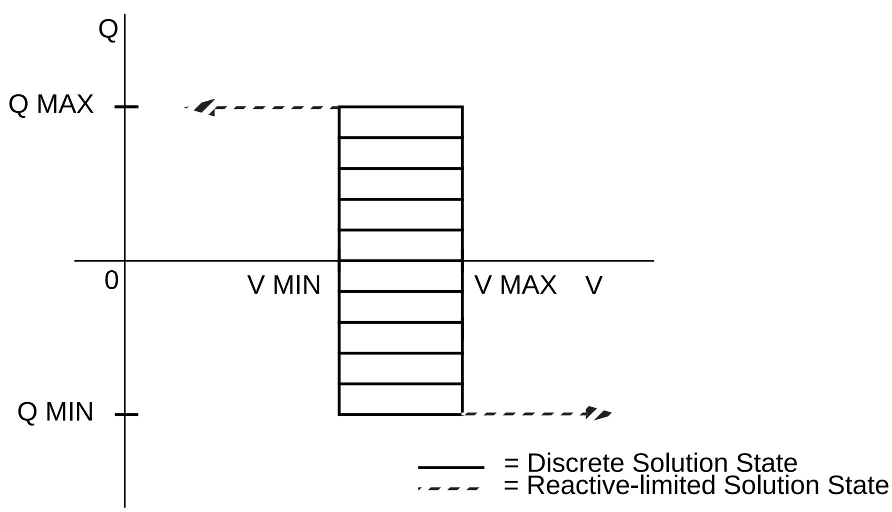
Note: The value on the B_shunt field dictates the initial value.

Table 3-17 Column Description for BX Bus Data

Column	ID Field	Format	Description
1-2	yes	A2	BX — Attempts constant V using switched Q
3	no	A1	Change code
4-6	no	A3	Ownership
7-14	yes	A8	Bus name
15-18	yes	F4.0	Base kV
19-20	no	A2	Zone
21-25	no	F5.0	Load MW
26-30	no	F5.0	Load MVAR

Table 3-17 Column Description for BX Bus Data (Continued)

Column	ID Field	Format	Description
31-34	no	F4.0	Shunt Admittance Load in MW at base kV
35-38	no	F4.0	Shunt Admittance in MVAR
39-42	no	F4.0	P MAX
43-47	no	F5.0	P GEN
48-52	no	F5.0	Q SCHED or QMAX
53-57	no	F5.0	Q MIN
58-61	no	F4.3	V MAX in per unit
62-65	no	F4.1	V MIN in per unit
66-77	no	A8,F4.0	Controlled bus name and kV (self or remote). If blank, self is assumed.
78-80	no	F3.0	N/A



Enclosed area depicts region of active control. Voltage and Q are variable within constraints shown.

Figure 3-24 Q-V Curve for BX Subtype

3.18 TWO-TERMINAL DC BUS (BD)

This record defines a dc bus to be used in conjunction with a two-terminal dc line. It is subtype `D` and interpreted with a different format from ac bus data records. No injections of any kind are permitted. The data contained on the record defines the rectifier or inverter valve characteristics. During the solution, the injection from the converter into the dc line is replaced with an equivalent but fictitious injection, and the dc line is removed entirely from the ac solution.

The dc model determines the initial ac injections and voltage magnitude on the converter bus. If these conditions can be held in the ac solution, no further dc adjustments occur. If the conditions cannot be held, the firing or extinction angles are readjusted to interface the current voltage magnitude on the converter buses while observing the scheduled dc power in the dc line. These adjustments will change the equivalent ac injections and will require a new ac solution.

The dc bus must be connected to a single ac bus through a commutating transformer. The commutating bus name is required, and the commutating transformer must be an LTC. All reactive sources supplying the harmonic filter must be connected on the commutating bus; it is not restricted in subtype.

Data for the inverter and rectifier buses are identical. Identification of each is by the dc line data record which compares the sign of the dc power flow with the dc terminal buses. The rectifier and inverter buses may be interchanging the sign of the scheduled dc power.

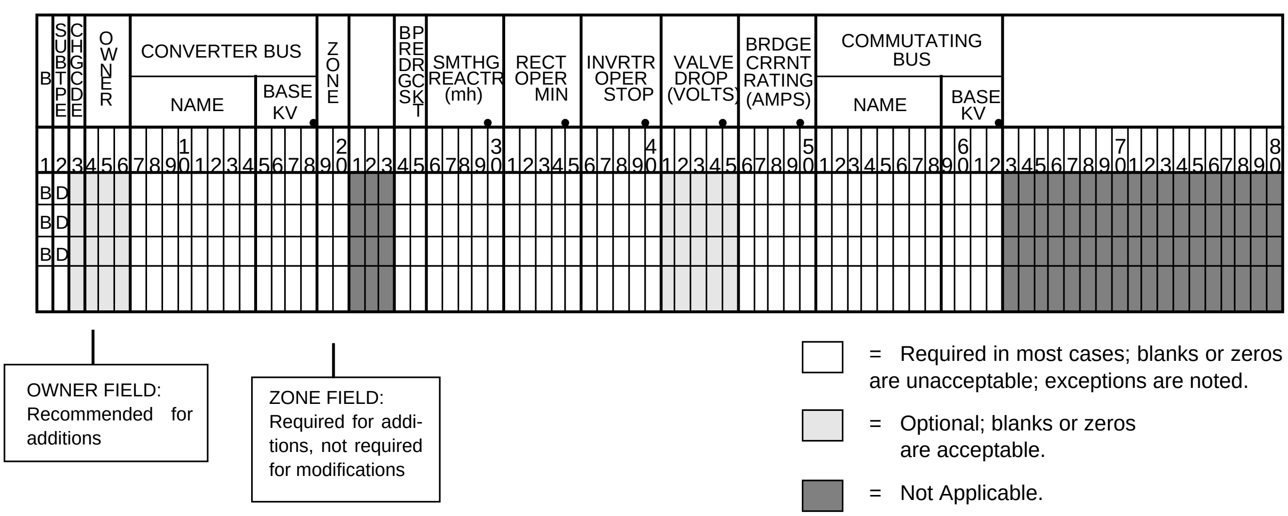


Figure 3-25 BD Bus Data Input Format

Table 3-18 Column Description for BD Bus Data

Column	ID Field	Format	Description
1-2	yes	A2	BD — Code for direct current (dc) bus, terminal of a dc line.
3	no	A1	Change code — see System Changes
4-6	no	A3	Ownership code
7-14	yes	A8	Bus name
15-18	yes	F4.0	Base kV
19-20	no	A2	Zone
24-25	no	I2	Bridges per ckt. — Number of valves in series per circuit.
26-30	no	F5.1	Smoothing reactor (mh) — Inductance of the smoothing reactor in millihenries.
31-35	no	F5.1	Rectifier operation (alpha min.) — Minimum firing angle in degrees as a rectifier.
36-40	no	F5.1	Inverter operation (alpha stop) — Maximum firing angle in degrees. Both inverter and rectifier buses have alpha. However, only the minimum alpha on the rectifier bus is used in the power flow. The remaining valves are required for the transient stability program in event of power reversals in the dc line.
41-45	no	F5.1	Valve drop (volts) — Valve voltage drop per bridge in volts.
46-50	no	F5.1	Bridge current rating (amps) — Maximum bridge current in amperes.
51-62	no	A8,F4.0	Commutating bus — Alphanumeric name in columns 51-58 and base kV in columns 59-62. This is on the ac system side of the commutating transformer bank

3.19 MULTI-TERMINAL DC BUS (BM)

The multi-terminal dc system introduces flexibility in network configuration which is already present in the ac system. This dc scheme is a general extension of the two-terminal dc scheme. The converter modeling itself is unchanged, but the dc converter control is more flexible.

All N-node dc systems must have N dc constraints. These are either converter dc voltage or dc power. At least one dc voltage constraint must be specified. It is permissible to constrain both dc voltage and power on the same node. The choice of voltage or power constraints on each converter is flexible.

It is possible to define a dc tap node. This node is passive only and is not a converter. Nevertheless, it implicitly constrains zero power on itself.

The distinction between rectifiers and inverters is very simple. Any converter's mode of operation is based upon the sign of the converter-calculated output power. The converter output power is positive for rectifiers and negative for inverters. Obviously, a dc tap node will have zero power.

The range of converter angle adjustments is determined by the converters's mode of operation.

$$\alpha_{min} \leq \alpha_{stop}$$
$$\gamma_0 \leq \alpha_{stop}$$

If an excessive number of dc constraints are specified, some superfluous power constraints will be omitted. If the dc system is unable to maintain the dc voltage constraints, the dc voltages will be changed to values realized by the actual commutator bus voltage and the converter angle limits.

It is permissible to model two-terminal dc networks with the multi-terminal type `M` formats. However, it is not permissible to mix two-terminal type `D` data with multi-terminal type `M` data on the same dc circuit. The two different types of dc data may coexist in the same case, but when both types are present, they must pertain to separate dc circuits.

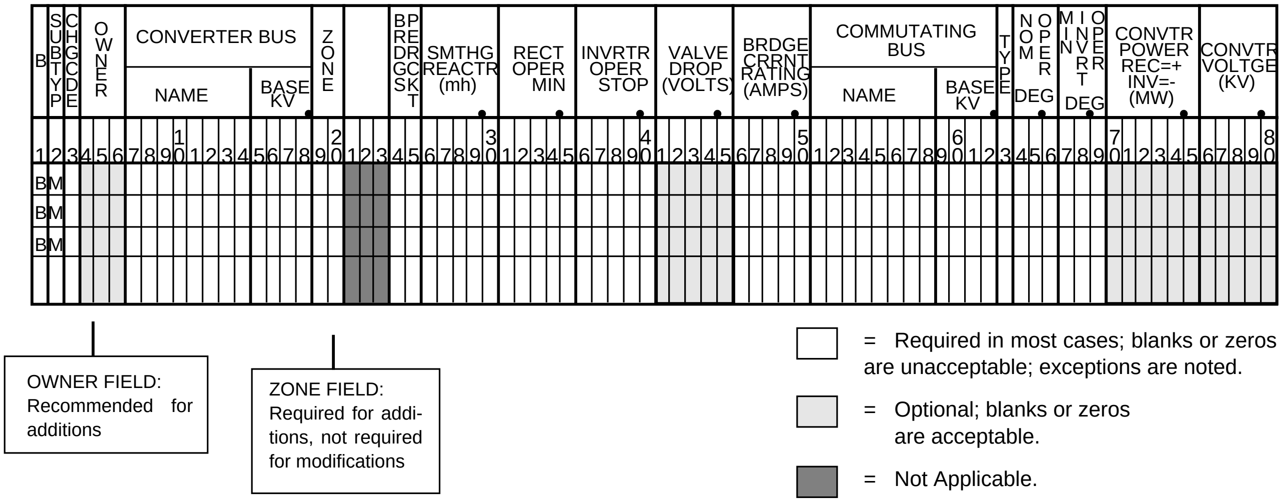


Figure 3-26 BM Bus Data Input Format

Table 3-19 Column Description for BM Bus Data

Column	ID Field	Format	Description
1-2	yes	A2	BM — Code for multi-terminal dc bus
3	no	A1	Change code — see System Changes
4-6	no	A3	Ownership code
7-14[a]	yes	A8	Bus name
15-18	yes	F4.0	Base kV
19-20	no	A2	Zone code
24-25	no	I2	Number of bridges per dc circuit — (Number of converters serially connected)
26-30	no	F5.1	Smoothing reactor inductance in mh
31-35	no	F5.1	Minimum ignition delay angle (alpha_min) in degrees
36-40	no	F5.1	Maximum ignition delay angle (alpha_stop) in degrees
41-45	no	F5.1	Converter valve drop per bridge in volts
46-50	no	F5.1	Maximum converter current in amps
51-62	no	A8,F4.0	Commutator bus name and base Kv of commutator.

Table 3-19 Column Description for BM Bus Data (Continued)

Column	ID Field	Format	Description
63[b]	no	A1	Converter code (R1): R — Normal operation as a rectifier I — Normal operation as an Inverter M — Normal operation as an inverter with current margin Blank — A passive dc tap
64-66	no	F3.1	Normal ignition delay angle (alpha_N) if a rectifier, or normal extinction angle (gamma_N) if an inverter, in degrees
67-69	no	F3.1	Minimum ignition angle (α_{min}) if a rectifier, or minimum extinction angle (γ_0) in degrees if an inverter
70-75[c]	no	F6.1	Scheduled net converter dc output power in MW
76-80[d]	no	F5.1	Scheduled converter dc voltage in kV

a. A passive dc node has columns 24-80 all blank

b. If the actual converter operation does not correspond to the converter code, subsequent swing studies will abort.

c. If the dc power or voltage is not constrained, leave the corresponding field blank or enter a zero value.

d. If the dc power or voltage is not constrained, leave the corresponding field blank or enter a zero value.

3.20 DELETE BUSES BY AREA (DA)

This command deletes all buses that reside in the area named in columns 4-13. Place a `DA` in the first two columns. Format of the input is shown below. This is a change record and must be preceded with a `/CHANGES` command or otherwise reside in a change set.

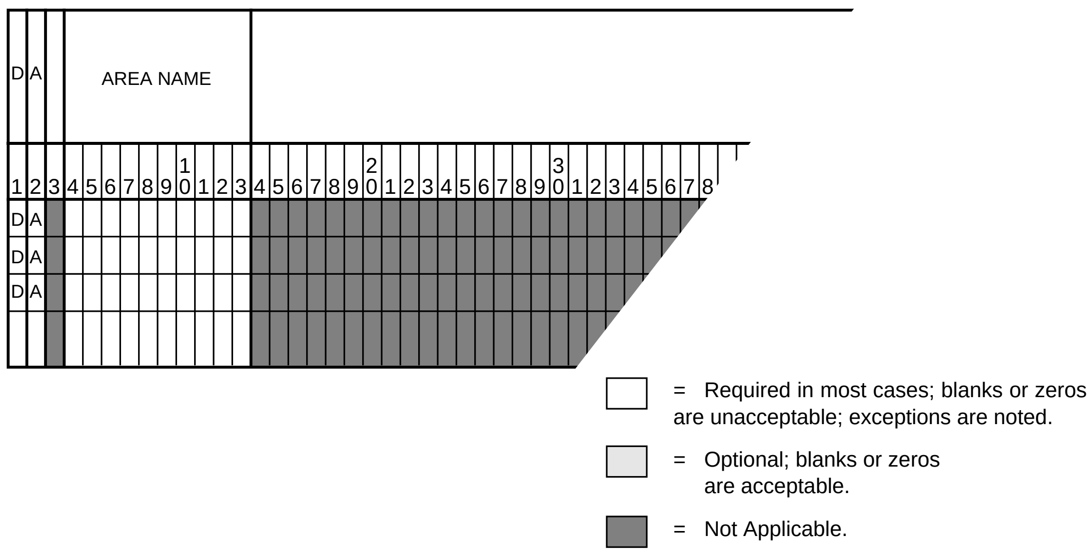


Figure 3-27 Area Delete Input Format

Table 3-20 Column Description for Delete Buses by Area Format

Column	ID Field	Format	Content
1-2	yes	A2	Record type - DA
4-13	yes	A10	Area Name

3.21 DELETE BUSES BY ZONE (DZ)

This command deletes all buses that reside in the zone named in columns 4-5. Place a `DZ` in the first two columns. Format for input is shown below. This is a change record and must be preceded with a `/CHANGES` command or otherwise reside in a change set.

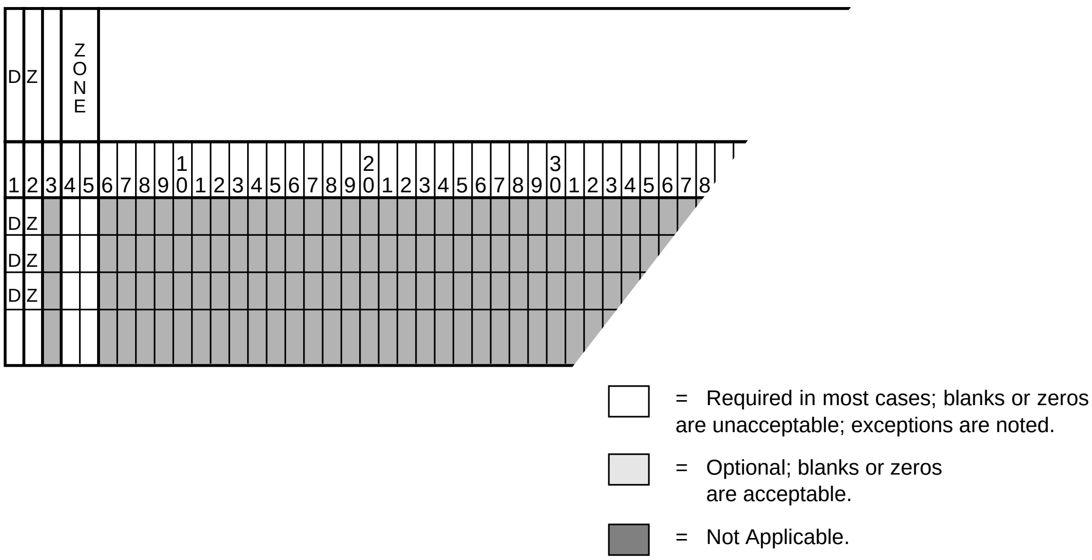


Figure 3-28 Zone Delete Input Format

Table 3-21 Column Description for Delete Buses by Zone Format

Column	ID Field	Format	Content
1-2	yes	A2	Record type - DZ
4-5	yes	A2	Zone Name

3.22 EQUIVALENT TRANSMISSION LINE BRANCH (E)

This record differs from the type `L` record by allowing for an asymmetrical pi. Two additional fields of data must describe the second leg to ground admittances. The additional fields occupy the columns which are used for line description and mileage on the `L` record. In all other aspects, the description of the `L` branch pertains also to the type `E` branch.

This branch representation is useful for modeling transmission line components that do not have evenly distributed parameters, such as lines with shunt capacitors and line/transformer combinations.

Following is a sample of a coding sheet for equivalent branch data along with descriptions of its various columns.

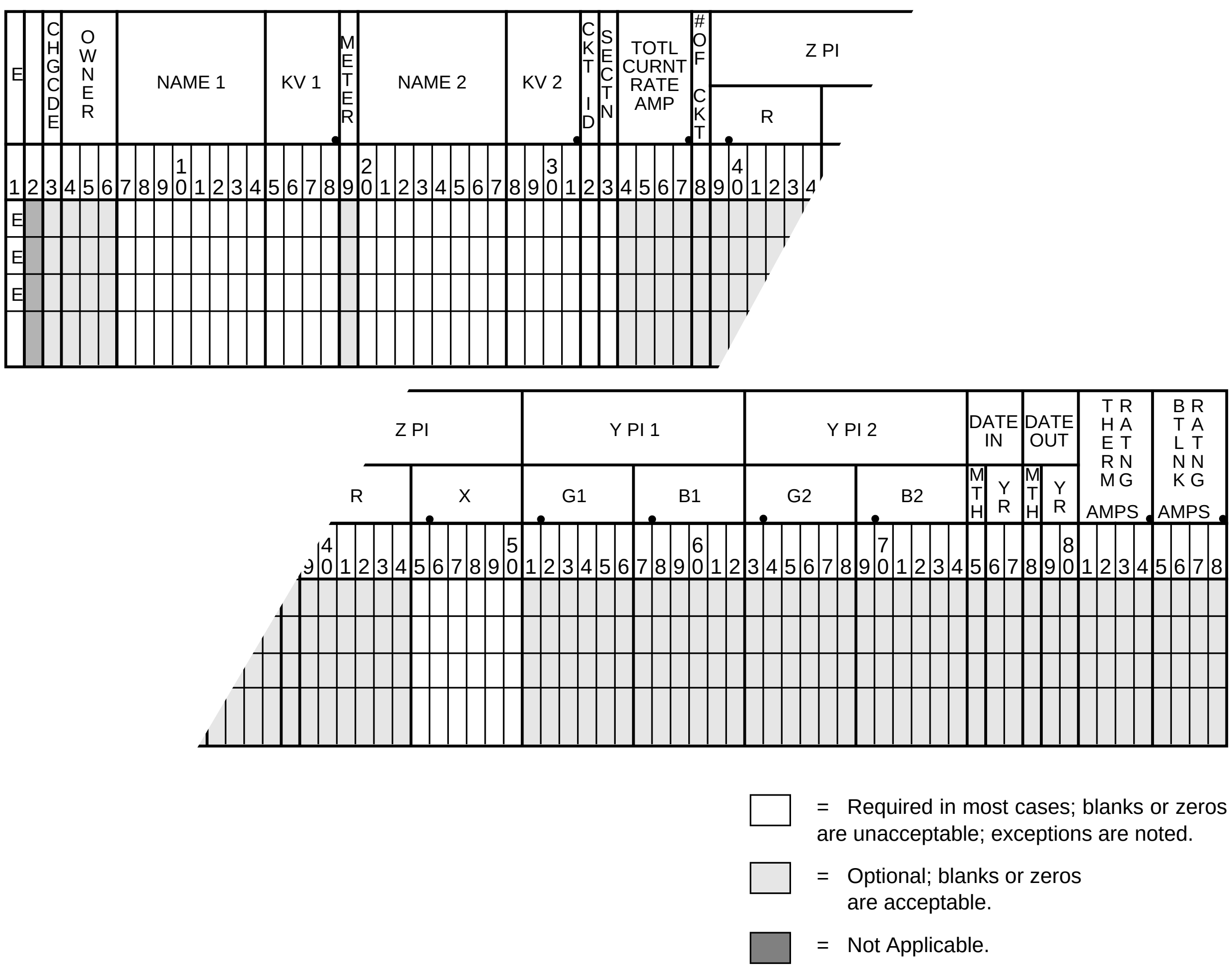


Figure 3-29 Equivalent Branch Data Input Format

Table 3-22 Column Description for Equivalent Branch Data

Column	ID Field	Format	Description
1	yes	A1	Record type - E for equivalent
2	no	A1	Blank
3	no	A1	Change code - see System Changes
4-6	no	A3	Ownership code - Line and transformer losses will be summarized by ownership at end of final area summary.
7-14	yes	A8	Bus name 1
15-18	yes	F4.0	Base kV 1
19	no	I1	Tie line metering point flag for area tie lines. 1 in column 19 provides for metering at bus name 1 2 in column 19 provides for metering at bus name 2 Blank allows for program assumption as follows: Metering point will be identified (1) by location where line ownership differs from bus ownership or (2) when buses at end of tie line have same ownership, then the bus Name 1 will be the metering point.
20-27	yes	A8	Bus name 2
29-31	yes	F4.0	Base kV 2
32	yes	A1	Circuit identification
33	yes	I1	Section number for making an equivalent for series elements. (numeric)
34-37	no	F4.0	Total ampere rating for all lines represented by this record.
38	no	I1	Number of parallel circuits represented by this record, for information purposes only. The equivalent impedance is entered in columns 39-74 for lines with unequal legs.
39-50	no	2F6.5	Per unit R and X on base kV and base MVA.
51-62	no	2F6.5	Per unit G and B at bus name 1 end of line.
63-74	no	2F6.5	Per unit G and B at bus name 2 end of line.
75-77	no	A1,I2	Energization Date — MYY M = {1,2,3,4,5,6,7,8,9,O,N,D} YY = last two digits of year

Table 3-22 Column Description for Equivalent Branch Data (Continued)

Column	ID Field	Format	Description
78-80	no	A1,I2	De-energization Data — MYY M = {0,1,2,3,4,5,6,7,8,9,O,N,D} YY = last two digits of year
81-84	no	F4.0	Thermal ratings in Amps
85-88	no	F4.0	Bottleneck rating in Amps

3.23 SCHEDULED AREA INTERTIE (I)

Intertie is the power flowing between two areas. *Scheduled Area Intertie* are the values scheduled on the area bubble diagrams from which the net area interchange export is derived. The net export is simply the sum of all individual interties emanating from each area. Intertie `I` records permit the net area interchange schedules to be defined directly from the scheduled intertie quantities. New net area export is computed from these values; they override any scheduled net interchange on the ac control records.

A coding sheet and column descriptions follow.

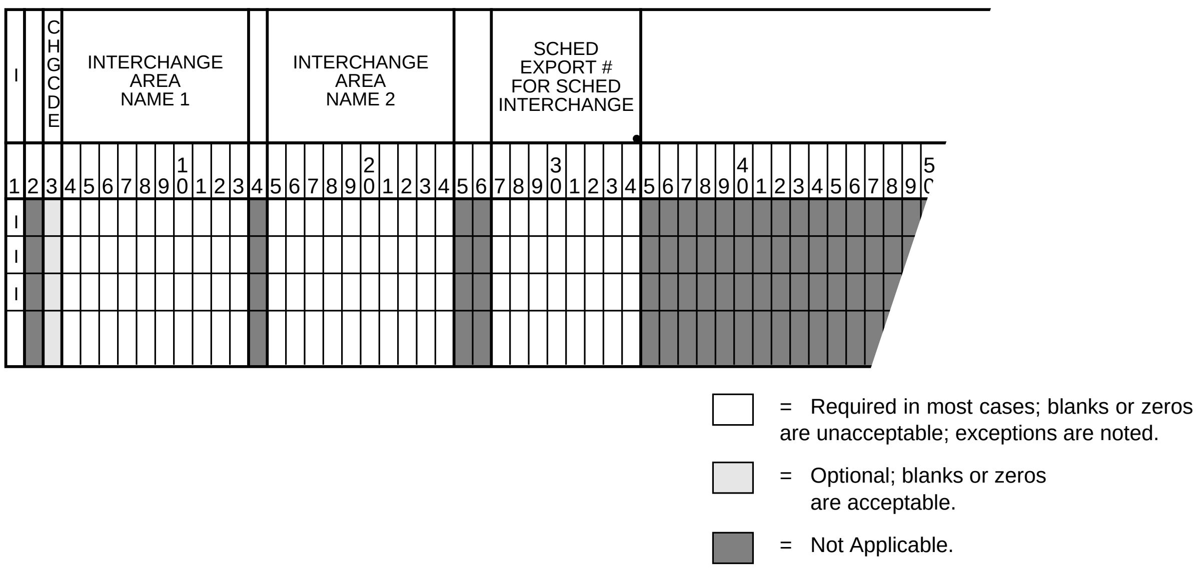


Figure 3-30 Area Intertie Input Format

Table 3-23 Column Description for Scheduled Area Intertie

Column	ID Field	Format	Description
1	yes	A1	Record type - I
3	no	A1	Change code - see System Changes
4-13	yes	A10	Area 1
15-24	yes	A10	Area 2
27-34	no	F8.0	Area 1 - Area 2 export in MW. (Import will be negative.) Blanks are interpreted as 0.0 scheduled export

"Scheduled" is actually misapplied because no direct controls are available to regulate the intertie flow between two areas. Net area export can be controlled using area slack buses, but not interarea export, which requires additional but unavailable intertie slack buses. Therefore, without direct control of intertie, the scheduled flow can never be maintained. The term *circulating flow* is introduced to reconcile the discrepancy between the scheduled and the actual flow:

Circulating flow = Scheduled flow - Actual flow

Circulating flow is also a misnomer because it implies wasteful circulating power eddies within a network. If any circulating flow exists, it is introduced deliberately with the application of transformers (MVAR) or phase shifters (MW). Otherwise the flows will always be distributed optimally to minimize losses by simply following Kirchoff's voltage and current laws. The circulating flows are calculated in the interchange output.

3.24 BALANCED TRANSMISSION LINE BRANCH (L)

This record defines the identification and the electrical characteristics of a line, section of a line or series capacitor. The model assumes the form of a lumped, symmetric pi. The following identifies a branch item:

- Line type (`L` in this case).
- Bus 1 (name and base kV) and bus 2 (name and base kV).
- Circuit identification if more than one parallel branch exits.
- Section number (if appropriate).

Lines can be divided into equivalent series elements identified with unique section numbers. Section numbers need not be consecutive, but must be unique. Sections are presumed to be physically ordered such that the lowest numbered section is connected to bus 1 and the highest is connected to bus 2.

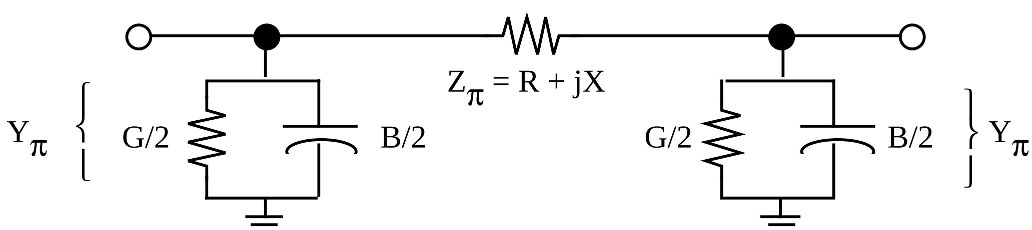


Figure 3-31 Balanced Transmission Line Branch

The entries in `RATING` and `MILES` are used in output to flag overloaded lines and produce a MW--Miles listing by ownership and voltage class if requested.

The metering point (1 or 2) is used when the line spans two areas which are controlled. A simple comparison of the zones for each terminal bus will determine if that branch is a tie line. The metering point field determines which end of a line will represent the area boundary. The line losses are assigned to the other area. The entry in the No. of CKTS field (column 38) identifies the number of parallel branches represented by the branch item. A blank or zero is interpreted as one. This is for information purposes only.

The DATE IN and DATE OUT columns specify the expected energization and de-energization dates. These are used for descriptive purposes.

To simulate a bus tie or bus sectionalizing breaker normally closed, a line impedance of X = 0.00020 p.u. is used. This allows two sections to be connected or disconnected by adding or deleting this branch.

A sample coding sheet with column explanations follows.

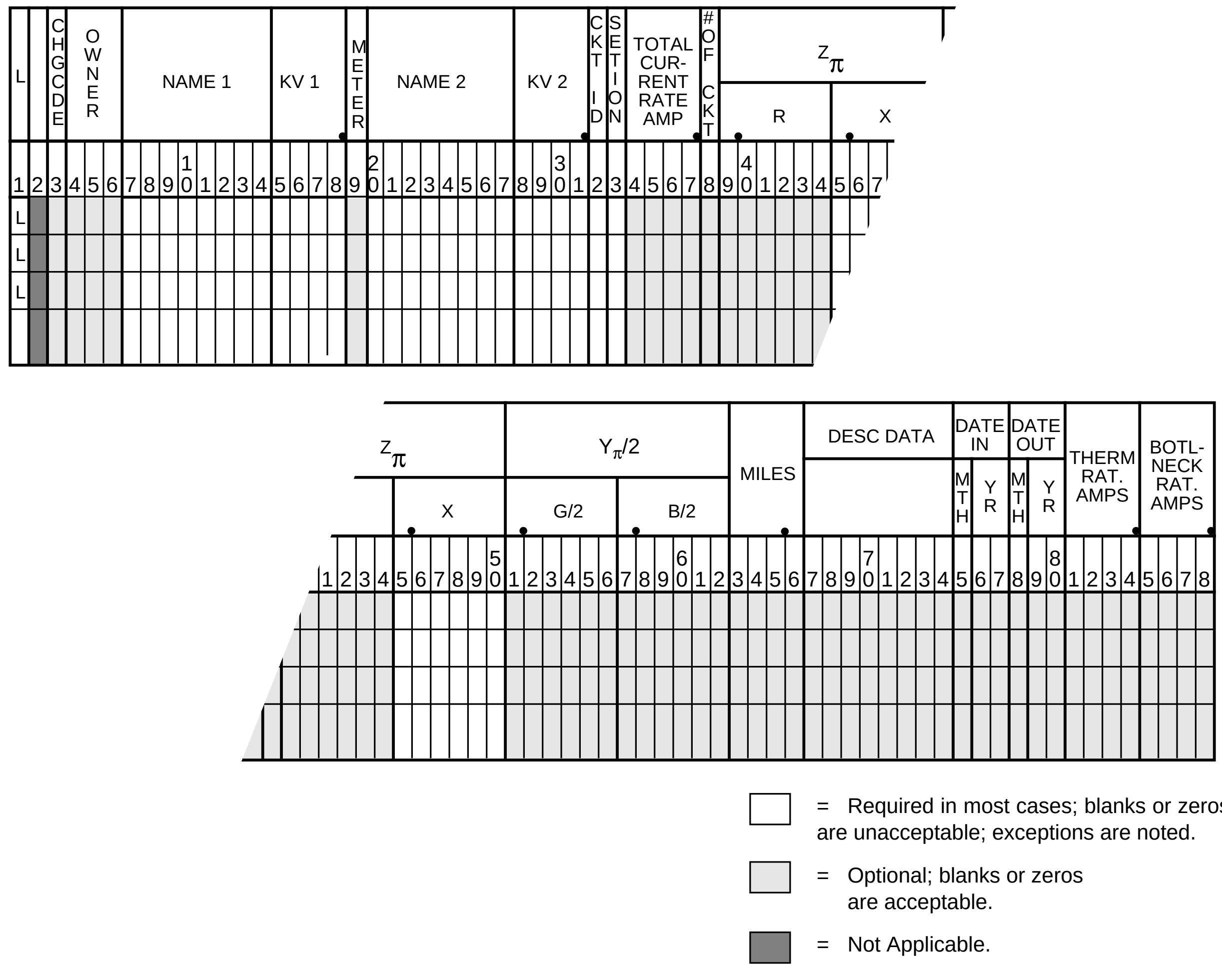


Figure 3-32 Transmission Line Data Input Format

Table 3-24 Column Description for Transmission Line Data

Column	ID Field	Format	Description
1	yes	A1	Record type - L for branch
2	no	A1	Blank
3	no	A1	Change code - see System Changes
4-6	no	A3	Ownership code - Line and transformer losses will be summarized by ownership at end of final area summary.
7-14	yes	A8	Bus name 1
15-18	yes	F4.0	Base kV 1
19	no	I1	The line metering point for area tie lines. 1 in column 19 provides for metering at bus name 1 end. 2 in column 19 provides for metering at bus name 2 end. Blank allows for program assumption as follows: Metering point will be identified (1) by location where line ownership differs from bus ownership or (2) when buses at end of tie line have same ownership, then the bus name 1 will be the metering point
20-27	yes	A8	Bus name 2
29-31	yes	F4.0	Base kV 2
32	no	A1	Circuit identification if more than one parallel branch exists.
33	no	I1	Section number for making an equivalent for series elements (numeric). Program assembles series elements in numerical order of section numbers (need not be consecutive).
34-37	no	F4.0	Total ampere rating for all lines.
38	no	I1	Number of parallel circuits represented by this record, for information purposes only. The equivalent impedance is entered in columns 39-62 for lines with equal legs.
39-44	no	F6.5	Per unit R at base kV and base MVA (normally 100).

Table 3-24 Column Description for Transmission Line Data (Continued)

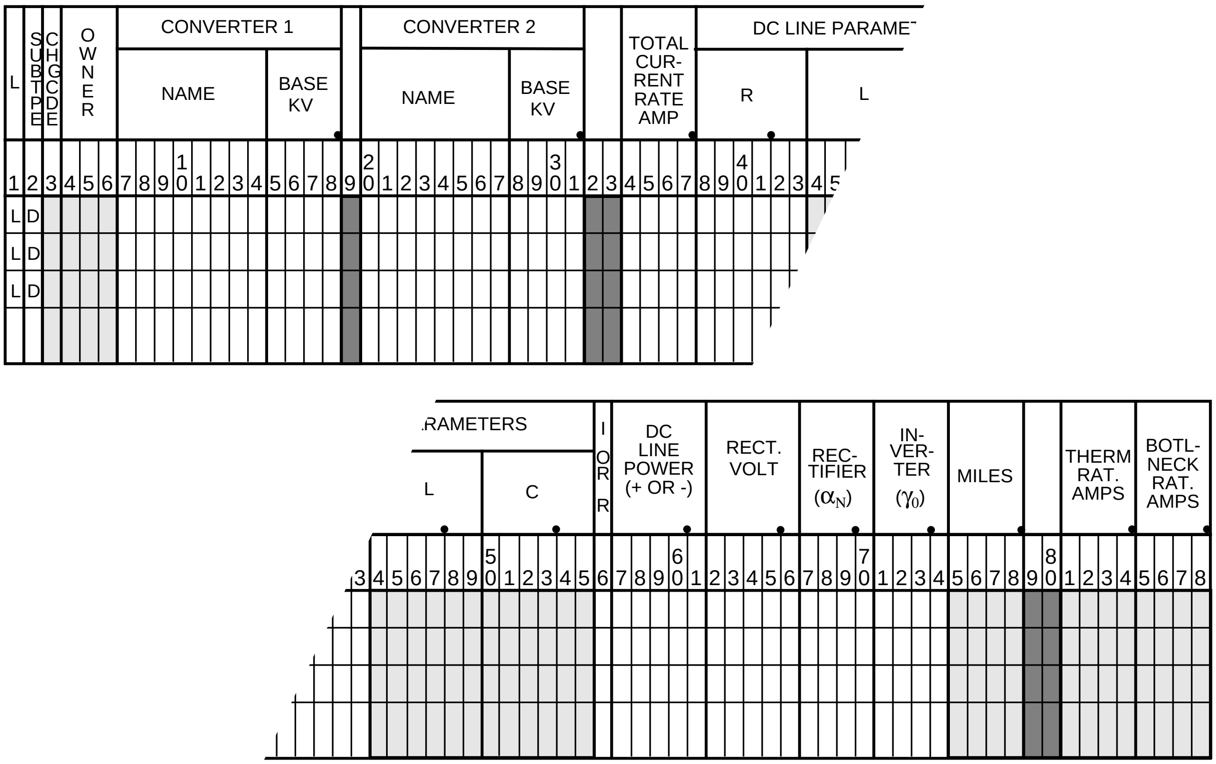
Column	ID Field	Format	Description
45-50	no	F6.5	Per unit X at base kV and base MVA (normally 100).
51-56	no	F6.5	Per unit G_pi/2 at base kV and MVA (normally 100). This format is for balanced lines when Y_pi sending equals Y_pi receiving and only Y_pi needs to be input.
57-62	no	F6.5	Per unit B_pi/2 at base kV and MVA (normally 100). This format is for balanced lines when Y_pi sending equals Y_pi receiving and only Y_pi needs to be input.
63-66	no	F4.1	Circuit miles of line or section.
67-74	no	A8	Descriptive data (alphanumeric, for example 6-wire).
75-77	no	A1,I2	Energization Date — MYY M = {1,2,3,4,5,6,7,8,9,O,N,D} YY = last two digits of year
78-80	no	A1,I2	De-energization Data — MYY M = {0,1,2,3,4,5,6,7,8,9,O,N,D} YY = last two digits of year
81-84	no	F4.0	Thermal rating in Amps
85-88	no	F4.0	Bottleneck rating in Amps

3.25 TWO-TERMINAL DC LINE (LD)

This record is used in conjunction with the two dc bus records; collectively they define the dc model. The dc line data contains pertinent information describing the electrical characteristics of the line, the scheduled dc power and voltage, and the initial firing and extinction angles.

Distinction between the inverter and rectifier buses is made with the dc line record using the sign of the scheduled dc power. The direction of power flow is always from rectifier to inverter, and the criteria assumes positive values from bus 1 to bus 2 on the record. Thus, simple modifications in the line data permit power reversals to be modeled with a minimum of data changes.

A sample dc line data coding form and column descriptions follow. See Figure 3-33 and Table 3-25.



= Required in most cases; blanks or zeros are unacceptable; exceptions are noted.

= Optional; blanks or zeros are acceptable.

= Not Applicable.

Figure 3-33 DC Line Data Input Format

Table 3-25 Column Description for DC Line Data

Columns	ID Field	Format	Descriptions
1-2	yes	A2	Record code — LD for dc line
3	no	A1	Change code — see System Changes
4-6	no	A3	Ownership code, same as on Bus record
7-14	yes	A8	Converter bus name 1 (conventionally the rectifier)

Table 3-25 Column Description for DC Line Data (Continued)

Columns	ID Field	Format	Descriptions
15-18	yes	F4.0	Base kV 1
20-27	yes	A8	Converter bus name 2 (conventionally the inverter)
29-31	yes	F4.0	Base kV 2
34-37	no	F4.0	I rating (amps) — Maximum dc line current in amperes.
38-43	no	F6.2	R (ohms) — dc line resistance, ohms.
44-49	no	F6.2	L (mh) — dc line inductance, millihenries
50-55	no	F6.2	C (uf) — dc line capacitance, microfarads.
56	no	A1	Inverter or rectifier control — Enter R for rectifier control or I for inverter control (point of dc line in which scheduled power is measured).
57-61	no	F5.1	Schedule dc power (MW) — Scheduled dc power in megawatts from converter 1 to 2 metered at the end indicated by I or R in column 56.
62-66	no	F5.1	Schedule dc line volts (kV) — at rectifier end of dc line.
67-70	no	F4.1	Rectifier (α_N) — Initial firing angle in degrees at rectifier.
71-74	no	F4.1	Inverter (γ_0) — Minimum margin angle in degrees at inverter.
75-78	no	F4.0	Miles — Descriptive information only.
81-84	no	F4.0	Thermal rating in Amps
85-88	no	F4.0	Bottleneck rating in Amps

3.26 MULTITERMINAL DC LINE (LM)

This data is used in conjunction with multiterminal dc bus data type `M`. The line data together with the dc bus data define the dc converter terminals and interconnecting dc lines for a multiterminal dc network. This line data contains only the fields for some of the converter quantities which were included on the two-terminal dc format.

Two-terminal (type `D`) and multiterminal (type `M`) data may coexist within the same base, but cannot coexist on the same dc circuit.

The following shows the multiterminal dc line data coding form format. It is followed by explanations of its various columns. See Figure 3-34 and Table 3-26.

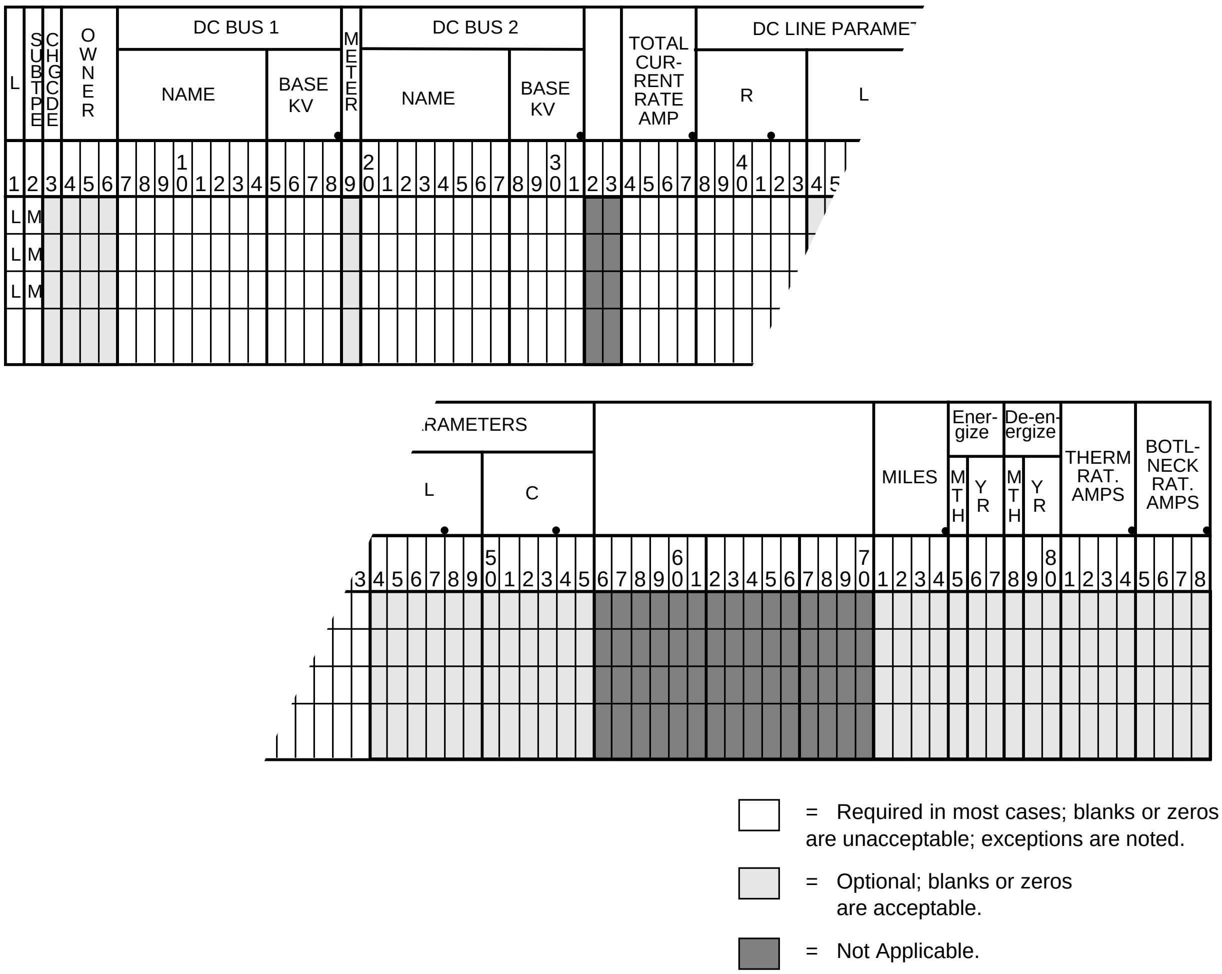


Figure 3-34 Multiterminal DC Line Data (Type M) Input Format

Table 3-26 Column Description for Multiterminal DC Line Type LM

Column	ID Field	Format	Description
1-2	yes	A2	Record Code — LM for multiterminal dc line
3	no	A1	Change code — see System Changes
4-6	no	A3	Ownership code, same as on bus data record

Table 3-26 Column Description for Multiterminal DC Line Type LM

Column	ID Field	Format	Description
7-14	yes	A8	DC bus name 1
15-18	yes	F4.0	Base kV 1
19	no	I1	Tie line metering point for area tie lines. 1 in column 19 provides for metering at bus name 1 end. 2 in column 19 provides for metering at bus name 2 end. Blank allows for program assumption as follows: Metering point will be identified (1) by location where line ownership differs from bus ownership or (2) when buses at end of tie line have same ownership, then the bus name 1 will be the metering point
20-27	yes	A8	DC bus name 2
29-31	yes	F4.0	Base kV 2
34-37	no	F4.0	I Rating (Amps) — Maximum dc line current in amperes
38-43	no	F6.2	R (Ohms) — dc line resistance in ohms
44-49	no	F6.2	L (mh) — dc line inductance in millihenries
50-55	no	F6.2	C (uf) — dc line capacitance in microfarads
71-74	no	F4.0	Miles — Descriptive information only
75-77	no	A1,I2	Energization Date — MYY M = {1,2,3,4,5,6,7,8,9,O,N,D} YY = last two digits of year
78-80	no	A1,I2	De-energization Data — MYY M = {0,1,2,3,4,5,6,7,8,9,O,N,D} YY = last two digits of year

3.27 FACTOR CHANGE (PO, PZ, PN, PA, PB, PC, PD)

Note: These change record types were formerly called "Percentage Changes." This is a change record and must be preceded with a `/CHANGES` command or otherwise reside in a change set.

A specialized change record with a `P` in column 1 enables the loads and generation for all or part of the network to be changed on a multiplying factor basis. These records follow a `/CHANGES` statement and any `Z` records. See Figure 3-35 through Figure 3-41 and also Table 3-27.

Factor changes are performed before any other bus changes are made; therefore, any subsequent bus changes will be unaffected by factor changes. Separate fields permit both active and reactive generation and the active and reactive load to be changed at independent factor. The formula is:

```
NEW INJECTION = OLD INJECTION  *  (FACTOR)
```

A blank or 1.0 factor retains the present value of the injection while a factor of 2.0 will double the present value.

There are separate factors for P and Q. If the Q factor is blank, it will default to the P factor. For example, if only the P is to be changed by 0.95 and the Q left alone, set the P factor = .95 and Q factor = 1.0.

Six different subtypes are permitted. Different subtypes may be submitted together. (Their formats are shown on the following pages.)

Subtype `O` Factor change by ownerships (20 maximum). All ac bus and continuation bus loads and generation with the given ownership will be changed by the specified factors.

Subtype `Z` Factor change by zones (20 maximum). All ac bus and continuation bus loads and generation within the depicted zones will be changed by the specified factors.

Subtype `N` Factor change by zone on all nonindustrial loads and generation (20 maximum). All ac bus and continuation bus data except `+A`, `+F`, `+I` or `+P` continuation bus data within the designated zones will be changed by the specified factors. All zones may be changed with one record having a key zone `00` (zero-zero).

Subtype `A` Factor change on all loads and generation on all ac bus and continuation bus data (1 only).

Subtype `B` Factor change by ownerships (20 maximum). All constant impedance and constant current distributed (`+ A01`, `+ *I`, `+ *P`) loads with the given ownership will be changed by the specified factor.

Subtype `C` Factor change by zones (20 maximum). All constant impedance and constant distributed loads (`+ A01`, `+ *I`, `+ *P`) with the given zone will be changed by the specified factor.

Subtype `D` Factor change by zones (20 maximum). all non-industrial loads within the given zones and optional ownership will be converted into constant impedance and constant current loads.

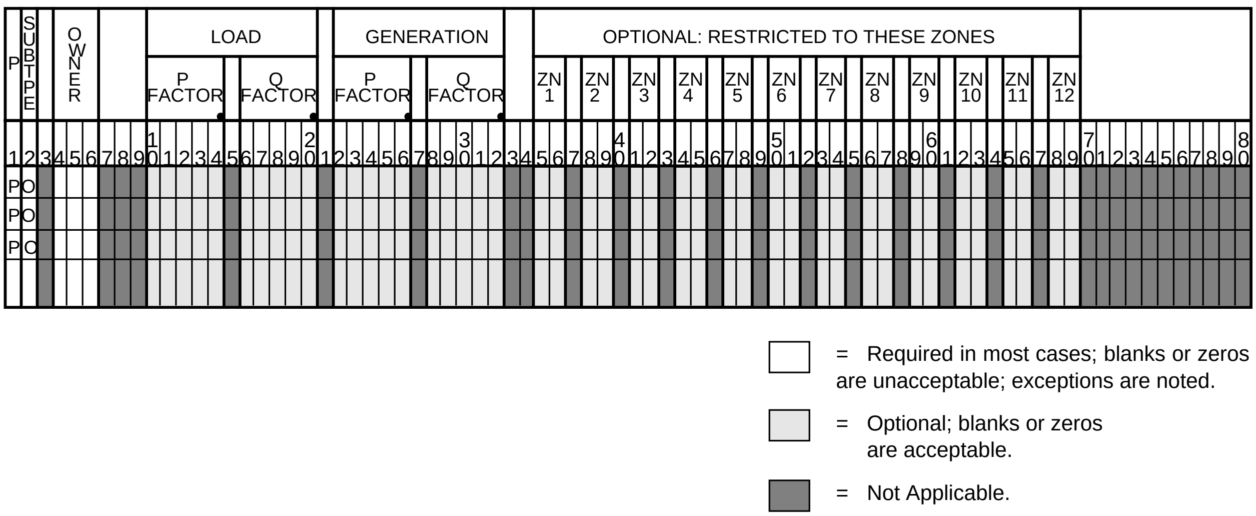
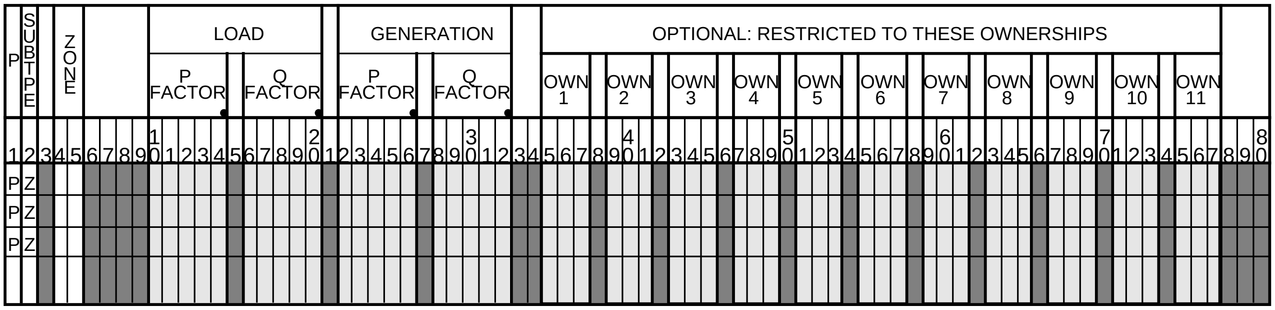


Figure 3-35 Factor Change by Ownerships

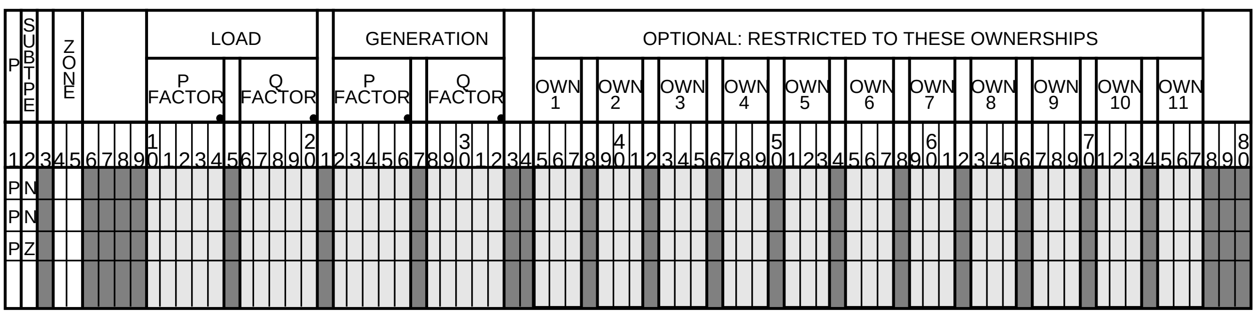


= Required in most cases; blanks or zeros are unacceptable; exceptions are noted.

= Optional; blanks or zeros are acceptable.

= Not Applicable.

Figure 3-36 Factor Change by Zones

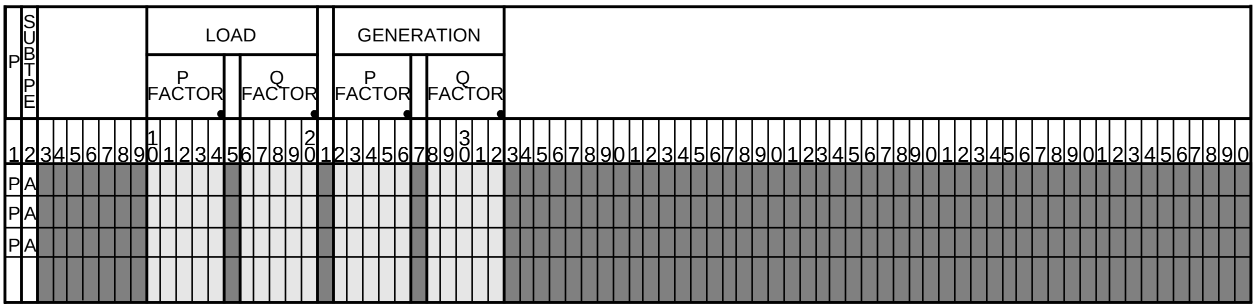


= Required in most cases; blanks or zeros are unacceptable; exceptions are noted.

= Optional; blanks or zeros are acceptable.

= Not Applicable.

Figure 3-37 Factor Change by Nonindustrial Loads

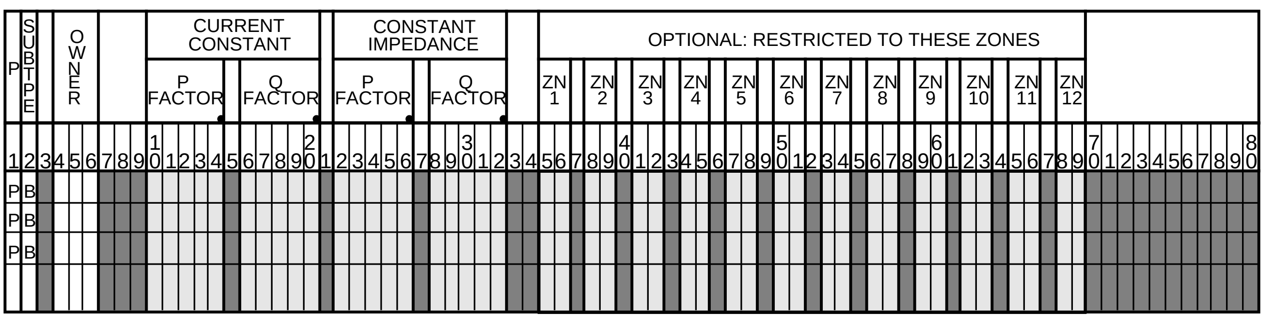


□ = Required in most cases; blanks or zeros are unacceptable; exceptions are noted.

□ = Optional; blanks or zeros are acceptable.

■ = Not Applicable.

Figure 3-38 Factor Change on All Loads and Generation

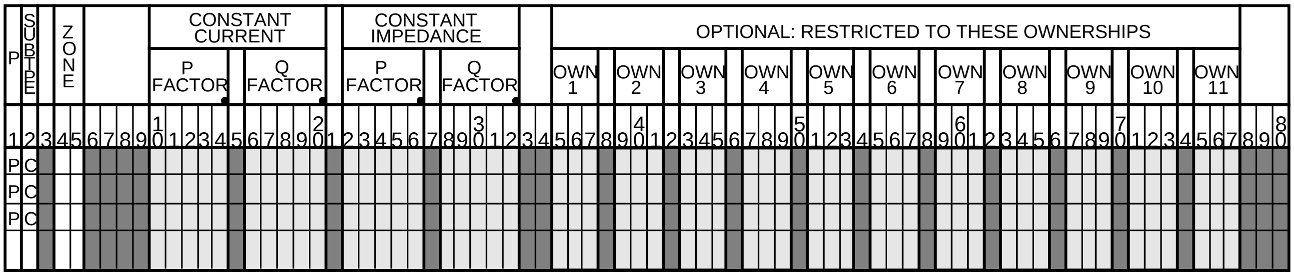


□ = Required in most cases; blanks or zeros are unacceptable; exceptions are noted.

□ = Optional; blanks or zeros are acceptable.

■ = Not Applicable.

Figure 3-39 F. C. by Ownerships of Constant Current and Impedance Loads

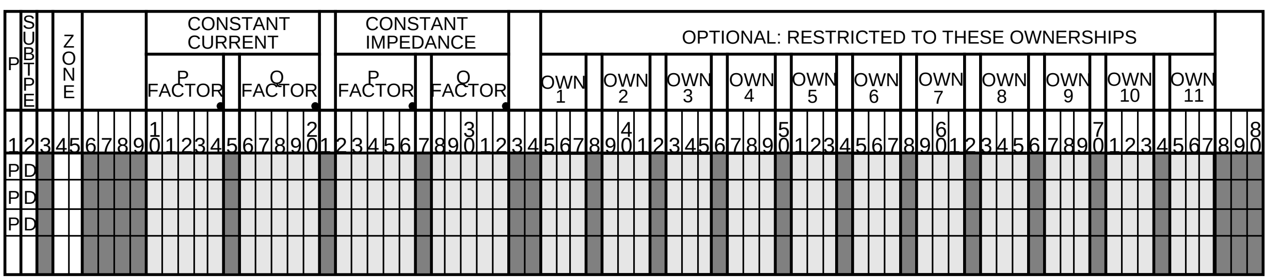


= Required in most cases; blanks or zeros are unacceptable; exceptions are noted.

= Optional; blanks or zeros are acceptable.

= Not Applicable.

Figure 3-40 F. C. by Zones of Constant Current and Impedance Loads



= Required in most cases; blanks or zeros are unacceptable; exceptions are noted.

= Optional; blanks or zeros are acceptable.

= Not Applicable.

Figure 3-41 F. C. by Nonindustrial Loads of Constant Current and Impedance

Table 3-27 Column Description of Factor Change Record

Column		Format	Description
1	yes	A1	Record type — P factor change (P represents its former name Percentage Changes)

Table 3-27 Column Description of Factor Change Record

Column		Format	Description
2	yes	A1	Subtype O for ownerships Z for all loads in selected zones N for nonindustrial loads in selected zones A for all loads and generatives B for constant current and constant impedance loads by ownership C for constant current and constant impedance loads by zones
10-14	no	F5.0	P factor (decimal fraction) for load
16-20	no	F5.0	Q factor (decimal fraction) for load
22-26	no	F5.0	P factor (decimal fraction) for generation or constant impedance loads
28-32	no	F5.0	Q factor (decimal fraction) for generation or constant impedance loads
Subtypes O and B - record			
4-6	yes	A3	Owner code
35-80	no	(A2,1X)	Optional list of zone codes separated by single blanks. Change will be restricted to these listed zones. If no list, all zones are assumed. Note: Subtype C is restricted to the following types of continuation buses: +A01, +A02, *P, *I.
Subtypes Z, C, and N			
4-5	yes	A2	Zone code
35-80	no	(A3,1X)	Optional list of ownership codes separated by single blanks. Change will be restricted to these listed owners, if no list, all owners are assumed. Note: Subtype C is restricted to the following types of continuation buses: +A01, +A02, *P, *I.

3.28 REACTIVE CAPABILITY CURVES (QP, QX, QN)

Three records are required to define a curve: QP, QX, and QN. They may appear anywhere in the input stream although they normally are put immediately after the bus record to which the curve applies. Each curve applies only to the bus named.

Description

The generator capability curve model is a composite of two representations of a synchronous machine capability curve. The first model consists of a set of 1-14 points depicting a piece-wise linear representation of the Q-P characteristics; the second model consists of an optional, constant MVA representation.

As shown in Figure 3-43, the generator capability curve model consists of a series of 1-15 points on the P-Q diagram and a constant MVA secant. Each point is defined by specifying a value for *P* followed by values for *Qmax* and *Qmin*. The constant MVA is specified with *MMVA (Machine MVA)*, a leading powerfactor (positive reactive), and a lagging powerfactor (negative reactive). If *MMVA* is zero, the reactive capability curve is specified exclusively with *P, Qmax*, and *Qmin* points

If the optional constant MVA representation is invoked, it takes precedence over any *(P, Qmax, Qmin*) point. (Overlap is determined by *Pgen*.)

If the minimum absolute value for *P* is less than the first entered value (P_1), then the model will set the values for *Qmax* and *Qmin* equal to $Qmax_1$ and $Qmin_1$. For any point ABS (*Pgen*) between P_1 and *MMVA*, the model will linearly interpolate between the *Q* values for P_j just greater than and P_{j-1} just less than ABS(*Pgen*). *Pgen* greater than *MMVA* generates a fatal data error.

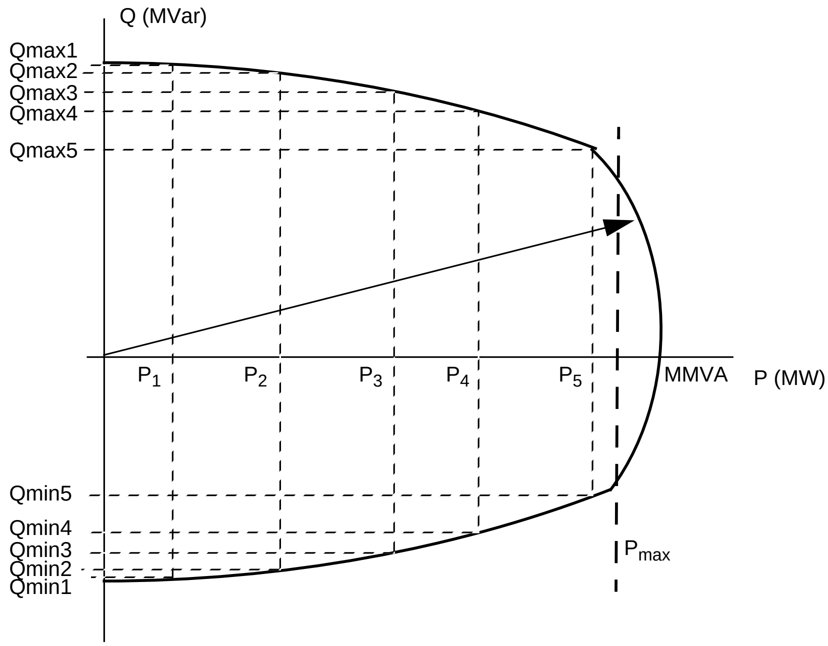


Figure 3-42 Generator Capability Curve Model

Processing

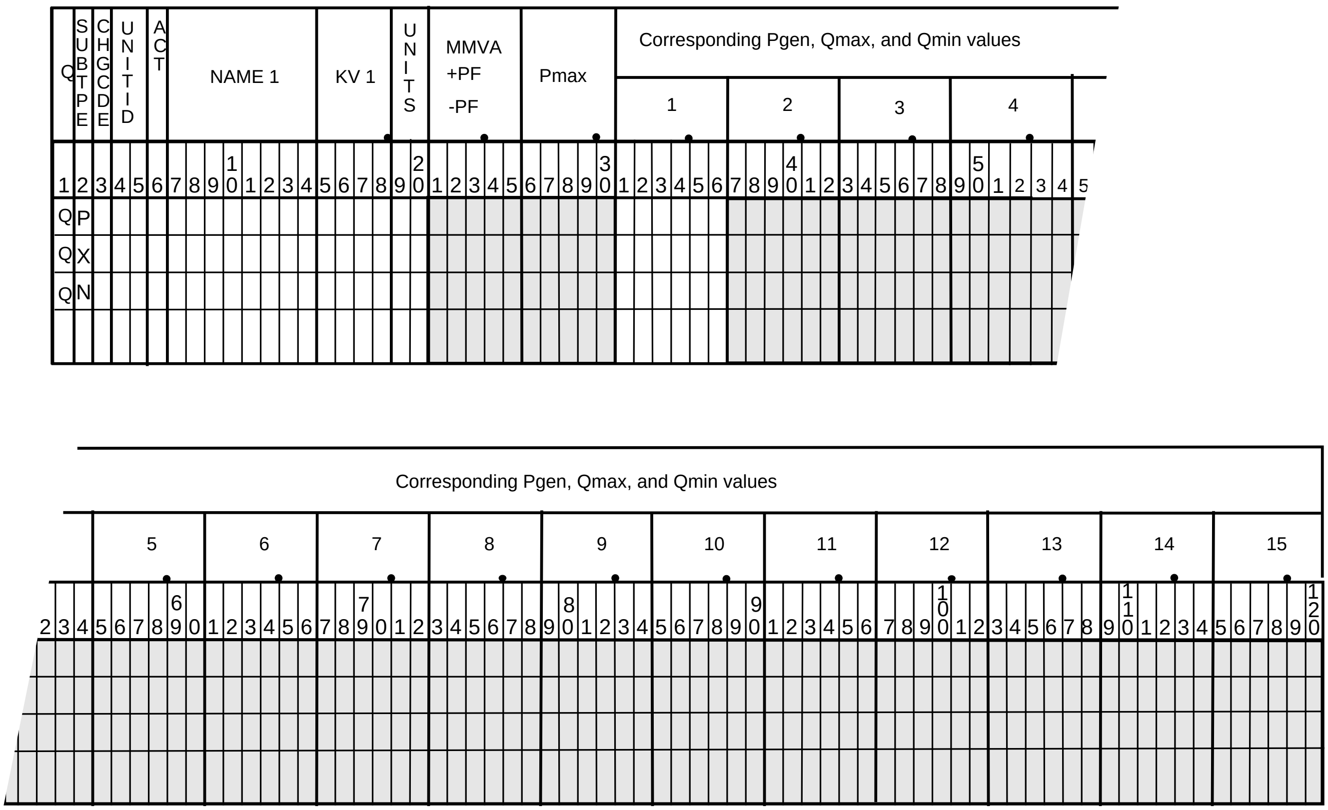
Before solution of the case, each BE, BG, BQ, BX, and BS bus is checked to see if a PQ curve is to be used to set its Q limits. If not, the Qmin and Qmax already stored are used, that is, those read from the bus record or calculated from a prior solution. If a curve is active, the values calculated using it replace those formerly stored. Original input values from the bus record are not saved.

Table 3-28 Column Description for Reactive Capability Curves

Column	ID Field	Format	Description
1-2	yes	A2	Record Code — QP for Pgen values (positive values only) QX for Qmax values (positive values) QN for Qmin values (negative values)

Table 3-28 Column Description for Reactive Capability Curves

Column	ID Field	Format	Description
3	no	A1	Change code — For QP record only: D = Delete curve for this bus. M = Change p.u. code or activity flag. *This cannot be used to alter curve data.* To change curve data, enter a complete new set. It is not necessary to delete the curve first; new data will replace the old. Column 3 must be *blank*.
4-5	no	A2	Unit ID (for informational purposes)
6	no	A1	Activity flag — For QP record only: Blank = Curve active (default when data is entered). * = Inactivate curve. A = Activate formerly inactive curve.
7-14	yes	A8	Bus name
15-18	yes	F4.0	Base kV
19-20	no	I2	Number of units. Total used is number of units times the values specified (*Pgen, Qmax, Qmin*))
21-25	no	F5.2	QP - Maximum *MVA* QX - Positive (leading) power factor for *Qmax* QN - Negative (lagging) power factor for *Qmin*
26-30	no	F5.2	Maximum *Pgen* (MW/unit). This is an optional hard limit, designating a maximum operating limit.
31-120	no	15F6.2	Up to 15 values for *Pgen, Qmax*, or *Qmin* depending on the card type. The values for *Pgen* can be in any order, but the related *Qmin, Qmax* values must correspond. Entries must be in consecutive fields with no blank entries between. *Pgen*(1) must be 0.0.



= Required in most cases; blanks or zeros are unacceptable; exceptions are noted.

= Optional; blanks or zeros are acceptable.

= Not Applicable.

Figure 3-43 Reactive Capability Curve QP Record

3.29 REGULATING TRANSFORMER (R, RV, RQ, RP, RN, RM)

This record gives a fixed transformer or phase shifter automatic regulating or control status, provided the proper LTC options on the `LTC` control record are specified to activate these controls. See Figure 3-44 and Table 3-29.

This record defines the range of adjustable taps or angles, identifies the adjustable tap side and specifies the desired control and quantity to be held.

The variable tap side of the LTC transformer can be specified in column 19. It can also be determined by comparing the tap range with the base kV at each terminal. If this fails to encompass either base kV, the variable tap side is assigned to the alphabetically highest terminal.

The tap or angle specified on a T record determines the initial parameter setting. If this setting is not encompassed by the LTC tap range, the R record is temporarily deactivated in the solution routine with diagnostic messages. The default LTC control can also be enabled by the command:

```
/ SOLUTION
> MISC_CNTRL, ..., LTC=ON, ... (Full LTC control)
                      ON_NV   (RP,RQ,RM,RN only)
                      ON_NPS  (R,RQ,RN only
                      ON_DCONL(commutating LTC transformers on)
                      OFF
```

If an LTC transformer reaches a tap limit, the control is temporarily deactivated.

All regulating transformers have provision for either continuous or discrete tap positions. Discretization occurs automatically after a continuous solution is formed.

Several subtypes are available:

Subtype Blank or *Subtype* `V` — This specifies LTC voltage control on either of the terminal buses. The controlled voltage is entered on the appropriate bus record. The terminal being controlled may be an subtype except `G`, `X` or `S`. If the controlled bus has local reactive control (subtypes `E` or `Q` within its limits) the LTC feature is temporarily deactivated. However, if both terminal buses of the transformer are simultaneously reactively controlled, the LTC transformer assumes a different control to minimize the var exchange between buses. This assumes most effective utilization of local var sources.

Subtype `Q` — This specifies an LTC transformer that controls the var flow through itself. Positive controlled quantities are from bus 1 to bus 2. However, for simplicity, the control point is taken inside the equivalent pi from the fixed tap side to the variable tap side. The controlled VARs value is Q_scheduled ± Q_tolerance when Q_tolerance is the MIN scheduled field and Q_scheduled is the MAX scheduled field.

Subtype `P` This subtype defines an LTC phase shifter that controls real power flowing through itself. Positive controlled quantities are from bus 1 to bus 2. However, for simplicity, the control point is taken inside the equivalent pi. The controlled power is P_scheduled ± P_tolerance (P_scheduled = MAX SCHED; P_tolerance = MIN SCHED).

Subtype `N` This specifies an LTC transformer that provides constraints on the reactive power flow through itself. Ordinarily, it provides no control, but if its reactive flow limits are exceeded, it becomes a type `Q` LTC transformer and holds the MVAR flow within the inequality constraints assigned. The controlled flow is within Q_min ≤ Q_max (Q_min = MIN SCHED; Q_max = MAX SCHED).

Subtype `M` This specifies an LTC phase shifter that provides constraints on the active power flow through itself. Ordinarily, it provides no control, but if its active power limits are exceeded, it becomes a type `P` LTC phase shifter and holds the MW flow within the inequality constraints assigned. The controlled real power flow is within limits P_min ≤ P_max (P_min = MIN SCHED; P_max = MAX SCHED).

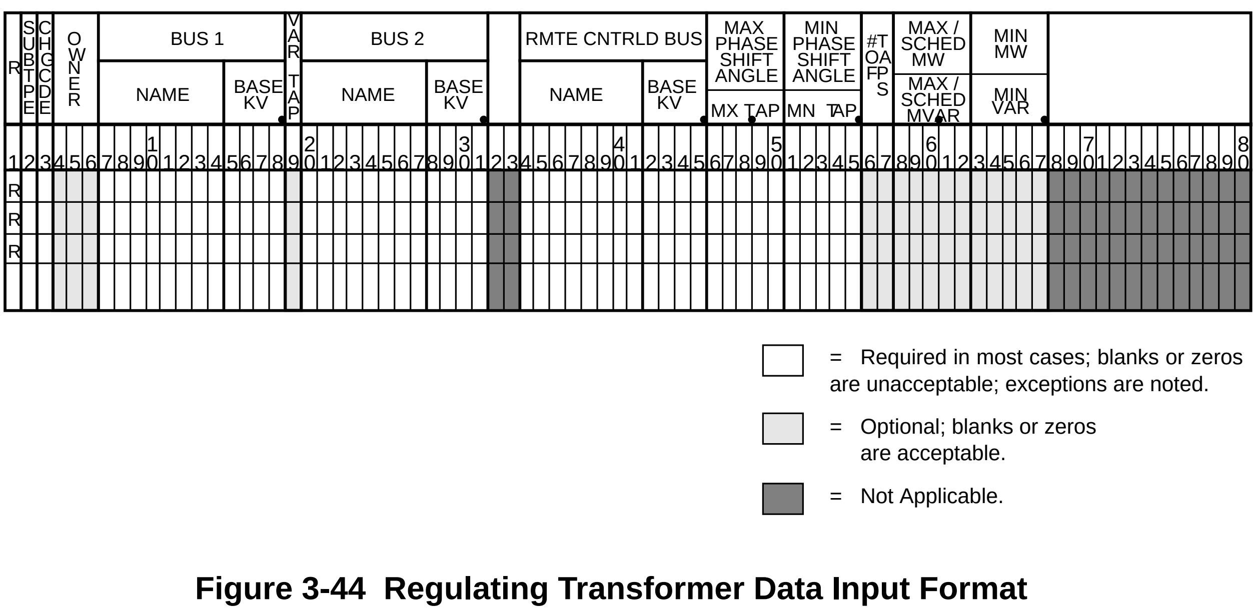


Figure 3-44 Regulating Transformer Data Input Format

Table 3-29 Column Description for Regulating Transformer Data

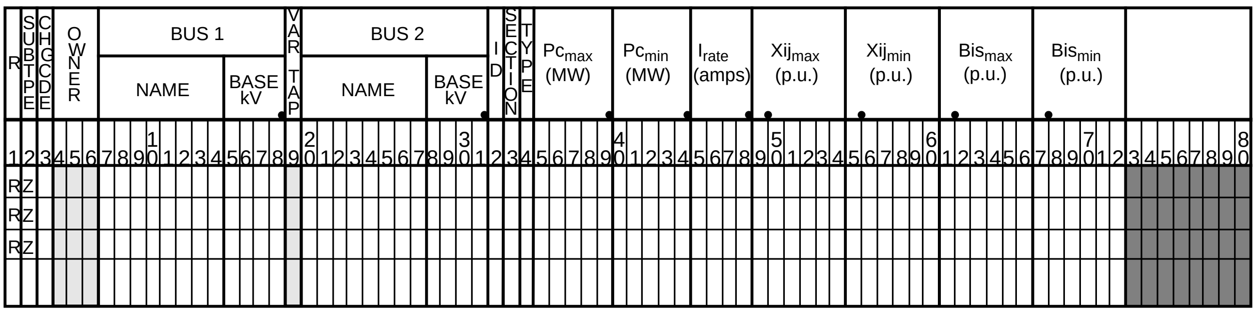
Column	ID Field	Format	Description
1	yes	A1	Record type — R for LTC and automatic phase-shifter data. A record type T must be in same system to provide full data required.
2	no	A1	Subtype — See regulating transformer and phase-shifter subtypes.
3	no	A1	Change code — see System Changes
4-6	no	A3	Ownership code
7-14	yes	A8	Bus name 1
15-18	yes	F4.0	Base kV 1
19	no	I1	Variable tap side if T_max and T_min cannot orient T_x. 0 — Low alpha is fixed 1 — Bus 1 is variable 2 — Bus 2 is variable
20-27	yes	A8	Bus name 2
29-31	yes	F4.0	Base kV 2
34-45	no	A8,F4.0	Controlled bus name and base kV
Multiple Use of columns 46-67 *For subtypes blank, V, Q and N*			
46-55	no	2F5.2	Maximum and minimum kV taps. Data must be entered.
56-57	no	I2	Total number of LTC taps. If blank, program assumes continuous action.
58-67	no	2F5.0	Scheduled MVAR flow (subtype Q) or maximum and minimum MVAR flow (subtype N) through transformer. Metered at bus name 1 on this record.
For subtypes P and M			
46-55	no	2F5.2	Maximum and minimum angle in degrees. Data must be entered.
56-57	no	I2	Total number of phase shift positions available. If blank, program assumes continuous action.
58-67	no	2F5.0	Scheduled MW flow (subtype P) or maximum and minimum MW flow (subtype M) through transformer. Metered at bus name 1 on this record.

Table 3-29 Column Description for Regulating Transformer Data (Continued)

Column	ID Field	Format	Description
For all subtypes			
75-77	no	A1,I2	Energization Date — MYY M = {1,2,3,4,5,6,7,8,9,O,N,D} YY = last two digits
78-80	no	A1,I2	De-energization Date — MYY M = {1,2,3,4,5,6,7,8,9,O,N,D} YY = last two digits

3.30 SERIES COMPENSATED RANI MODEL (RZ)

RANI stands for Rapid Adjustment of Network Impedance and represents a series connected thyristor which changes its series impedance to control power or voltage. See Table 3-30.



= Required in most cases; blanks or zeros are unacceptable; exceptions are noted.

= Optional; blanks or zeros are acceptable.

= Not Applicable.

Figure 3-45 RANI Thyristor Data Input Format

Table 3-30 Column Description for Series Compensated RANI Model

Column	ID Field	Format	Description
1-2	yes	A2	RZ Identification
3	no	A1	Change Code Blank — add M — modify D — delete R — restore
7-14	yes	A8	Bus name 1
15-18	yes	F4.0	Base kV 1
19	no	I1	Variable tap side if T_max and T_min cannot orient T_x. 0 — Low alpha is fixed 1 — Bus 1 is variable 2 — Bus 2 is variable
20-27	yes	A8	Bus name 2

Table 3-30 Column Description for Series Compensated RANI Model (Continued)

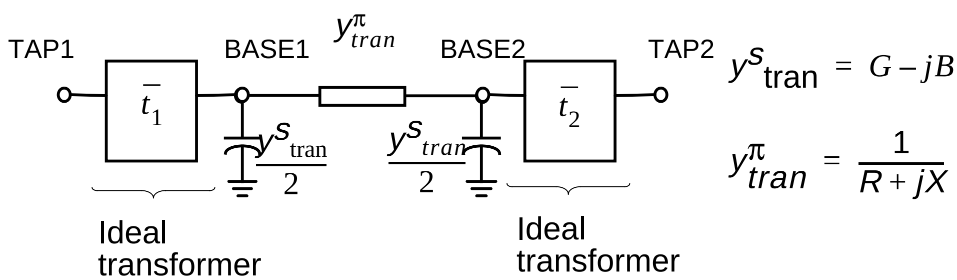
Column	ID Field	Format	Description
29-31	yes	F4.0	Base kV 2
32	yes	A1	ID
33	yes	I1	SECTION
34	no	A1	TYPE 1, 2, or 3 TYPE 1 — Control Pc using Xij TYPE 2 — Control V using Xij TYPE 3 — Control V using Bis
35-39	no	F5.0	Pc_{max}(Mw)
40-44	no	F5.0	Pc_{min}(Mw)
45-48	no	F4.0	Irate(amps)
49-54	no	F6.5	Xij_{max}(p.u.)
55-60	no	F6.5	Xij_{min}(p.u.)
61-66	no	F6.5	Bis_{max}(p.u.)
67-72	no	F6.5	Bis_{min}(p.u.)

3.31 TRANSFORMER DATA (T,TP)

This record is applied to two-winding transformers and phase shifters. An equivalent pi representation depicts the transformer admittance in series with an ideal transformer. The electrical data is specified in terms of the transformer data which is defined as follows:

- `R` Equivalent resistance due to copper loss.
- `X` Leakage reactance.
- `G` Equivalent core loss conductance.
- `B` Magnetizing susceptance (always assumed negative; any sign is overridden).

Transformer taps are specified as fixed values for each voltage level or variable (LTC) taps with control over voltage, real power or reactive power. Variable tap transformers are defined with the addition of a regulating transformer data record (`R`) described in Section 3.26. See Figure 3-46, Figure 3-47, and Table 3-31.



Transformers: $t_1 = \frac{\text{TAP1}}{\text{BASE1}}$ $\quad t_2 = \frac{\text{TAP2}}{\text{BASE2}}$

Phase shifters $t_2 = \varepsilon^{J\frac{TAP1}{57.2957795}}$ $\quad t_2 = 1$

Figure 3-46 Transformer Data

The following three assumptions are made:

- Nominal base kV of transformer is identical to that of the bus.
- Nominal base MVA of transformer is the same as the system base MVA.

- R, X, G and B are evaluated on the nominal base and not on the tap setting.

The base kV is used to calculate the equivalent pi. Complications arise when step-up/step-down transformers are represented as sections in passive node sequence; there is no means to identify the base of the intermittent terminals. This combination is therefore illegal and will abort with fatal diagnostics.

A transformer is identified by subtype blank and a viable entry for TAP 2. A phase shifter is identified either by a subtype P or by a blank field for TAP 2. However, the program always adds the subtype P for distinction and convenience in data changes. The ANGLE is TAP 1 interpreted in degrees. If TAP 2 is blank, a nominal tap is presumed. A phase shifter assumes a pure voltage rotation and an optional transformation. Increasing the ANGLE will decrease the power flowing from bus 1 and bus 2.

Four MVA ratings are used to flag overloaded transformers: nominal, thermal, emergency, and bottleneck. The latter three are "extended ratings", which supersede nominal ratings. Other entries are similar to the type L record. A sample of the format and explanations follow.

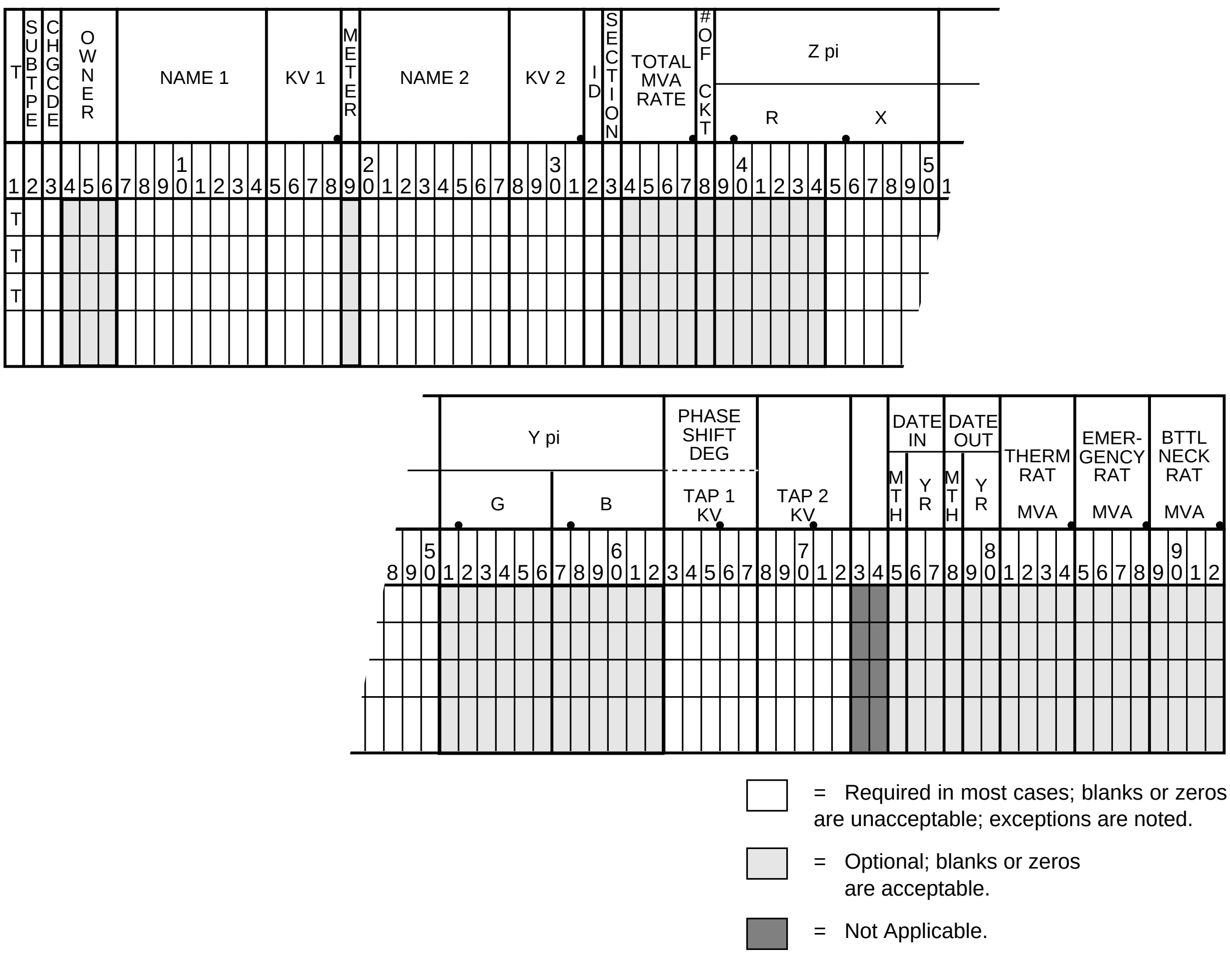


Figure 3-47 Transformer Data Input Format

Table 3-31 Column Description for Transformer Data

Column	ID Field	Format	Description
1	yes	A1	Record type — T for transformer or phase shifter
2	no	A1	Blank or P
3	no	A1	Change code — see System Changes
4-6	no	A3	Ownership code — Line and transformer losses will be summarized by ownership at end of final Area Summary.

Table 3-31 Column Description for Transformer Data (Continued)

Column	ID Field	Format	Description
7-14	yes	A8	Bus name 1
15-18	yes	F4.0	Base kV 1
19	no	I1	Tie line metering point flag for area tie lines. 1 in column 19 provides for metering at bus 1 end. 2 in column 19 provides for metering at bus 2 end. Blank allows for program assumption as follows: Metering point will be identified (1) by location where line ownership differs from bus ownership or (2) when buses at end of tie line have same ownership, then bus 1 will be the metering point.
20-27	yes	A8	Bus name 2
29-31	yes	F4.0	Base kV 2
32	yes	A1	Circuit identification
33	yes	I1	Section number for making an equivalent for series elements (numeric)
34-37	no	F4.0	Total MVA rating for all transformers represented by this record.
38	no	I1	Number of parallel transformer banks represented by this record, for information purposes only. The equivalent impedance is entered in columns 39-62.
39-44	no	F6.5	Per unit impedance R through transformer from bus 1 to bus 2 on the system base MVA for both windings.
45-50	no	F6.5	Per unit impedance X through transformer from bus 1 to bus 2 on the system base MVA for both windings.
51-56	no	F6.5	Per unit G of iron losses on the system base MVA.
57-62	no	F6.5	Per unit B magnetizing current on the system base MVA. Note that any sign is ignored. This quantity will always be processed as a negative value.
63-67	no	F5.2	Fixed bus 1 TAP or fixed phase shift in degrees which describe bus 1 relative to bus 2.
68-72	no	F5.2	Fixed bus 2 TAP or blank for fixed phase shifter.
75-77	no	A1,I2	Energization Date — MYY M = {1,2,3,4,5,6,7,8,9,O,N,D} YY = last two digits

Table 3-31 Column Description for Transformer Data (Continued)

Column	ID Field	Format	Description
78-80	no	A1,I2	De-energization Date — MYY M = {1,2,3,4,5,6,7,8,9,O,N,D} YY = last two digits
81-84	no	F4.0	Thermal rating in MVA
85-88	no	F4.0	Emergency rating in MVA
89-92	no	F4.0	Bottleneck rating in MVA

3.32 SWITCHED REACTANCE (X)

Normally shunt capacitor or shunt reactor installations are represented in power flow programs as fixed MVAR values. However, there frequently is a need to represent voltage controlled capacitor schemes. This program allows for voltage controlled shunt device installations through use of a switched reactance record type X. See Figure 3-49 and Table 3-32.

This data record must be used with a type BX bus record. The data on the X record identifies blocks of discrete shunt susceptance available for reactive control. The blocks may be either inductive (negative) or capacitive (positive). If both types exist, negative blocks must be given first. Values are given in MVAR at the rated base kV; the actual MVAR is dependent on the voltage. Discrete reactance units are also referred to as *statics*.

The discrete segments are specified in steps and increments. Steps defines the number of switchable susceptance units. The MVAR value of each unit is given in increments. Normally, each unit has a unique MVAR value. In general, when both reactive and capacitive blocks coexist, two switching lists are given. The reactors are switched first in the following order: unit 1, unit 2,..., unit k, where k is the unit number of last reactor. Similarly, the capacitors are switched next in the following order: unit k+1, unit k+2,..., unit (last). When reactors are switched in, all capacitors are removed and vice versa. Units are sequentially disconnected in the reverse order. For example, the following one line diagram depicts a capacitor installation requiring discrete switching. See Figure 3-48.

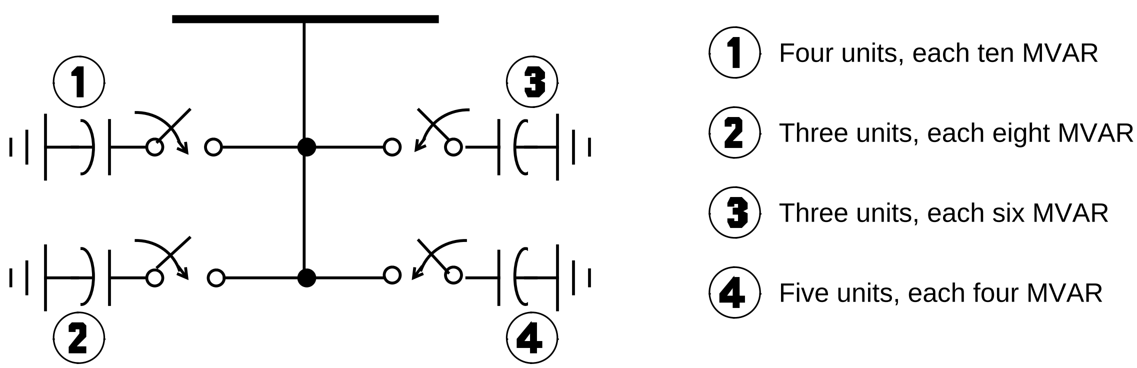


Figure 3-48 Capacitor Installation Requiring Discrete Switching

For this example the sequential operation would be as follows. Increment 1, 10 MVAR, would be added up to the number of steps specified (4). If the bus voltage is below the scheduled value after a total of 40 MVARS have been added to the bus, increment 2 would be added to the number of steps specified, and so on until the scheduled voltage is achieved. These statics would be disconnected in a similar fashion, but in the reverse order, to reduce the bus voltage.

Shunt susceptance on BX records is ignored when X records are present. Any shunt susceptance listed on any following **+** records is considered fixed and is therefore exempt from the above switching.

The format for inputting switched reactance data follows; and then descriptions of the various columns are given.

> *Note:* Negative MVARs must be listed first.

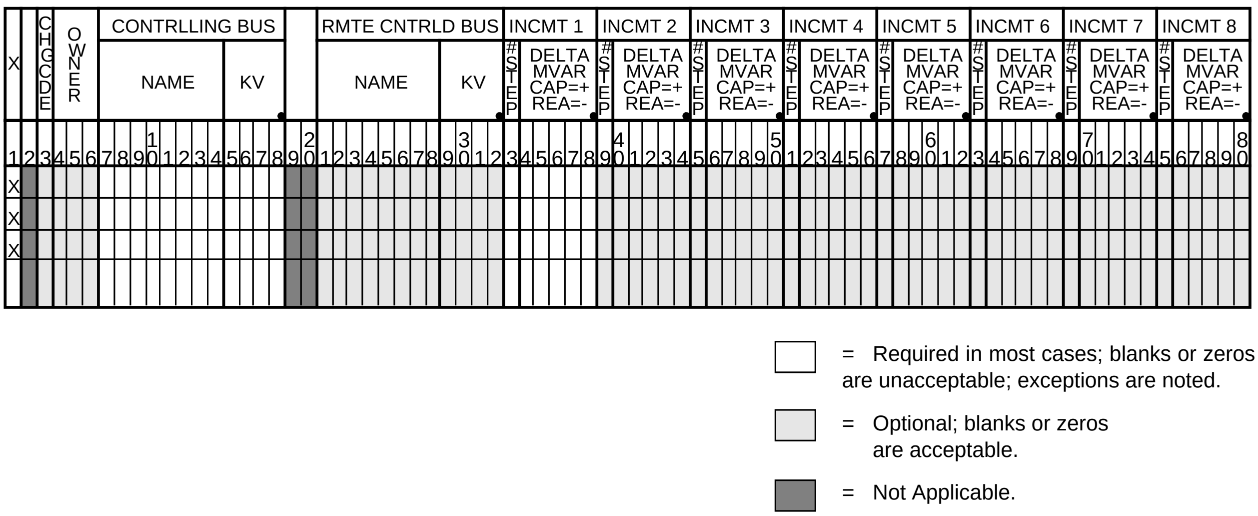


Figure 3-49 Switched Reactance Data Input Format

Table 3-32 Column Description for Switched Reactance Data

Column	ID Field	Format	Description
1	yes	A1	Record code — X for switched reactance
2	no		Blank
3	no	A1	Change code — see System Changes
4-6	no	A3	Ownership code

Table 3-32 Column Description for Switched Reactance Data (Continued)

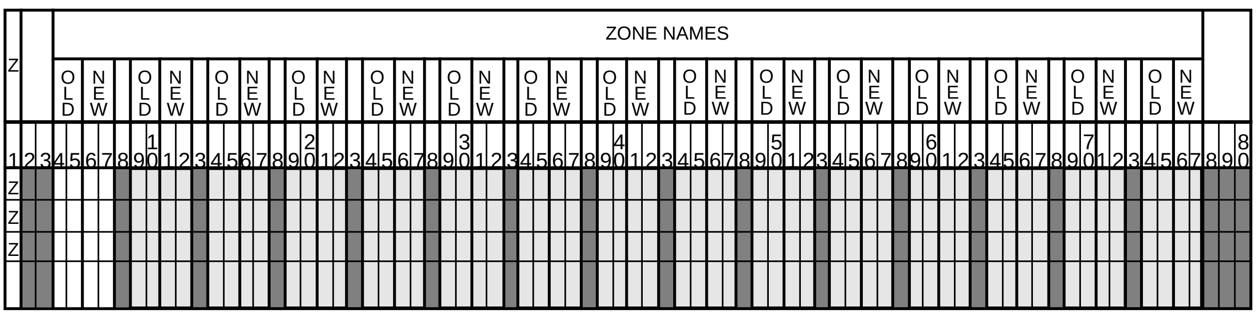
Column	ID Field	Format	Description
7-14	yes	A8	Bus name 1. This is the bus to which the switched reactances are connected. Must be a type BX bus.
15-18	yes	F4.0	Base kV 1
21-28	yes	A8	Bus name 2. Controlled bus name — This bus may be local or remote.
30-32	yes	F4.0	Base kV 2
Increment 1:			
33	no	I1	Number of steps — Number of repetitions (from 1 to 9) to be performed using the value given in columns 34-38.
34-38	no	F5.0	MVAR — Value at base kV of each step of Increment 1.
Increment 2:			
39	no	I1	Number of steps — Number of times the value given in columns 40-44 will be connected. (Will not begin until Increment 1 is completed.)
40-44	no	F5.0	MVAR — Value at base kV of each step of Increment 2.
Increment 3:			
45	no	I1	Number of steps — Number of times the value given in columns 46-50 will be connected. (Will not begin until Increment 2 is completed.)
46-50	no	F5.0	MVAR — Value at base kV of each step of Increment 3.
Increment 4:			
51	no	I1	Number of steps — Number of times the value given in columns 52-56 will be connected. (Will not begin until Increment 3 is completed.)
52-56	no	F5.0	MVAR — Value at base kV of each step of Increment 4.
57-80	no	Add data for Increments 5 through 8 in a similar fashion.	

3.33 ZONE RENAME (Z)

This is a specialized change record which permits the bus zones to be permanently renamed. This record has a Z in column 1, followed by a maximum of 15 pairs of old zone names/new zone names. Additional Z records may follow to change a maximum of 150 zones. See Table 3-33.

Several old zones may be consolidated into a single new zone name. However, an old zone may not be segregated into two more new zones.

Any Z record must be the first change record encountered. The zones are immediately renamed. Following these records, additional system changes may be entered in the normal way, and all data are assumed to conform with the new zone names.



= Required in most cases; blanks or zeros are unacceptable; exceptions are noted.

= Optional; blanks or zeros are acceptable.

= Not Applicable.

Table 3-33 Column Description for Zone Rename

Column	ID Field	Format	Description
1	yes	A1	Record type — Z
2-3	no	A2	Blank
4-5	no	A2	Old zone name — any blank zone to be changed must appear in this column. Otherwise, blank "old zones," terminate the scan.
6-7	no	A2	New zone name
8	no	A2	Blank

Table 3-33 Column Description for Zone Rename

Column	ID Field	Format	Description
9-10	no	A2	Old zone name
11-12	no	A2	New zone name
13	no	A1	Blank
14-15	no	A2	Old zone name
16-17	no	A2	New zone name
18-77	no	-	Repeat of the above format sequence: one blank followed by two columns for old zone name and two more columns for new zone name.

3.34 AREA RENAME (ZA)

This is a specialized change record that permits area names to be changed. Each ZA record renames one area.

The new name must be unique. If the new name exists, the rename is ignored. Thus, Area Rename cannot be used to consolidate areas.

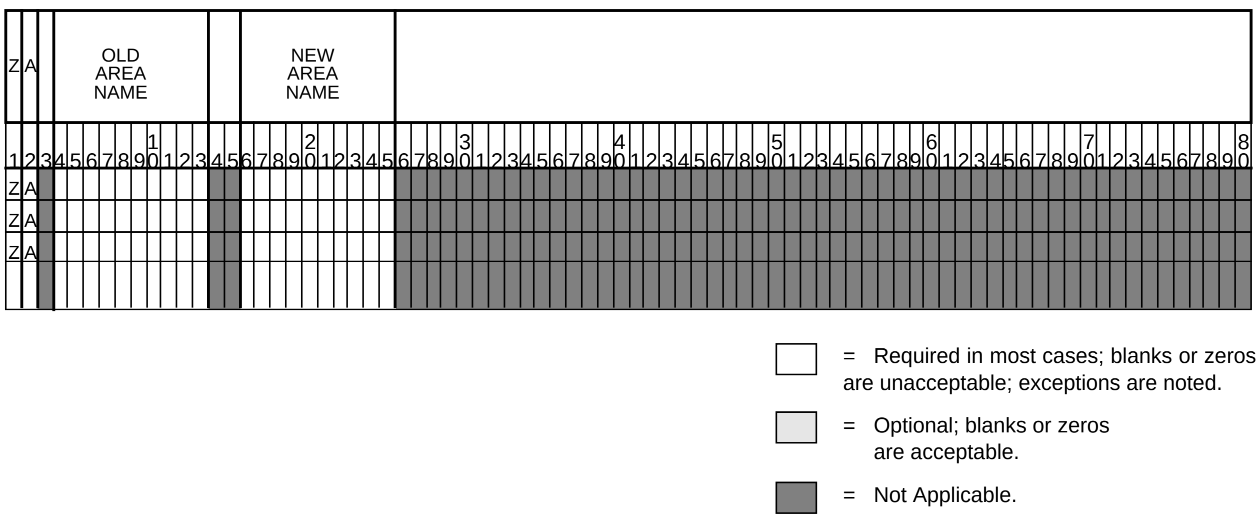


Figure 3-50 Area Rename Data Input Format

Table 3-34 Column Description for Area Rename

Column	ID Field	Format	Description
1-2	yes	A2	Record type — ZA
3			NA
4-13	no	A10	Old area name
14-15			NA
16-25	no	A10	New area name
26-80			NA

3.35 BUS RENAME (ZB)

This is a specialized change record that permits bus names and base kV's as well to be altered. Each ZB record renames one bus.

The new name must be unique. If the new name exists, the rename is ignored. Thus, Bus Rename cannot be used to consolidate buses.

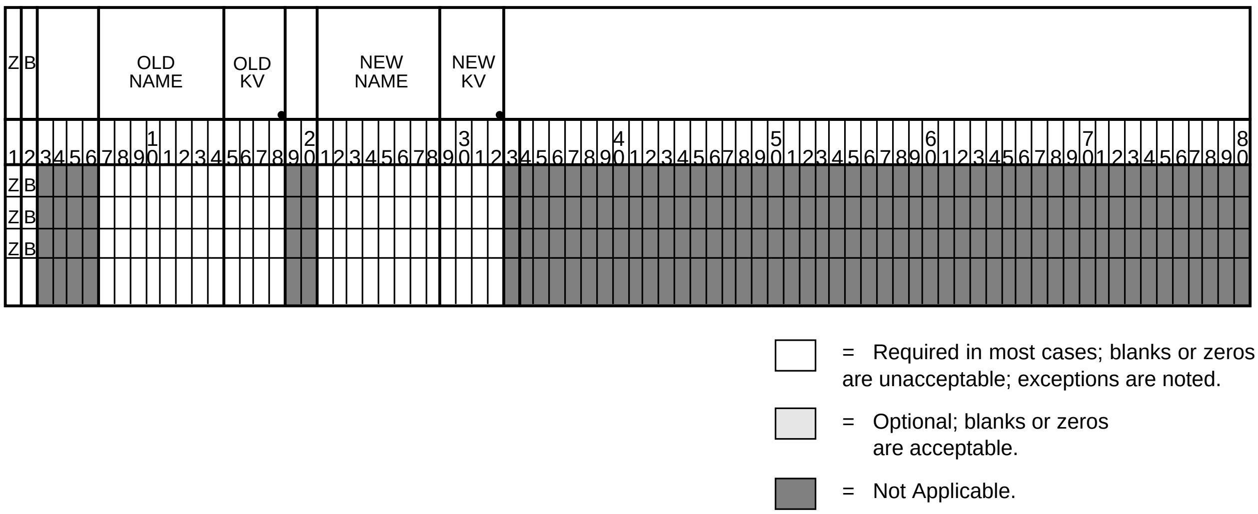


Figure 3-51 Bus Rename Data Input Format

Table 3-35 Column Description for Bus Rename

Column	ID Field	Format	Description
1-2	yes	A2	Record type — ZB
3-6			NA
7-14	no	A8	Old bus name
15-18	no	F4.0	Old base kV
19-20			NA
21-28	no	A8	New bus name
29-32	no	F4.0	New base kV
33-80			NA

CHAPTER 4

PROGRAM CONTROL AND DATABASE FILES

4.1 OVERVIEW

This chapter describes the batch Power Flow Control Language (PFC) and its syntax, commands and subcommands. Command entries follow the PFC description in alphabetical order. Table 4-1 helps you turn quickly to a specific command entry. The table also gives you a quick description of all of the commands.

Each command entry explains the meaning of the command and gives its syntax. Some commands have subcommands, which are also described. Many entries have additional discussion, and some have examples, particularly where a command's usage may not be immediately obvious.

4.2 THE BPF CONTROL LANGUAGE

The BPF Power Flow Control Language (PFC) consists of a sequence of program control statements, each of which in turn consists of commands, subcommands, keywords, and values. All statements have a reserved symbol in column 1 to identify a command or subcommand.

Every statement is scanned, and each command or subcommand found is compared with a dictionary in the program to find the relevant instructions. With the exception of the identifier in column 1 of each statement, PFC is free-form. All statements must be in the `PFC` file.

PFC has three levels of control, which are identified by one of three identifiers in column one. See Figure 4-1.

1. The left parenthesis "(" identifies the top (or process) level of control. Only four commands are valid here — `(POWERFLOW`, `(NEXTCASE`, and `(STOP` or `(END`.
2. The slash "/" identifies the second (or command) level of control. Many commands are valid here, and they are listed and described in this chapter. Commands generally enable or disable output options, define parameters needed for the process, etc. Subprocesses are major operations involving considerable processing and additional data. Only optional IPF processes are requested with these commands.
3. The right angle bracket ">" identifies the third (or subcommand) level of control. A few commands have subcommands associated with them. These subcommands are described in the associated command entries. These subcommands act as qualifiers for the second-level commands.

In addition to the foregoing syntactic units, a command enabling a microfiche option is available. Its control symbol is the left square bracket ([).

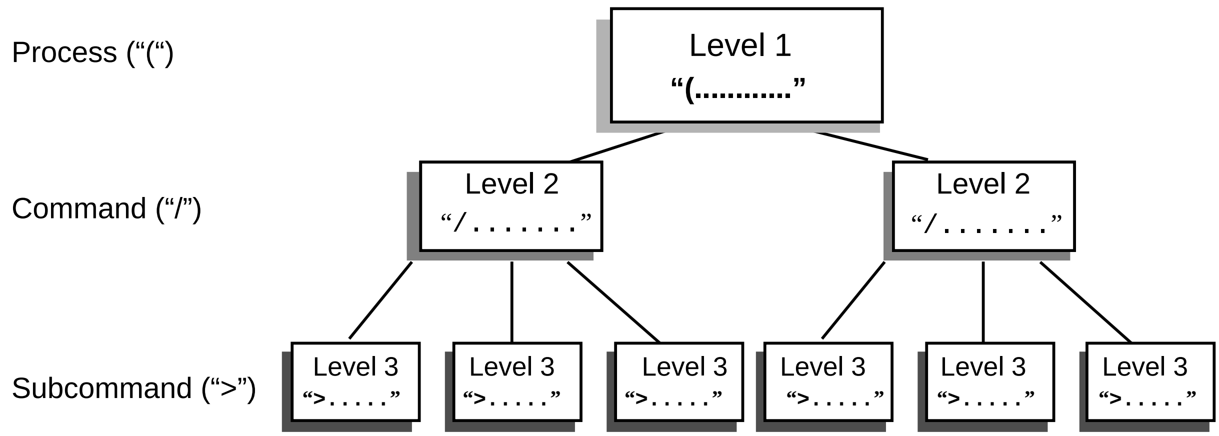


Figure 4-1 Hierarchical Levels of PFC Statements

Almost every PFC statement fits one of the following formats, and the few that do not are very similar. (Note that spaces can be used for readability. Commas are used to separate syntactic units such as a list of values or keyword/value assignments.) Most statements fit on one line, but some extend over multiple lines. These exceptions are noted. When used, put a hyphen (-) where you want to break and continue the command parameters starting in or after column 2 of the next line, column 1 must be blank.

Each general format is followed by an example.

- A simple command with no keywords or values:

  / *command*
  `/ REDUCTION`

- A command assigned a simple keyword. (This is a "telescoped" syntax available for some commands.)

  / *command*=*keyword*
  `/ AI_CONTROL = CON`

- A command followed by a comma with a keyword. (This is a "telescoped" syntax available for some commands.)

```
/ command,keyword
/ F_INPUTLIST,NONE
```

- A command followed by a comma with a value assigned to a keyword.

```
/ command,keyword=value
/ P_ANALYSIS_RPT, LEVEL = 4
```

- A command followed by a comma with multiple values assigned to a keyword. Note optional continuation with hyphen (-).

```
/ command,keyword=value,value,value,...
/ P_INPUT_LIST, ZONES=NA,NB,NC,ND,NE,NF, -
         NG,NH,NI,NJ,NK
```

- A command followed by a comma with multiple value/keyword assignments.

```
/ command, keyword=value,keyword=value,...
/ MERGE_OLD_BASE, SUB_SYSTEM_ID = AREA-1, OLD_BASE = TESTDC.BAS
```

- A command followed by a data record(s).

```
/ command
data record
/ NETWORK_DATA
B     GEN1 HI    230  2  -0.0  -0.0  0.0  0.0     -0.0 -0.0 -0.0
B     GEN2 HI    230  1  -0.0  -0.0  0.0 0.0      -0.0 -0.0 -0.0
B     GEN3 HI    230   2  -0.0  -0.0  0.0 0.0      -0.0 -0.0 -0.0
```

- A subcommand followed by a comma with multiple comma-separated values.

```
>subcommand,value,value,value,...
>SAVE_ZONES,NA,NB,NC,ND,NE,NF,NG,NH,NI,NJ,NR
```

- A subcommand followed by a data record on the next line.

```
>subcommand
data record
>SAVE_AREAS
A  AREA 2
```

4.3 SPECIAL CHARACTERS

Two special characters are available to document the control stream or to improve readability.

- A "`.`" (period) in column 1 of a record identifies a command comment and the record will be ignored by the processing. It is used to document a `PFC` file or to improve readability. This comment is only visible in a listing of the `PFC` file or in the editor used to create it.

- The underscore symbol "_" has no syntactic significance and may be used freely to punctuate a word for visual readability.

  Note: The hyphen or minus sign "-" and the underscore "_" symbol are different characters!

  Thus, `P_O_W_E_R_F_L_O_W` is the same as `POWER_FLOW` which is the equivalent of `POWERFLOW. OLD_BASE` is the same as `OLDBASE` but not the same as `OLD-BASE`, etc.

4.4 DEFAULT CONVENTION

All default values for a command are listed on the first line in the command descriptions. Various keywords are listed below the default values. Default values have been selected to satisfy a majority of users; therefore, their use is to invoke exceptions to standard conventions. Once a default value has been enabled, it remains in force for the duration of the process. There is one exception to this:

```
/ P_INPUT_LIST
```

After the first case has been processed, `P_INPUT_LIST` is set to `NONE`. This conforms to the default philosophy of selecting all options that fulfill a majority of requirements.

4.5 MICROFICHE CONTROL STATEMENT

`[ FICHE,COPIES = n ]` or
`( FICHE,COPIES = n )`

This command requests `n` copies of microfiche listings to be made. If it is omitted, the fiche file is not saved. If `n` is zero or omitted, no copies are made. When it is used, this control must be first in the job stream.

4.6 LEVEL 1 PFC COMMANDS

The first-level control commands and examples follow.

`( POWERFLOW )`

This command initiates the processing of the network which is defined with subsequent commands and subcommands.

`( NEXTCASE )`

This is the same as `( POWERFLOW )` except that the base network to be processed is the current network. Changes are expected; otherwise, the same network is processed again with the same data and controls in memory from the previous case. `( NEXT_CASE )` cannot be the first command in a program control file.

`( END )` *or* `( STOP )`

This stops the execution of the IPF program.

Each network is processed with a `( POWERFLOW )` or `( NEXTCASE )` command. The first must always be `( POWERFLOW )`. Several cases may be concatenated (stacked) in the following format:

`( POWERFLOW )` *statement for case 1*
`( POWERFLOW )` *statement* or `( NEXTCASE )` *statement for case 2*
.
.
.
`( POWERFLOW )` *statement* or `( NEXTCASE )` *statement for case n*
`( STOP )`

The following control statement and the optional keywords that go with it identify the `OLD_BASE` file, optionally perform miscellaneous temporary changes to `OLDBASE`, set solution parameters, and solve the resultant network.

```
(POWERFLOW  CASEID = <casename>, PROJECT = <projname>)
```

`casename` is a user-assigned 10-character identification for the case.

`projname` is a user-assigned, 20-character identification for the project or study to which this case applies. (*No blanks are allowed*; use hyphens instead.)

The following statement is used if the Powerflow solution is to be run starting with data and controls from the previous base case in residence.

```
( NEXTCASE, CASEID = <casename>, PROJECT = <projname> )
```

Note that `/ OLD_BASE` is not used with a `( NEXTCASE )` statement since a base data file is already in residence.

4.7 LEVEL 2 AND 3 PFC COMMANDS

Each Level 2 statement starts with a slash (`/`) in the first position.

After the slash are keywords and/or values separated by a comma (`,`). Specific values are assigned to the keywords in the following format:

```
keyword = value
```

When a keyword is requesting a list, for example, a zone list, the list may be continued on the next record by leaving column 1 of that record blank or by putting a comma in column 1 and continuing the list.

Level 3 statements consist of subcommands that specify keyword values for second-level commands only. Each subcommand for level 3 statements starts with the right angle bracket (>) in column 1. After the right angle bracket are keywords and/or values separated by commas (`,`). Most often, specific values are assigned by following a keyword with an equal sign (=) and then the desired value.

4.8 PFC COMMANDS

The rest of this chapter discusses all the PFC commands, in alphabetical order. Each command entry includes the details of syntax and usage. The more involved commands show examples of use. To make the commands easy to find, each entry begins at the top of a page, and you will find each command name in the heading information on each page. Refer to Table 4-1 to locate a PFC command quickly.

In the format statement for each command, the keywords and parameter values are all vertically aligned in the same column. The top row is the default value. Alternate value assignments such as `ON` or `OFF` are identified by the appropriate symbols and have the syntax `keyword=value`.

Required text is shown in `UPPER-CASE` while parameter values specified by the user are printed in `lower-case` and usually enclosed by angle brackets, thus, `<list>.` Angle brackets are omitted when they may cause confusion with the Level 3 control symbol.

The optional underscore symbol (_) may be used to break up words for visual readability. The computer will read the words as though they were not broken.

Table 4-1 PFC Commands

Page	Command Name	Description
4-10	AGC	Emulates automatic generation control.
4-13	AI_LIST	Specifies detail in area interchange listing.
4-14	ANALYSIS_SELECT	Selects analysis reports for printing or micro-fiche.
4-16	BRANCH_DATA	Specifies a master branch and bus data file for base case.
4-17	BUS_SENSITIVITIES	Calculates system response to capacitor switching operations.
4-22	CHANGE_BUS_TYPE	Disables voltage control in system.
4-27	CHANGE_PARAMETERS	Perturbs parameters for start of new solution.
4-33	CHANGES	Specifies system data change records.
4-34	COMMENT	Specifies comment records.
	COMMON_MODE_ANALYSIS	Analyzes the results from a series of common mode cases in the format of the OUTAGE_SIMULATION

Table 4-1 PFC Commands

Page	Command Name	Description
4-36	F_ANALYSIS_RPT	Specifies report of zones or owners for microfiche.
4-38	F_INPUT_LIST	Lists input data on microfiche.
4-39	F_OUTPUT_LIST	Lists output data on microfiche.
4-40	GEN_DROP	Balances generation drop by picking up generation.
4-44	HEADER	Specifies header information for reports.
4-45	INCLUDE_CONTROL	Specifies a file for control commands.
4-46	LINE_EFF	Defines minimum percent line loading for report.
4-47	LINE_SENSITIVITIES	Determines line sensitivity by controlling LTC and AI_CONTROL.
4-50	%LOAD_DISTRIBUTION	Converts constant power, etc., into user-specified MVA, etc.
4-63	LOSS_SENSITIVITIES	Gives information about system losses.
4-65	MERGE_OLD_BASE and MERGE_NEW_BASE	Extracts information from two subsystems to create a new system.
4-71	MVA_BASE	Changes base MVA to an assigned MVA.
4-72	NETWORK_DATA	Specifies bus and branch data.
4-73	NEW_BASE	Defines the file name for a new case.
4-74	OI_LIST	Lists ownership interchange.
4-75	OLD_BASE	Specifies a previously existing solved case as the new case to start with.
4-76	OUTAGE_SIMULATION	Simulates line outages, load dropping, generator outages and rescheduling.
4-83	OVERLOAD_RPT	Specifies overload parameter limits for report.
4-84	P_ANALYSIS_RPT	Creates an analysis report.
4-86	P_INPUT_LIST	Lists input data on paper.
4-87	P_OUTPUT_LIST	Lists output on paper.
4-89	REBUILD	Rebuilds all data tables from current OLD-BASE file.

Table 4-1 PFC Commands

Page	Command Name	Description
4-90	REDUCTION	Reduces a network.
4-95	RPT_SORT	Sorts output data of solved network.
4-96	SAVE_FILE	Creates various output files, including the SIF (Stability Interface File).
4-98	SOLUTION	Enables solution options and post-solution processes.
4-104	SORT_ANALYSIS	Controls sort order for analysis listings.
4-105	TRACE	Monitors data to aid data verification.
4-106	TRANSFER_SENSITIVITIES	Causes analysis of transfer sensitivities.
4-107	TX_EFF	Compares total and core transformer losses.
4-108	USER_ANALYSIS	Generates custom analysis listings.

4.9 AGC

This command emulates automatic generation control (AGC) in the solution algorithm. Under AGC, real power excursions on several generators from base values are allocated in proportion to their total excursion. This in effect distributes the slack bus real power excursions to a set of selected units. The slack bus excursion, which drives AGC, may be either a system slack bus or an area slack bus.

The individual AGC units are identified with type B (bus) records which follow the `/ AGC` command. columns (1:18) correspond with the original format. Beyond column 18, data is free field.

```
B  <bus_name,base kV>  Pmin=<##>, Pmax=<##>, Pgen=<##>, %=<##>
```

where

`Pmin` Minimum generation in MW. Default value is 0.0.

`Pmax` Maximum generation in MW. Default is `Pmax`, which is specified on the bus record.

`Pgen` Base generation is MW, which is used to compute the excursions. Default is scheduled or actual MW from the base case.

`%` Percentage. The default allocates% in proportion to `Pmax`.

A maximum of 24 AGC units may be specified. One of the units must be a system or area slack bus. Usually, AGC schemes converge faster than non-AGC. The exception occurs when `P_min` or `P_max` limits are hit and some readjustment occurs.

4.9.1 General Description

An example illustrates the concept. In Case 1, there are two generators, GEN1 and GEN2, with initial and final values shown in Table 4-2.

Table 4-2 Values Without AGC

Bus	Initial P	Final P	Excursion
GEN1 (slack)	1000	1442	442
GEN2	1000	1000	0
TOTAL	2000	2442	442

In Case 2, we apply AGC with 50% on each machine. Presuming that losses are unchanged (for simplicity), the initial and final values are shown in Table 4-3.

Table 4-3 Values With AGC

Bus	Initial P	%	Final P	Excursion
GEN1 (slack)	1000	50	1221	221
GEN2	1000	50	1221	221
TOTAL	2000	100	2442	442

4.9.2 Example Control Card Setup

```
( POWERFLOW, CASEID = TEST_CHANGE_PAR, PROJECT = TEST-WSCC-DATA )
/ P_INPUTLIST,FULL
/ F_INPUTLIST,NONE
/ P_OUTPUTLIST,FULL
/ F_OUTPUTLIST,NONE
/ F_ANALYSIS_RPT,LEVEL=0
/ F_ANALYSIS_RPT,LEVEL=4
/ OLD_BASE,FILE = TESTCHANGE.BSE
/ AGC
B       G1      13.8    PGEN = 1000,     PMAX = 1250,     % = 30
B       G2      13.8    PGEN = 1000,     PMAX = 1200,     % = 40
B       G4      22.     PGEN = 1000,     PMAX = 1250,     % = 30
/ SOLUTION
( END )
```

Notes and Restrictions

A maximum of 24 generators are permitted. One of the generators must be a system slack bus or an area interchange bus. Recall that the dynamics which drive AGC comes from slack bus P excursions.

If any unit hits a limit, the remaining active units redistribute their percentages and continue AGC control.

The results are summarized in the listing `AGC Control`. This listing is controlled with `/ ANALYSIS_SELECT` command.

```
/ ANALYSIS_SELECT
> SUM%VAR
```

If area interchange control is ON, all AGC units should reside in the same area. Violations of this rule are flagged with warning diagnostics.

AGC control will obscure the change in slack bus power shown in the tie line Summary of Area Interchange. The true slack bus effects within the area would be the aggregate effects of all AGC units. The area interchange summary obscures this effect.

When `/ AGC's` and `/ GEN_DROP` coexist, `/ AGC` operates with a higher priority. In actuality, the two should not coexist.

The validity of AGC can be verified in the analysis summary `AGC Control`. In normal conditions, the scheduled and actual percentage participation should be equal.

If these quantities are not equal, it is usually because P_max or P_min limits have been hit. In this instance, a comment appears.

```
Actual % / Sched % = ****.*
```

All of the active units should have an individual ratio.

4.10 AI_LIST

This command controls the level of detail in the area interchange listing.

```
/ AI_LIST = FULL
```

FULL is the default. The options are:

`FULL`	Area interchange matrix, Area slack bus summary, and tie line flows.
`MATRIX`	Area interchange matrix.
`TIELINE`	Tie line flow summary.

4.11 ANALYSIS_SELECT

This selects individual analysis reports for printing or microfiche. It supersedes `/ F_ANALYSIS` and `/ P_ANALYSIS`. Unlike these commands which select groups of reports according to their “level” the `/ ANALYSIS_SELECT` command selects reports individually.

A solitary `/ ANALYSIS_SELECT` command defaults all analysis listings to no print/no fiche status.

Printing and/or microfiche are enabled with the commands: `> FICHE` and `> PAPER`. These commands independently restrict the contents of `FICHE` or `PAPER` reports to subsets of Zones, Ownerships or Areas.

The desired analysis reports are individually selected using **>** commands containing abbreviated report names, e.g., `> UNSCH`.

Each `> (report)` command accepts an optional `F` or `P` qualifier. This will restrict the selected report to Fiche or Print respectively. If neither appear, both `F` and `P` are presumed to be selected. For example, `> UNSCH, P` will print the unscheduled reactive report.

A special option exists on the `> LINEFF` report. Its entirety is:

```
> LINEFF, SORT = BUS_NAME, OUTPUT=filename, FIELD_WIDTH =  132,F,P
                                                            80,F,P
>        VOLTAGE,
         OWNER,
         ZONE,
```

All quantities are optional.

`SORT` Controls sorting by bus kV_name, owner_name, or name.

`OUTPUT` Copies a duplicate report to the named file.

`FIELD_WIDTH` Controls the report width or the named file.

The following is a full list of the `/ ANALYSIS_SELECT` command set.

```
/ ANALYSIS_SELECT
> FICHE,ZONES=<zone1,...>,AREAS=<area1,...>,OWNERS=<owner1,...>
> PAPER,ZONES=<zone1,...>,AREAS=<area1,...>,OWNERS=<owner1,...>
> USERAN       - User-defined analysis listing. (Used with / USER_ANALYSIS.)
> UNSCH        - Buses With Unscheduled Reactive.
> LOSSOWN      - Total System Generations and Loads by Owner.
> SYSTEMZONE   - System Generations,Loads,Losses and Shunts by Zones.
> UVOV         - Undervoltage-Overvoltage Buses.
> LINELOAD     - Transmission Lines Loaded Above xxx.x% of Ratings or with
```

```
                     more than 30 degrees of electrical angle.
> TRANLOAD     - Transformers Loaded Above xxx.x% of Ratings.
> TRANEX       - Transformers Excited Above xxx.x% over Tap.
> XSYSTEMLOSS  - Transmission System Losses.
> BPALOADS     - BPA Industrial Loads.
> DCSYSTEM     - DC System.
> SHUNTSUM     - Shunt Reactive Summary.
> SUMLTC       - Summary of LTC Transformers.
               - Summary of LTC Reactive Utilization
> SUMPHASE     - Summary of Phase-shifters.
> SUM%VAR      - Summary of %Var-controlled buses.
               - Summary of AGC Control
               - Summary of Line Drop Compensation
> SUMBX        - Summary of Type BX buses.
> SUMRAN       - Summary of Adjustable Var compensation.
> SERIESCOMP   - Transmission Lines Containing Series Compensation.
> BUS          - Bus Quantities.
> SPIN         - Spinning Reserves.
> LINEEFF      - Transmission Line Efficiency Analysis. (Lines Loaded
                 Above xxx.x % of Nominal Ratings).
> TRANEFF      - Transformer Efficiency Analysis.
               - Total Losses Above xx.xx % of Nominal Ratings.
> TRANLOSS     - Transformer Efficiency Analysis
               - Core Losses Above xx.xx % of Nominal Ratings.
```

4.12 BRANCH_DATA

```
/ BRANCH_DATA, FILE = <filespec>, DATE = <myy>, -
               BUSDATA_FILE = *
                              <filespec>
```

This command specifies that the base case will be established from a master branch data file and associated bus data file. Branch data selected from this file will have an energization date (date in) and a de-energization date (date out) corresponding with the `DATE` specified on the above command.

If `BUSDATA` is not specified or has parameter value **`*`**, the program expects bus data to follow in the input stream.

See `MERGE_OLD_BASE` and `MERGE_NEW_BASE` for more information about branch data file merging. Using the `MERGE_OLD_BASE` and `MERGE_NEW_BASE` commands is preferred.

4.13 BUS_SENSITIVITIES

```
/ BUS_SENSITIVITIES
```

The primary motive of sensitivity is to calculate the instantaneous system response to sudden capacitor switching operations. This is difficult to model in the Powerflow because all LTCs must be turned off. This may cause solution divergence because LTCs are an integral part of any dc system. This problem is circumvented using sensitivities.

By recalculating the Jacobian matrix, various constraints can be changed. The flexibility of these constraints is evident in the format of the sensitivity command.

```
/ BUS_SENSITIVITIES,LTC=ON,AI_CONTROL=CON,Q_SHUNT=ADJ,Q_GEN=ADJ
                 OFF,           OFF         FIXED     FIXED
                                MON
```

The top line defines the default values.

The first two options correspond with the standard solution options. The second two options define the conditions in which type `BQ` and `BG` buses can operate holding constant voltage.

For example, enabling the option `Q_SHUNT = FIXED`, type `BQ` buses have all shunt fixed. If there is no rotating machinery (Q_{max} and Q_{min} are zero), then the bus holds constant Q (PQ). Since type `BG` buses always have Q_shunt fixed, this option has no affect on generator buses.

Similarly, by enabling the option `Q_GEN = FIXED`, type `BQ` and `BG` buses have all generation fixed and operate in state PQ. Type `BG` buses will operate in state PQ. If `BQ` buses have no shunt, they also will operate in state PQ.

In order of time response, the generators respond within several seconds. Thus, `Q_GEN` will normally be adjustable. LTC’s, dc LTC’s, and switched capacitors are controlled by time-delayed voltage relays to minimize spurious operation.

`LTC`’s 0.5 - 3.0 minutes

`dc LTC`’s 5 seconds

`CAP/REACTORS`:5 - 30 seconds

The slowest component is area interchange control. Its response time is 0.5 to 10 minutes.

By appropriate selection of options, the Jacobian matrix can represent nearly any time frame of response.

4.13.1 Selected Buses

Following the `BUS_SENSITIVITIES` record, individual buses are selected for perturbation. These buses are identified by the `B` formatted records that follow them. A maximum of 50 buses may be specified.

The perturbed quantity is identified by nonzero entities in one of the fields: `P_load`, `Q_load`, `G_shunt`, `B_shunt`, `P_generation` or `Q_generation`.

The fields on the B-blank record determine which sensitivity dP/dθ, dP/dV, or dQ/dV is computed.

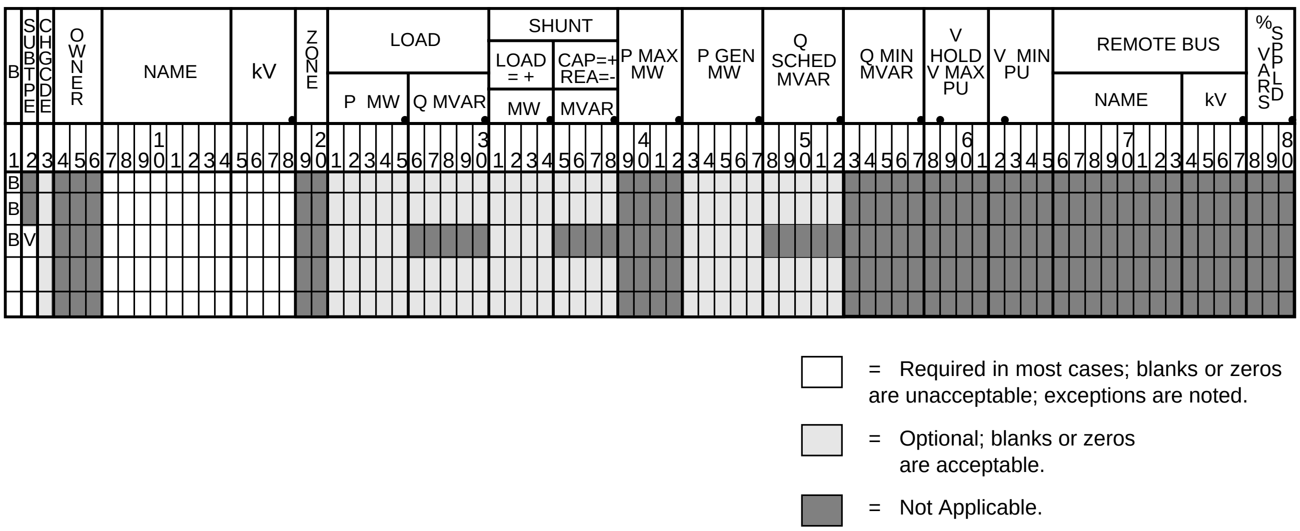


Figure 4-2 B-blank Record Sensitivity Fields

Table 4-4 Field Values for Sensitivities

Sensitivity	Column 2	PLOAD, PSHUNT, PGEN	QLOAD, QSHUNT, QSCHED
dP/dθ	Not required	Required	Not required
dP/dV	LIteral: "V"	Required	Not required
dQ/dV	Not required	Not required	Required
dQ/dV[a]	(blank)	(blank)	(blank)

a. This is the default.

4.13.2 Repeat Sensitivities

A powerful feature of the sensitivity process is the ability to refactor the Jacobian matrix under different control schemes. For example, one `/ BUS_SENSITIVITIES` record could enable only the `Q_GEN` option (exciters on, everything else off) for an instantaneous response. Following the necessary `B` formatted records a second `/ BUS_SENSITIVITIES` record could enable all options for a long term response. Assuming the same bus list is repeated, then a comparison between the two corresponding sensitivities would yield the short-term and long-term effects of the bus's injection perturbation.

4.13.3 Example

The following is an actual case. Bus `OLYMPIA 230` was specified for a -172 MVAR shunt application. If `Q_Load` or `Q_Generator` was specified, the actual `Q_Perturbation` would be -172 MVAR. For `Q_Shunt`, the `Q_Perturbation` is calculated.

```
Delta (Q)= Q_Shunt * V**2
= -172 * (1.067)**2
= -195.82 MVAR
New_Voltage (kV) = Old_Voltage (kV) + Sensitivity * Delta_Q
= 245.45 kV + 0.0334 * (-195.82)
= 245.45 kV - 6.54 kV
= 238.91 kV
```

The correct computed value on the listing is 238.90 kV. The different figures in the example are due to round off.

The correlation with actual Powerflow cases is very close. The calculated voltage excursion -6.54 kV is within two percent of the actual excursion. The accuracy is significant because the actual and estimated voltages will differ 0.001 per unit at most! See Figure 4-3.

4.13.4 Sample Deck Setup

```
(POWERFLOW,...)
.
.
.
/ CHANGES
.
.
.
/ BUS_SENSITIVITIES,LTC=ON,AI_CON=OFF,Q_SHUNT=ADJ,Q_GEN=ADJ
B    MONROE   500       316
```

```
BUS_SENSITIVITIES COMPUTED WITH THE FOLLOWING CONTROLS:

              LTC CONTROL            ( )  OFF
              --- -------            (X)  ON (FULL CONTROL     )
                                     ( )  ON (NO VOLTAGE CONTROL)

              AI CONTROL             (X)  OFF
              -- -------             ( )  CONTROL (DEFAULT)
                                     ( )  MONITOR

              Q_SHUNT CONTROL        (X)  ADJUSTABLE
              ------- -------        ( )  FIXED

              Q_GENERATION CONTROL   (X)  ADJUSTABLE
              ------------ -------   ( )  FIXED


0 MONROE   500.0 A  316.0 MVAR CHANGE IN SHUNT AT THIS BUS WILL CAUSE THE FOLLOWING VOLTAGE CHANGES

0      BUS      BASE   BUS      BASE   ----- DVOLT/DQ  -----   ------ BASE VOLTAGE -------   ------ NEW VOLTAGE -------
                                       (P.U./P.U.)  (KV/MVAR) (P.U. KV)          (KV)    (P.U.KV)            (KV)
       MV-SVC    19.6                    -0.0106    -0.0023       1.118           21.92     1.081            21.10
       MONROE   500.0                     0.0061     0.0321       1.052          525.84     1.073           537.05
       WRK 25    25.2                     0.0040     0.0010       1.041           26.22     1.054            26.59
       MONROE   230.0                     0.0039     0.0092       1.037          238.54     1.051           241.77
       GDK 4      4.0                     0.0039     0.0002       1.049            4.20     1.063             4.25
       MONROE T 230.0                     0.0038     0.0090       1.035          237.98     1.048           241.12
       RIM 12    12.6                     0.0037     0.0005       1.041           13.11     1.054            13.29
       RYL 12    12.6                     0.0037     0.0005       0.996           12.55     1.009            12.71
       WRK 60B2  60.0                     0.0037     0.0023       1.020           61.17     1.033            61.97
       WRK 60B1  60.0                     0.0037     0.0023       1.020           61.22     1.033            62.01
```

Figure 4-3 Output From Bus Sensitivity Example

4.14 CHANGE_BUS_TYPE

`/ CHANGE_BUS_TYPE`

This command disables voltage control in selected areas of the system and performs bus type changes from a voltage control type to a more passive type. The changes it makes are permanent and apply to the case in residence. If this command appears before any system changes, the bus type changes will apply before the system changes, exempting any new or changed buses. If this command appears after any system changes, any new or changed buses will be subject to bus type changes invoked with this command. See Table 4-5.

An example is shown below.

```
/ CHANGE_BUS_TYPE, BQ=B,  BG=BQ, BT=B , BX=B , -
                   LTC = OFF, -
                   AREAS=<area_1,...>, -
                   ZONES=<zone_1,...>, -
                   LIST=ON
```

4.14.1 Bus type changes

Four types of buses may be changed: `BQ`, `BG`, `BT` and `BX`. All possible bus type transitions are depicted above using the format `<old_type> = <new_type>`.

The full repertoire is listed in Table 4-5. (Note that some restrictions apply.)

Table 4-5 Bus Type Changes

Change	Restriction
BQ --> B	If `PGEN = 0.0` and `QGEN =0.0`
BQ --> BF	If `PGEN <= 0.0`.
BQ --> BF*	Unconditional.
BG --> BQ	If `PGEN > 0.0`.
BG --> B	If `PGEN <= 0.0`.
BG --> BF	If `PGEN = 0.0`.
BG --> BF*	Unconditional.
BT --> B	(This deletes any adjacent LTCs which are controlling BT nodes.)

Table 4-5 Bus Type Changes

Change	Restriction
BX --> B	
BX --> BF	
BX --> BF*	

4.14.2 LTC Transformer Control

A bus type change `BT=B` will delete LTCs only if the controlled bus is type `BT`. A more general option:

```
LTC = OFF
```

disables all LTCs within the specified area except for any dc commutating transformers.

4.14.3 LIST

The LIST parameter accepts two values -- ON and OFF. The default is ON. This applies to the CHANGE_BUS_TYPE summary where the initial and final state of each bus affected is depicted. Setting LIST=OFF is recommended for repetitious batch runs.

4.14.4 Exclude Buses

Means are available to exempt individual buses from type changes defined in the `/CHANGE_BUS_TYPE` command. These buses are excluded with the following command:

```
>EXCLUDE_BUS
B          name     base
B          name     base
. . .
. . .
```

4.14.5 Line Drop Compensation

This feature temporarily replaces the ordinary BG -> BC voltage control of a remote bus with a BG control of a compensated voltage, which is specified as a percentage within the step up transformer. This control scheme is valid only for this case, and may be introduced only within context of a `CHANGE_BUS_TYPE` command. In subsequent cases, these generators revert to their normal control mode

The target compensated voltage is defined with a computed voltage limit. That limit is derived from two base case terminal voltages -- the BG bus and the remote BC bus (the remote bus may be another type). The formula used is

$$V_{max} = V_{min} = PCT \bullet V^{base}{}_{BG} + (1 - PCT) \bullet V^{base}{}_{BC}$$

Example:

```
/ CHANGE_BUS_TYPE, BQ = B, BX = B, BG = BQ
...
> LINE_DROP_COMPENSATION
BG    COULEE 13.8, 70%
BG    CHIEF JO13.8, 80%
```

Restrictions on Line Drop Compensation

The following restrictions apply to line drop compensation:

- All buses selected for Line Drop Compensation must be type BG. All buses selected are exempt from any bus type change BG -> BQ or BG => B.
- The controlled remote bus must be immediately adjacent to the generator.
- The specified percentage should be between 0 and 100%. A warning is issued if the specified percentage is outside this range.
- A maximum of 20 generators may be selected for line drop compensation.
- The line drop compensation is case specific. It defines the base solution, but is not saved on the base history data file.

4.14.6 Reactive Compensation

This feature is similar to the *Raindrop Compensatio*n; it temporarily replaces the ordinary BG -> BC voltage control of a remote bus with a BG control of a compensated voltage, which is specified as the voltage drop from the bus terminal voltage computed with the generator reactive power in series with a user-specified impedance. This control scheme is valid only for this case, and may be introduced only within context of a `CHANGE_BUS_TYPE` command. In subsequent cases, these generators revert to their normal control mode

The target compensated voltage is defined with a computed voltage limit. That limit is derived from two base case terminal voltages -- the BG bus and the remote BC bus (the remote bus may be another type). The formula used is

$$V_{max} = V_{min} = V^{base}{}_{BG} - Q_{BG}/V_{BG} \bullet X_{BC}$$

$$X_c = (PCT/100) \bullet (100/MVA_{base})$$

where `PCT` is the user-specified percentage and MVA_{base}. is the user-specified machine MVA.

Example:

```
/ CHANGE_BUS_TYPE, BQ = B, BX = B, BG = BQ
...
> REACTIVE_COMPENSATION
BG    COULEE  13.8, 5%, 100
BG    CHIEF JO13.8, 5%, 100
```

Restrictions on Reactive Compensation

The following restrictions apply to reactive compensation are identical to those which apply to line drop compensation:

- All buses selected for Reactive Compensation must be type BG. All buses selected are exempt from any bus type change BG -> BQ or BG => B.
- The controlled remote bus must be immediately adjacent to the generator.
- The specified percentage is typically in the range 5-6%. It may be negative if the voltage is internal to the machine.
- A maximum of 20 generators may be selected for reactive compensation.
- The reactive compensation is case specific. It defines the base solution, but is not saved on the base history data file.

Output Reports

A special summary of all line drop compensation buses is listed in the analysis group under the title *Summary of Line Drop Compensation*. It is available either as a level 4 option on the `/P_ANALYSIS` or `/F_ANALYSIS` command or as the `SUM%VAR` option on the `/ANALYSIS_SELECT` command.

```
/ANALYSIS_SELECT
SUM%VAR
```

4.14.7 Example

An example is shown below.

```
( POWERFLOW, ...)
...
...
...
/ CHANGES, ...
...
...
...
/ CHANGE_BUS_TYPE, BG=BQ, BT=B ,BX=B, -
                    LTC = OFF, -
                    AREAS = NORTHWEST, LIST=OFF
/ CHANGE _BUS_TYPES,BQ=B,BX=B,BG=BQ,LTC=OFF,AREAS=NORTHWEST,BC-HYDRO
>EXCLUDE_BUSES
B    CENTRALA20.0
B    BONN PH213.8
B    BONNVIL213.8
B    DALLES 313.8
B    DALLES2113.8
B    DALLES2213.8
/ SOLUTION
( END )
```

In this example, the disabling of remote voltage control is restricted to area `NORTHWEST`. Within this area, all `BG` generators are permanently changed to type `BQ`; all LTCs are disabled; and all `BX` buses are frozen to their discrete value.

4.15 CHANGE_PARAMETERS

```
/ CHANGE_PARAMETERS, BUS=<name, base>,V=<set_value>,Q=?
                                      VX=<set_value>,QY=?
                                      Q=<set_value>,V=?
                                      QY=<set_value>,QV=?
                                      P=<set_value>,V=?
                                      P=<set_value>,V=?
> BX = LOCKED
B      OSTRNDER 500
B      MALIN    500
```

or

```
/ CHANGE_PARAMETERS,  BUS=<name, base),V=?, -
           %LOAD_CHANGE,%PY=<##>, %QX=<##, -
                %PX=<##>, %QY=<##, -
           ZONES=NA, NB, ..., -
           OWNERS=BPA, PSP, ..., -
           AREAS=NORTHWEST
```

or

```
/ CHANGE_PARAMETERS,  BUS=<name, base),V=?, -
           %GEN_CHANGE,%PY=<##>, %QX=<##, -
                %PX=<##>, %QY=<##, -
           ZONES=NA, NB, ..., -
           OWNERS=BPA, PSP, ..., -
           AREAS=NORTHWEST
```

Note: This is one of the three commands which are order-dependent on the `/SOLUTION` command (the other two commands are `LINE_SENSITIVITIES` and `LOSS_SENSITIVITIES).` Each of these must follow the /`SOLUTION` command.

The /CHANGE_PARAMETERS command perturbs a specified network parameter immediately after a successful solution, and initiates a new solution. The process continues until the last /CHANGE_PARAMETERS command has been read. All changed network parameters are permanent in the base case in residence. The output, analysis, and saved base case reflecting the final values of the parameters from the last change.

The /CHANGE_ANALYSIS feature is extremely useful to quickly and accurately generate a set of points for plotting Q-V and P-V curves. When used in conjunction with /USER_ANALYSIS, the values of additional network quantities can be extracted during each /CHANGE_PARAMETERS, enriching the scope of examination into the network.

The distribution VX, VY, etc., designates both the quantity and the axis on the X-Y data file. Default values (V, Q, etc.) are shown in Table 4-6.

4.15.1 BX = LOCKED

Type BX buses selected with this feature emulate the characteristics of mechanically switched shunt capacitors (MSC) controlled by a voltage relay. This voltage relay operates within a voltage deadband (V_{min}, V_{max}):

1. If Vmin < V < V_{max}, then freeze present X_{shunt} value.
2. If V < V_{min}, switch in additional capacitor steps or switch out connected reactor steps to raise the voltage, one step at a time.
3. If V > V_{min}, switch out connected capacitor steps or switch in additional reactor steps to lower the voltage, one step at a time.

For exposition, the feature is called *BX Locking*. In the absence of this feature, the normal operation is to switch X_{shunt} one step per iteration to bias the bus voltage to V_{max}.

4.15.2 Restrictions on BX Locking

The following restrictions apply to BX locking:

- Only bus type BX buses may be selected for BX locking.
- The feature is limited to a maximum of 10 BX locked buses.
- This feature can be inserted after any `/ CHANGE_PARAMETERS` command. It defines *when* BX switching on selected BX buses becomes locked. Once defined, BX locking remains in effect for the duration of the study.
- The voltage limits may be temporarily modified for BX locking. The new voltage limits are entered in columns (58:65) in the ordinary manner. These limits are temporary. After the solution, the original limits will be used for analysis reports.
- The BX locking feature is not saved on any generated base case.

4.15.3 Bus Perturbation

Two forms of `/ CHANGE_PARAMETERS` are shown. The first form is bus perturbation. Three types of quantities may be perturbed:

`V = <set_value>` Perturbs the Bus voltage magnitude (p.u.).

`P = <set_value>` Perturbs the Pgen (MW).

`Q = <set_value>` Perturbs the Qgen (MVAR).

4.15.4 Restrictions

V-perturbations are applied on V-constrained buses: `BQ` not at Q-limits, `BE` and `BS` types. If the bus type is unacceptable, it is automatically changed to a type `BE` and a warning diagnostic is issued.

Q-perturbations are applied on Q-constrained buses: `B`, `BC`, `BT` and `BQ` in state `Q_min` or `Q_max`. If the bus type is unacceptable, it is automatically changed to a type `B` and a warning diagnostic is issued.

P-perturbation can only be applied on P-constrained buses: all types except `BS`, `BD`, `BM`, and area slack buses.

4.15.5 Load Perturbation

The second form of `/ CHANGE_PARAMETERS` is `LOAD` perturbation. Either the `P_load` or the `Q_load`, or both, may be perturbed a set percentage.

If no `ZONES`, `OWNERS`, or `AREAS` are specified, the percentage change applies to the entire system.

Note that the %P or %Q quantities in the output file correspond to the load that is changed. It may not be the total system load.

The inclusion of `OWNERS` with either `ZONES` or `AREAS` select candidates that are mutually inclusive.

Note that continuation records are accepted here.

For best results, the `%LOAD_CHANGE` option should be used in conjunction with `GEN_DROP`. Otherwise, all increase in load is picked up by the area and system slack buses.

4.15.6 Generation Perturbation

The third form of `/ CHANGE_PARAMETERS` is `GENERATION` perturbation. Either the `P_gen` or the `Q_gen`, or both, may be perturbed a set percentage.

If no `ZONES`, `OWNERS`, or `AREAS` are specified, the percentage change applies to the entire system.

Note that the %P or %Q quantities in the output file correspond to the generation that is changed. It may not be the total system generation.

The inclusion of `OWNERS` with either `ZONES` or `AREAS` select candidates that are mutually inclusive.

Note that continuation records are accepted here.

For best results, the `%GEN_CHANGE` option should be used in conjunction with `GEN_DROP`. Otherwise, all increase in generation is compensated by the area and system slack buses.

4.15.7 Bus Monitored Quantities

Two types of bus quantities can be monitored:

`V = ?`	Monitors the voltage magnitude.
`Q = ?`	Monitors the reactive allocation including short and unscheduled VARS.

Restrictions apply. `V = ?` pertains to a `BE` bus. `Q=?` pertains to a `B` bus. Warning diagnostics flag these conditions.

4.15.8 PLOT File

Each `/ CHANGE_PARAMETERS` command generates an x,y plot point in a file with subtype `.QVPT`.

The composition of these points is dependent upon the composition of the `CHANGE_PARAMETERS` command. Table 4-6 summarizes the output.

Table 4-6 CHANGE_PARAMETERS Values in .QVPT File

Set Point	Monitored Point	X Value	Y Value
V=<##>	Q=?	Q	V
Q=<##>	V=?	Q	V
P=<##>	Q=?	Q	P
P=<##>	V=?	P	V
%P=<##>	V=?	P_Load	V
%P=<##>	Q=?	P_Load	Q
%Q=<##>	V=?	Q_L0ad	V
%Q=<##>	Q=?	Q_Load	Q

Each line in the `QVPT` file is interpreted in the `.PFO` (power flow output) file.

Example

```
PLOT POINT 3 X (Q) = ####   Y (V) = ####
```

This statement says point X_3 pertains to Q and Y_3 pertains to V.

4.15.9 User Analysis

To circumvent the limitations of monitoring a single bus's V or Q, additional quantities may be monitored using a user-defined analysis file defined with the `/ USER_ANALYSIS` command.

The user analysis file is processed for each encountered `/ CHANGE_PARAMETERS` command. Its output is appended into an output file with subtype .`USR_REPORT`

4.15.10 Example 1

```
/ CHANGES,FILE= *
.
/ CHANGE_BUS_TYPES,BQ=B,BQ=BQ,BX=B,LTC=OFF,AREA=NORTHWEST
.
/ SOLUTION
.
/ CHANGE_PARAMETERS, BUS = RAVER    500., VY = 1.065, QX = ?
/ CHANGE_PARAMETERS, BUS = RAVER    500., VY = 1.060, QX = ?
/ CHANGE_PARAMETERS, BUS = RAVER    500., VY = 1.055, QX = ?
.
.
.
/ CHANGE_PARAMETERS, BUS = RAVER    500., VY = 1.000, QX = ?
(END)
```

In this example, buses in area `NORTHWEST` with types `BQ`, `BG`, and `BX` were changed to bring about a freeze in voltage control. The `/ SOLUTION` command is a dummy command, introduced to illustrate the position of the pure `/ CHANGE_PARAMETERS` commands. If the bus name following the `BUS =` keyword has imbedded blanks, insert a # (pound sign), for example, `BELL#BPA`.

At the conclusion of an ordinary successful solution, the `/ CHANGE_PARAMETERS` records are processed, one by one. The first encounter will internally change the bus type of `RAVER 500` to `BE`, if it is another type, and set its voltage to `V=1.065` p.u. The perturbation will force a new Newton-Raphson solution. The `Q` of `RAVER` is monitored. Its perturbed solved values will be printed out.

Subsequent `/ CHANGE_PARAMETERS` commands will perform additional perturbations.

4.15.11 Example 2

```
/ USER_ANALYSIS,FILE=DRB2:[EOFBMJL]USANLINE.DAT
/ CHANGE_BUS_TYPES, BQ=B,BX=B,BG=BQ,LTC=OFF,AREA=NORTHWEST,BC-HYDRO
/ CHANGE,FILE= *
.
.   THIS CASE MODELS THE P-V CURVE FOR THE POST TRANSIENT
.   CONDITIONS FOLLOWING
.   LOSS OF THE COULEE - RAVER #1 500 kV LINE.
.   INSTALL LINE DROP COMPENSATORS ON COULEE
.   500 UNITS AND JOHN DAY
.   AND ALL DALLES UNITS (EXCEPT 115 kV) AND
.   BONNEVILLE (EXCEPT 115 kV)
.   AND CENTRALIA AND CHIEF JOE
.   300 MVAR SVC AT KEELER AND MAPLE VALLEY
.
BGM   CENTRALA20.0
BGM   BONN PH213.8
.
/ GEN_DROP, INIT=75,AREA=NORTHWEST,BC-HYDRO
B       LIBBY    13.8,   PMIN= 289.2,  PMAX=289.2
.
/ SOLUTION
>AI_CONTROL=MON
.
.MONITOR RAVER 500 VOLTAGE AND INCREASE ZONE NA LOAD
.
/ CHANGE_PARAMETERS, BUS = RAVER    500., V = ? -
                          %LOAD_CHANGE  %P = 0.5, %Q = 0.5, ZONES = NA
/ CHANGE_PARAMETERS, BUS= RAVER     500.,  V= ? -
                          %LOAD_CHANGE  %P = 0.5, %Q = 0.5, ZONES = NA
/ CHANGE_PARAMETERS, BUS= RAVER      500., V= ? -
                          %LOAD_CHANGE  %P = 0.5, %Q = 0.5, ZONES = NA
.
.
(END)
```

4.15.12 Miscellaneous Notes

If the system is severely perturbed, `/ CHANGE_PARAMETERS` will cause divergence. If this happens, it is assumed that subsequent perturbations will be severe, so divergence will cause them to be ignored. A diagnostic will be issued.

4.16 CHANGES

```
/ CHANGES, FILE = file_name
```

This command introduces system data change records. Column 3 on all bus, branch, area interchange and area intertie records contain a change code:

blank	Add.
`M`	Modify (non-blank fields are changes).
`D`	Delete.
`R`	Restore (previously deleted, available only on `(NEXTCASE)` runs).

The following is a list of some specialized change commands.

`DA`	Delete all buses within named areas.
`DZ`	Delete all buses within named zones.
`PO`, `PZ`, `PN`, `PA`	Perform percentage changes according to type.

`FILE` is optional. If included, records in that file will be processed before any additional change records, which may be in the input stream.

4.17 COMMENT

```
/ COMMENT
```

This command introduces comment records into the output report. The comments will appear at the beginning of some output listings. The "/COMMENT" command is optional; all "C" comments in the BPF control file will be processed.

Comment text must have a `C` in column 1. Up to 20 comment records are permitted. Comment text is put in columns 2-80. Comments are saved in any `NEW_BASE` file for use when getting a plot.

When BPF loads a base file, any previous comments are deleted, then all comments in the BPF control file are added. The result is that only the comments in the BPF control file are saved.

4.18 COMMON_MODE_ANALYSIS

```
/COMMON_MODE_ANALYSIS, BASE_FILE = <base_file_name>, -
                       COMMON_MODE = <common_mode_file>, -
                       OUTAGE_FILE = <outage_file>, -
                       OUT_FILE = <output_file>
```

This command combines features of a common mode file used in the CFLOW program PVCurve with the output reports used in the Outage Simulation program, in effect emulating a "slow outage" program. It was written specifically to accept the PVCurve input file without modification.

The outages, defined as MODE within the script in the `COMMON_MODE` file, typically consists of a sequence of commands `/CHANGE_BUS_TYPES, /CHANGES, /SOLUTION`, and `/GEN_DROP`. The mode itself is defined by name on a leading >MODE record; its composition is defined with the change records following a /CHANGES command.

At the end of each >MODE set contaiined within the file named in the COMMMON_MODE command, the solution results (or divergence state) are analyzed: line overloads and bus under/over voltages are written to the user-specified output file in the same format for the OUTAGE_SIMULATION program.

The capability to restrict the analyzed output to subsystems defined with base kV's and zones as is now done in the OUTAGE_SIMULATION program also exists in this feature. That is the purpose of the OUTAGE_FILE. The OUTAGE_FILE is a bone fide OUTAGE_SIMULATION file which processes only two of its commands: `>OVERLOAD` and `>OUTAGE`. All others are ignored. (The >OUTAGE command is used only if the >OVERLOAD commnad is missing and becomes a clone of an implied >OVERLOAD command.)

4.18.1 Description of Operation.

Three phases are involved.

1. Initialization phase. The /COMMON_MODE_ANALYSIS record is parsed and the relevant input and output files are opened.
2. The mail loop to process >MODE records. The base case in residence is reloaded and the associated processes within the >MODE set are processed exactly in the manner performed in the batch powerflow program. At the conclusion of a solution the output results (line overloads, bus under/over voltages, and any solution divergence) are tabulated in interrnal arrays.
3. At the conclusion of the last > MODE command, the tabulated results are cross-compiled and outputted exzactly in the form as is none in the OUTAGE_SIMULATION program.

4.19 F_ANALYSIS_RPT

```
/ F_ANALYSIS_RPT , LEVEL =4 , *
                          1   ZONES = <list>
                          2   OWNERS = <list>
                          3
```

This command requests that an analysis report for selected zones or owners be added to the microfiche output file. Note that a separate command `[FICHE]` must be present in order to save anything on microfiche, regardless of printer and analysis options selected.

When `<list>` is blank, asterisk, or null, `ALL` is assumed unless limited by a preceding statement.

The level number determines the analysis summaries to be displayed.

For `LEVEL=1`, the following summaries are included:

- User-defined analysis (optional).
- Buses with unscheduled reactive.

For `LEVEL=2`, the following are displayed with summaries for `LEVEL=1`:

- Total system generations and loads by owner.
- System generations, loads, losses and shunts by zones.
- Undervoltage-overvoltage buses.
- Transmission lines loaded above XX.X% of ratings.
- Transformers loaded above XX.X% of ratings.
- Transformer excited above 5% over tap.
- Transmission system losses.
- BPA industrial loads.
- dc system.
- Shunt reactive summary.
- Summary of LTC transformers.
- Summary of phase-shifters.
- Summary of %Var-controlled buses.
- Summary of type BX buses.
- Summary of adjustable Var compensation.

- Transmission lines containing series compensation.

For `LEVEL=3,` the following is displayed in addition to the `LEVEL=2` output:

- Bus quantities.

For `LEVEL=4`, the following are displayed in addition to the `LEVEL=3` display:

- Spinning reserves.
- Transmission line efficiency analysis. Lines loaded above XX.X% of nominal ratings.
- Transformer efficiency analysis. Total losses above X.XX% of nominal ratings.
- Transformer efficiency analysis. Core losses above X.XX% of nominal ratings.

4.19.1 Example

```
/ F_ANALYSIS_RPT, LEVEL=4, OWNERS= BPA,PGE,PPL,WPS
/ P_ANALYSIS_RPT, LEVEL=1, ZONES = NA, NB, NC
/ F_ANALYSIS_RPT, LEVEL=4, *
/ P_ANALYSIS_RPT, LEVEL=1, ZONES = *
```

4.20 F_INPUT_LIST

```
/ F_INPUT_LIST, FULL,  ERRORS = NO_LIST
                NONE            LIST
                ZONES = <list>
                ZONES = ALL, FULL or NONE
```

This command lists input data on `FICHE`. Output can be restricted to individual zones specified in `<list>` and separated with commas. Note that `FULL` or `NONE` may be specified in two forms.

The `ERRORS` option is set to suppress the input fiche if any fatal (F) errors are encountered. This is the default. It can be overridden by setting `ERRORS = LIST`.

4.21 F_OUTPUT_LIST

```
/ F_OUTPUT_LIST, FULL, FAILED_SOL = FULL_LIST
                 NONE               PARTIAL_LIST
                 ZONES = <list>     NO_LIST
                 ZONES = ALL, FULL or NONE
```

This command lists output on FICHE. Output can be restricted to individual zones specified in <list> which are separated with commas. Note that FULL or NONE may be specified in two forms.

The FAILED_SOL option is set to override the output listing if a failed solution occurs. It defaults to a full listing. A PARTIAL_LIST observes zone lists.

4.22 GEN_DROP

```
/ GEN_DROP, ..., INITIAL_DROP=#### ...
```

This feature picks up generation from selected generators to balance generation drop. Generation is dropped in one of two ways:

- By system changes with the amount specified under INITIAL_DROP.
- By PMIN and PMAX limits on selected generators. (These buses are specified with specially formatted B records which follow.)

Generator dropping emulates the short-term characteristics of a system’s response where the generation deficit is automatically picked by other machines. The magnitude is presumed to be proportional to PMAX after the effects of the machine’s transients have damped out.

Candidate generators that pickup are those in the area of interest with a spinning reserve (a surplus of PMAX over PGEN). The pickup of an eligible machine “i” is allocated proportionally by the ratio

```
GEN_PICKUP(i) = PMAX(i) * (TOTAL_DROPPED / TOTAL_PMAX)
```

where TOTAL_DROPPED is the sum of dropped MW, and TOTAL_PMAX is the sum of all candidate machines with spinning reserve.

Some machines may be driven to their PMAX limits during reallocation. In this case, the allocation becomes nonlinear and several iterations may be required.

A detailed list of each command follows.

```
/ GEN_DROP, AI_CONTROL=CON, INITIAL_DROP= ####, TOL=####, -
                      MON
                      OFF
           AREAS=<area_1,...>     Optional. Do not use with ZONE.
           ZONES=<zone_1,...>     Optional. Do not use with  AREA.
```

Note that continuation records are acceptable here.

The individual fields of the GEN_DROP command follow.

4.22.1 Area Interchange Control

If generation dropping and allocation occurs over several areas, intertie flows may be substantially affected, and it is recommended to change the area interchange from control to monitor unless the new interchange schedule is known.

```
AI_CONTROL = CON :      Control area interchange.
```

```
OFF :      Turn off area interchange.
MON :      Monitor area interchange.
```

Note: One other command also affects area interchange control, the `>AI_CONTROL` option on the `/SOLUTION` record. If this follows the `/GEN_DROP` command above, it may overwrite the selected option.

4.22.2 Initial Dropped Generation

This is necessary if the dropped generators are deleted or modified in a change case.

```
INITIAL_DROP = ####
```

The field #### denotes the numerical values in MW.

Initial dropped generation may be specified in an alternate method, called the "computed dropped generation."

4.22.3 Tolerance

Generation reallocation continues until the mismatch between generation dropped and generation pickup is less than the tolerance. The default value is 10 MW.

```
TOL = ####
```

The field #### denotes the numerical values in MW.

4.22.4 Areas or Zones

The generation to be picked up may be either system-wide (the default) or restricted to a set of areas or zones.

```
AREAS = <area_1,...>
```

or

```
ZONES = <zone_1,...>
```

The individual areas are separated with a comma (,). If the area name contains a blank, temporarily replace the blank field with a pound sign (#). Continuation records may be employed for aesthetics.

For example,

```
AREAS =NORTHWEST, -
   BC-HYDRO, -
   IDAHO, -
```

```
MONTANA, -
TRANSALTA, -
WKOOTENAY
```

4.22.5 Exclude Buses

Means are available to contract the system or subsystem defined in the /GEN_DROP command. Individual buses may be excluded from participating in generator pick-up. These buses are selected with the following command:

```
>EXCLUDE_BUS
B  name   base
B  name   base
```

4.22.6 Selected Generators To Be Dropped

The amount of generation is defined as the sum of INITIAL_DROP plus the computed generation to be dropped. The computed generation drop is the amount of violation of P-limits on all specified buses:

```
PMIN  < PGEN  < PMAX
```

Obviously, only area and slack buses and AGC candidates permit the P-generation to change. Limits can be placed on these buses by specifying a + or - tolerance, or a Pmin and Pmax (in MWs). Examples:

```
B      MORRO 4 18.0, TOL = 20
B      MORRO 4 18.0, PMIN = 147, PMAX = 167
```

PMIN keeps slack buses within a narrow range. The special B records introduce these limits explicitly. This is illustrated with the following example:

If the key words PTOL, PMIN, or PMAX are omitted, PMAX is taken from the PMAX field on the original or changed bus data record. Recall that on the bus record there is no corresponding field for PMIN. Consequently, PMIN = 0.0. At least one B record must be present.

4.22.7 Example

```
( POWERFLOW, ...)
...
...
/ CHANGES, ...
...
... (changes which drop 2450 MW of generation in the Northwest)
...
/ GEN_DROP, AI_CONTROL=MON, TOL=1.0, INIT=2450
BX    MORRO 4   18, PMIN = 147, PMAX = 167
```

```
/ SOLUTION
( END )
```

Note: `MORRO 4` is held between 147 and 167 MWs. Dropping 2450 MWs and picking it up elsewhere will change the generation flows and, quite likely, will alter the system losses. The system slack bus accommodates these changes in losses.

4.23 HEADER

```
/ HEADER
```

This command introduces one or two header records into the pagination. Its text will be repeated on the top of each page in the output report. Each header record begins with an `H` in column 1. It is used to supply the lines of text that will be printed at the top of every page of an output listing, below the standard header1, which contains the caseid, project, program version, and date. These header records are saved in the base case file, and any previous headers are deleted. This is similar to the `/COMMENT` command. See Figure 4-4.

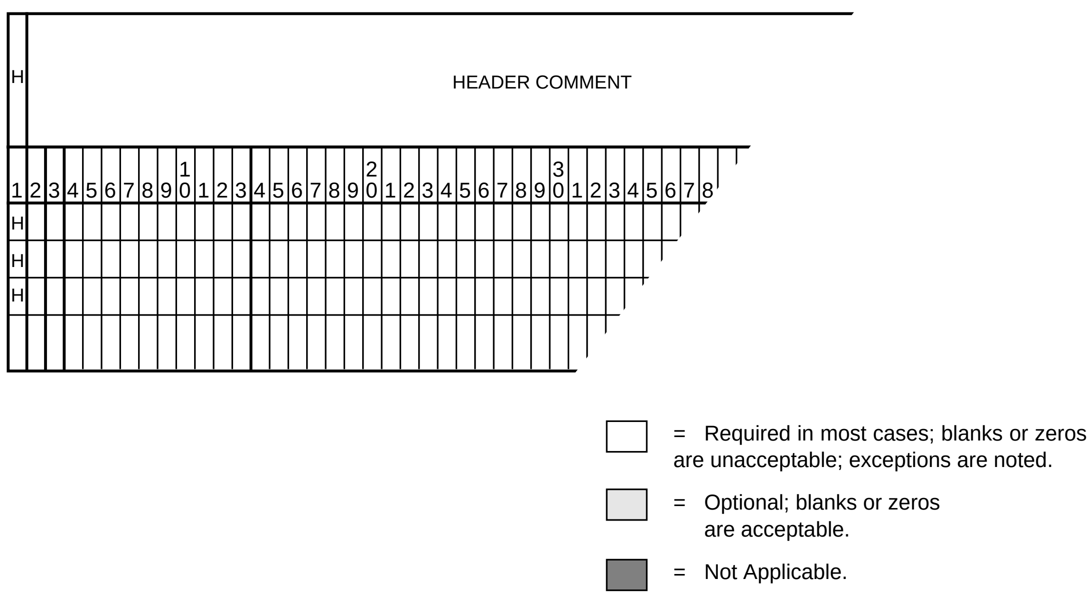


Figure 4-4 Header Comment Input Format

4.24 INCLUDE_CONTROL

```
/ INCLUDE_CONTROL, file = <filespec>
```

This command permits the input stream containing commands to be temporarily diverted to the named file. Following an end-of-file, control reverts to the normal input stream.

Some restrictions apply. This "included" command file cannot contain any of the following commands:

`/ INCLUDE_CON` statement
`/ MERGE_BASE` statement
`/ OUTAGE_SIM` statement
`/ REDUCTION` statement
`/ CHANGES` statement

4.25 LINE_EFF

```
/ LINE_EFF, LOADING = <nn>, OWNERS = <list>
```

Use this command to list lines that are loaded above the prescribed `LOADING`. The output can be filtered by owners. `BPA` is the default if no owners are specified.

4.26 LINE_SENSITIVITIES

```
/ LINE_SENSITIVITIES
```

Note: Three commands are dependent on the `SOLUTION` command. The commands are `CHANGE_PARAMETERS`, `LINE_SENSITIVITIES`, and `LOSS_SENSITIVITIES.` These three work correctly only if they immediately follow the `SOLUTION` command.

Line sensitivities relate line immittances (impedance or admittance) to voltage, real power flow, and system losses. Six types are available.

dP_{ij}/dX_t	Change in lineflow P_{ij} with respect to change in transfer reactance X_t.
dP_{ij}/dB_s	Change in lineflow P_{ij} with respect to change in shunt susceptance B_s.
$dLoss/dX_t$	Change in system losses with respect to a change in transfer reactance X_t.
$dLoss/dB_s$	Change in system losses with respect to a change in shunt susceptance B_s.
dV_i/dX_t	Change in bus voltage (V_i) with respect to a change in transfer reactance X_t.
dV_i/dB_s	Change in bus voltage (V_i) with respect to a change in shunt susceptance B_s.

The change in transfer reactance `X_t` or shunt susceptance `B_s` pertains to an existing line. The command statement which invokes line sensitivities is

```
/ LINE_SENSITIVITIES, LTC =ON, AI_CONTROL = CON
                           OFF              MON
                                            OFF
```

The top line depicts default quantities. The options `LTC` and `AI_CONTROL` pertain to LTC transformers and area interchange control.

The second part of the sensitivities is the perturbed quantities dX_t or dB_s. They are defined with specially formatted `>` records and are similar to `L` records. See Table 4-7.

Table 4-7 Line Sensitivities

Columns	Format	Description
(1:3)	A3	>PB: dP_{ij}/dB_s or dP_{ij}/dX_t

Table 4-7 Line Sensitivities

Columns	Format	Description
		>LB: dLoss/dB_s or dLoss/dX_t
		>VB: dV_i/dB_s or dV_i/dX_t
(7:18)	A8,F4.0	Bus1 name and base kV
(20:31)	A8,F4.0	Bus2 name and base kV
(32)	A1	Circuit Id
(33)	I1	Section number
(45:50)	F6.5	Perturbed X_t
(57:62)	F6.5	Perturbed B_s

A maximum of 50 perturbed quantity > records may be present.

The ambiguity d(.)/dB_s or d(.)/dX_t is resolved by non-zero entities for X_t or B_s. If both are zero, the default is X_t. Non-zero entities define the magnitude of the perturbed quantity Delta__X_t or Delta_B_s. Perturbed flows, losses, or voltages will be computed using these values.

The perturbed branch flows P_ij are identified with the individual `L` records that follow. If parallel lines are present, P_ij pertains to the total of all parallel flows.

The perturbed voltages are the 20 largest excursions effected by the change in immittance. The perturbed losses are a simple quantity. An example setup follows.

```
( POWERFLOW, ...)
...
...
...
/ SOLUTION
...
...
...
/ LINE_SENSITIVITIES, AI_CONTROL=ON, LTC=ON
>PB   RAVER    500 TACOMA   500
L     RAVER    500 TACOMA   500
L     GRIZZLY  500 JOHN DAY 500
L     GRIZZLY  500 MALIN    500
L     HANFORD  500 JOHN DAY 500
L     HANFORD  500 LOW MON  500
```

```
L     HANFORD  500 OSTRNDER 500
L     HANFORD  500 VANTAGE  500
>LB   RAVER    500 TACOMA   500
>VB   RAVER    500 TACOMA   500
>PB   GRIZZLY  500 JOHN DAY 500
L     RAVER    500 TACOMA   500
L     GRIZZLY  500 JOHN DAY 500
L     GRIZZLY  500 MALIN    500
L     HANFORD  500 JOHN DAY 500
L     HANFORD  500 LOW MON  500
L     HANFORD  500 OSTRNDER 500
L     HANFORD  500 VANTAGE  500
( STOP )
```

4.26.1 Notes

The first perturbation `>PB` with blank X_t and B_s fields requests dP_{ij}/dX_t (the default). The individual P_{ij}s are identified with the following `L` records.

The second perturbation `>LB` with blank X_t and B_s fields requests $dLoss/dX_t$ (the default). No `L` records follow because the monitored quantities are system losses.

The third perturbation `>VB` with blank X_t and B_s fields requests dV_i/dX_t (the default). No `L` records follow because the monitored quantities are perturbed voltages. The 20 largest excursions are listed.

4.26.2 Sample Deck Set-up

```
(POWERFLOW,...)
.
.
. / CHANGES
.
.
. / SOLUTION
.
.
.
/ BUS_SENSITIVITIES,LTC=ON,AI_CON=ON,Q_GEN=ON,Q_SHUNT=ON
B    SATSUP  230     -172
B    OLYMPIA 230     -172
/ BUS_SENSITIVITIES,LTC=OFF,AI_CON=OFF,Q_GEN=ON,Q_SHUNT=FIXED
B    SATSUP  230     -172
B    OLYMPIA 230     -172
(END)
```

4.27 %LOAD_DISTRIBUTION

```
/ %LOAD_DISTRIBUTION, DISTRIBUTED_VOLTAGE = NOMINAL_BASE
```

This set of commands automatically converts constant power, constant current, or constant impedance loads to a user-specified distribution of constant MVA, constant current, and constant impedance.

The option `DISTRIBUTED_VOLTAGE` (or `DIST` for abbreviated form) selects either `NOMINAL` (all voltages are 1.0 p.u.) or `BASE`, which is the individual bus's voltage.

4.27.1 Constant Current and Impedance Loads

Constant current loads and constant impedance loads are defined by continuation bus (+) records using reserved `TYPE`s and `CODE_YR`s. Constant impedance loads differ from G_shunt and B_shunt quantities in the sense that these quantities are converted into loads and appear in special analysis summaries. Table 4-8 describes these special codes and their interpretations.

Table 4-8 Special Continuation Bus Types

Type	Owner	CODE_YR	P_LOAD	Q_LOAD	G_SHUNT	B_SHUNT
+A						B_fixed[a]
+A		00				B_fixed
+A		01	P(I)[b]	Q(I)[c]	P(G)[d]	Q(B)[e]
+A		01	P(I)	Q(I)	G_equiv[f]	B_equiv[g]
+A		02			P(G)	Q(B)
		*I	P(I)	Q(I)	P(G)	Q(B)
		*P			P(G)	Q(B)

a. B_fixed = Shunt is pi_back shunt impedance from `/ CUTTING`.
b. P(I) = Power is a function of current (constant current).
c. Q(I) = Reactive is a function of current (constant current).
d. P(G) = Power is a function of shunt G (constant impedance).
e. Q(B) = Reactive is a function of shunt B (constant impedance).
f. G_equiv = Shunt is equivalent shunt impedance from `/ REDUCTION`.
g. B_equiv = Shunt is equivalent shunt impedance from `/ REDUCTION`.

4.27.2 Description of Constant Current Load Model

For expositional purposes, we will call constant current `Aload` and `Bload`. This nomenclature is consistent with the expression for complex current:

```
I  = A + jB
```

The power at a constant current load is computed with the expression

$$P_{load} + j\ Q_{load} = complx(\ V\ )\ *conjg(\ I\ )$$

where `complx(V)` is the complex voltage and `conjg(I)` is the conjugate of the complex current. The use of the conjugate expression is needlessly complicated for this simple application and has been relaxed. The quantity `Bload` is stored as its conjugate, that is, no sign reversal is needed to interpret the correct sign of the load in MVAR.

Let `V` denote the per unit base or nominal voltage magnitude—depending upon the option `DISTRIBUTED_VOLTAGE`. The distributed constant current loads in MW and MVAR are computed as follows:

$$P_{load} = A_{load} * V$$
$$Q_{load} = B_{load} * V$$

Readers may note that this is not true constant current. True constant current loads involve the system phase angle. The modelling here is more lenient: it is constant power factor.

4.27.3 Description of Distribution Factors

Six percentage distribution factors can be specified by the user. The following example illustrates the relation.

```
PLOAD = 50% P +  25% I +  25% Z
QLOAD = 50% Q +  25% I +  25% Z
```

From this command, the following quantities will be defined:

PP (%Constant P_{load}) = 50%
PI (%Constant I_{load}) = 25%
PZ (%Constant Z_{load}) = 25%
QP (%Constant Q_{load}) = 50%
QI (%Constant I_{load}) = 25%
QZ (%Constant Z_{load}) = 25%

There are restrictions; the percentage distributions must be complete.

```
PP + PI + PZ = 100.0
QP + QI + QZ = 100.0
```

This means that if some load is to be unchanged, a value of 100% must be entered for `PLOAD` or `QLOAD`.

The following relations hold at the base voltages:

Constant MVA		Constant MVA		Constant I		Constant Z
P_{load_old}	=	P_{load_new}	+	$A_{load} * V$	+	$G_{shunt} * V^2$
Q_{load_old}	=	Q_{load_new}	+	$B_{load} * V$	--	$B_{shunt} * V^2$

where

$$P_{load\_new}\ (MW) = P_{load\_old}\ (MW) * PL / 100$$
$$Q_{load\_new}\ (MVAR) = Q_{load\_old}\ (MVAR) * QL / 100$$
$$A_{load}\ (MW) = P_{load\_old}\ (MW) * PI / (100 * V)$$
$$B_{load}\ (MVAR) = Q_{load\_old}\ (MVAR) * QI / (100 * V)$$
$$G_{shunt}\ (MW) = P_{load\_old}\ (MW) * PZ / (100 * V^2)$$
$$B_{shunt}\ (MVAR) = --Q_{load\_old}\ (MVAR) * QZ / (100 * V^2)$$

The negative sign for B_{shunt} is correct. The actual expression is

$$P + jQ = conjg\ (Y) * V^2$$

A positive value of G_{shunt} is the same sign as load; a positive value of B_{shunt} is the same sign as generation.

Those buses whose loads can be distributed can be selected either individually or systematically. Individually selected buses require the `> CHANGE_BUSES` command. Systematically selected buses require the `> CHANGE_SYSTEM` command.

4.27.4 Systematically Selected Buses

```
> CHANGE_SYSTEM, PLOAD  = ##% P + ##% I + ##% Z, -
                 QLOAD  = ##% Q + ##% I + ##% Z, -
                 AREAS  = area_1. ...,
                 ZONES  = zones_1, ...,
                 OWNERS = owner_1,
> EXCLUDE_BUSES
B      name    base
B      name    base
B      name    base
```

This example redistributes constant power loads according to the specified percentages.

The redistributed constant current and constant impedance loads are transferred to a new +A01 continuation bus record. The redistributed constant power loads replace the original constant power load.

A special feature has been added to redistribute constant current and constant impedance loads that already have been distributed. As such, these loads are restricted to +A01 and +A02 continuation bus records. Table 4-9 describes these options.

Table 4-9 Constant Power, Current, and Impedance Keywords

Type of Load to Convert	Keyword for Real Part	Keyword for Reactive Part
Constant Power	PLOAD =	QLOAD =
Constant Current	ALOAD =	BLOAD =
Constant Impedance	RLOAD =	XLOAD =

For example, to change constant current loads, the following commands are used:

```
> CHANGE_SYSTEM, ALOAD = ##%  P + ##% I + ##% Z, -
                 BLOAD = ##% Q + ##% I + ##% Z, -
```

The network affected by the specified load change percentages can be restricted to buses within a given subsystem. This subsystem can be defined by those buses having common attributes in two sets:

```
{ AREAS, OWNERS }
```

or

```
{ ZONES, OWNERS }
```

`ZONES` and `AREAS` are mutually exclusive; only one of the above can be specified.

If no owners are specified, all ownerships are implied. The selected subsystem can be further defined by excluding specific bases with the `>EXCLUDE` option.

More than one set of `CHANGE_SYSTEM` commands is permitted. This would permit buses in different areas or zones to have different percentage distribution factors. In case of overlap, precedence is given to the first definition.

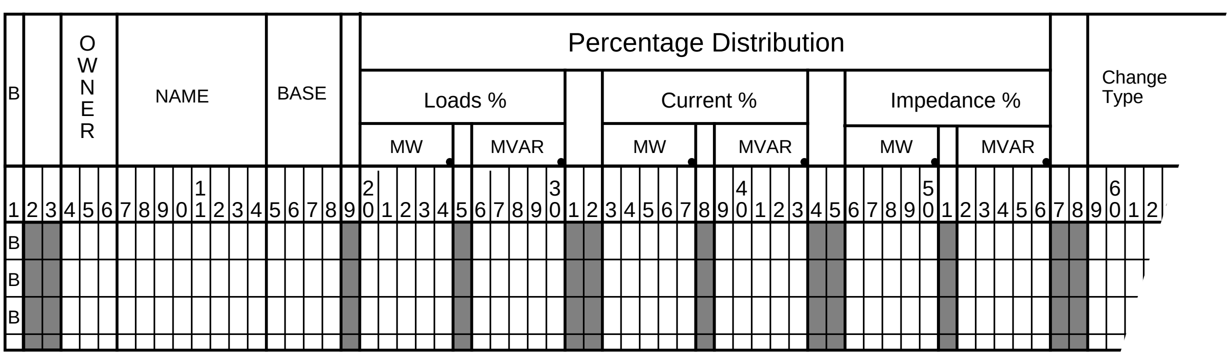
4.27.5 Individually Selected Buses

```
> CHANGE_BUSES, CHANGE_TYPE = PLOAD
                              ALOAD
                              RLOAD
B    ownname    base    ####  ####   ####  ####   ####  ####  PLOAD
B    ownname    base    ####  ####   ####  ####   ####  ####  ALOAD
+x   ownname    base yr ####  ####   ####  ####   ####  ####
+x   ownname    base yr ####  ####   ####  ####   ####  ####
```

This command permits unique distribution factors to be specified for individual buses. The buses and their distribution factors are identified on fixed field records. The format of the B % load change record is shown in Figure 4-5. `CHANGE_TYPE` is optional. `ALOAD` and `RLOAD` have the same interpretation given in Table 4-8. Thus, they would apply to `+` records, but not to `B` records.

If the ownership field is blank or includes the bus ownership, the percentages apply only to data on the bus `B` record. Continuation bus data will not be affected.

On the other hand, if the ownership is the magic code ###, the percentages apply to data on the bus `B` record and also to data on all associated continuation bus records.



=Required in most cases; blanks or zeros are unacceptable; exceptions are noted.

=Optional; blanks or zeros are acceptable.

Figure 4-5 CHANGE_BUS % Load Input Format for B Records

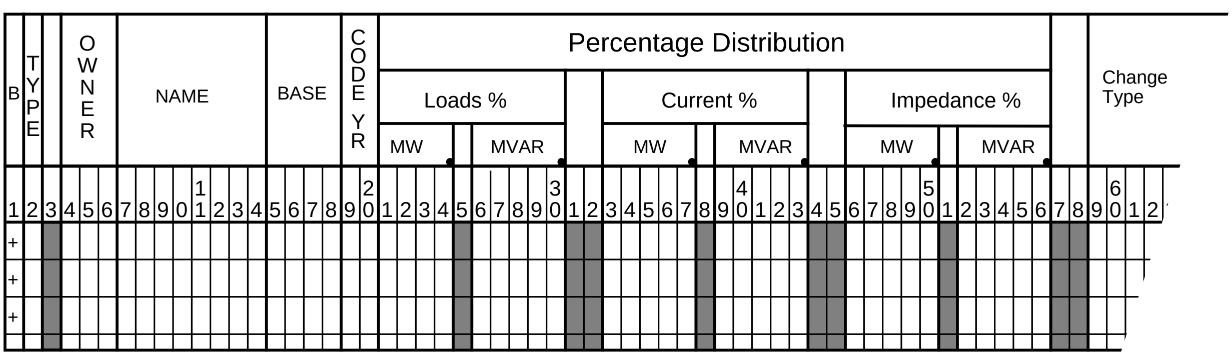
If separate % changes are to apply to bus and continuation bus records, separate + % change records must be used—one for the bus B record and others for the specific + bus records.

The identification fields for + % bus records are identical to those for the + records as in Table 4-10.

Table 4-10 Identification Fields for +% Records

Column	Quantity
1	+
2	Type
3- 6	Ownership
7-18	Bus Name and Base kV
19-20	Code Year

The format of the + % load change records is shown in Figure 4-6.



=Required in most cases; blanks or zeros are unacceptable; exceptions are noted.

=Optional; blanks or zeros are acceptable.

Figure 4-6 CHANGE_BUS % Load Input Format for + Records

Wildcards are permitted in these fields: `TYPE, OWNER`, and `CODE_YR`. The wild card character(s) for those fields are #, ###, and ## respectively.

The percentages apply to the distribution of `QLOAD` and `PLOAD` to `ALOAD` and `BLOAD`, or to `RLOAD` and `XLOAD`. They must total 100% each.

If an overlap occurs with the `CHANGE_SYSTEM` command, precedence is given to the individually specified buses.

A maximum of 2000 buses may be specified. Once identified, that bus will be unaffected by any subsequent commands.

Example 1.

`PLOAD`, `QLOAD` distributions applied to a bus record. See Figure 4-7.

```
PLOAD = % PL + % PI + % PZ
QLOAD = %QL + % QI + % QZ
```

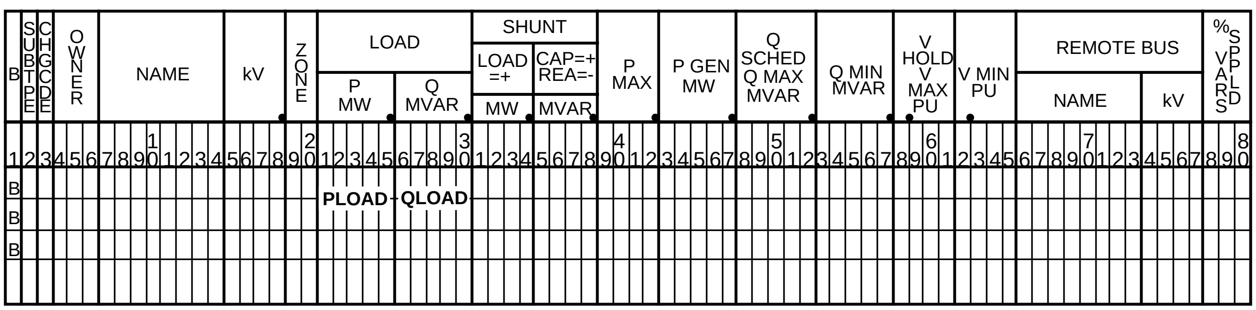


Figure 4-7 Original B Record

1. Remove `PLOAD` and `QLOAD` quantities from bus record above.
2. Calculate the following quantities:

```
P1 = PLOAD * %PL
Q1 = QLOAD * %QL
P2 = PLOAD * %PI  / VOLTAGE
Q2 = QLOAD * %QI / VOLTAGE
P3 = PLOAD * %PZ / VOLTAGE ** 2
Q3 = QLOAD * %QZ / VOLTAGE ** 2
```

3. Replace the load and shunt fields on the `B` record and on a new `+A*I` record.

Modified B record and new `+A*I` record. See Figure 4-8.

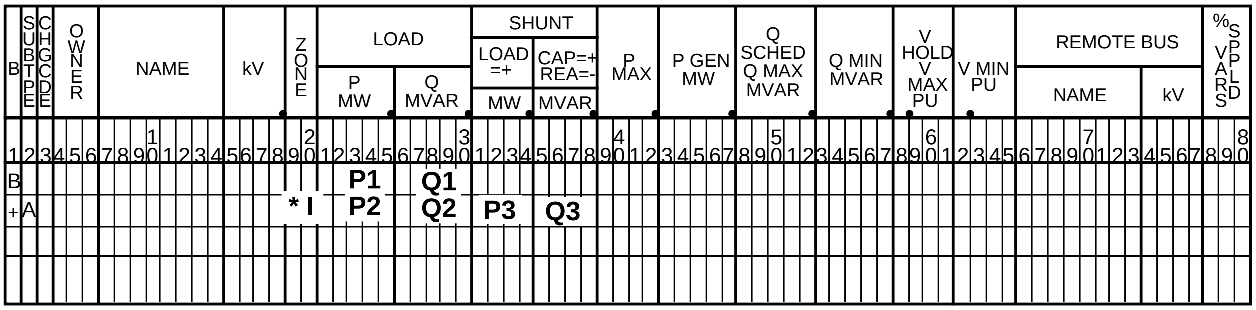


Figure 4-8 Modified B Record

Example 1

`ALOAD`, `BLOAD` distributions applied on a +X*P bus record.

```
ALOAD = %PL + %PI + %PZ
BLOAD = %QL + %QI + %QZ
```

Note that `ALOAD` and `BLOAD` quantities are generated by prior `%LOAD_DISTRIBUTION`. Thus, this record corresponds to a + record having the same `TYPE` and `CODE_YEAR`. See Figure 4-9.

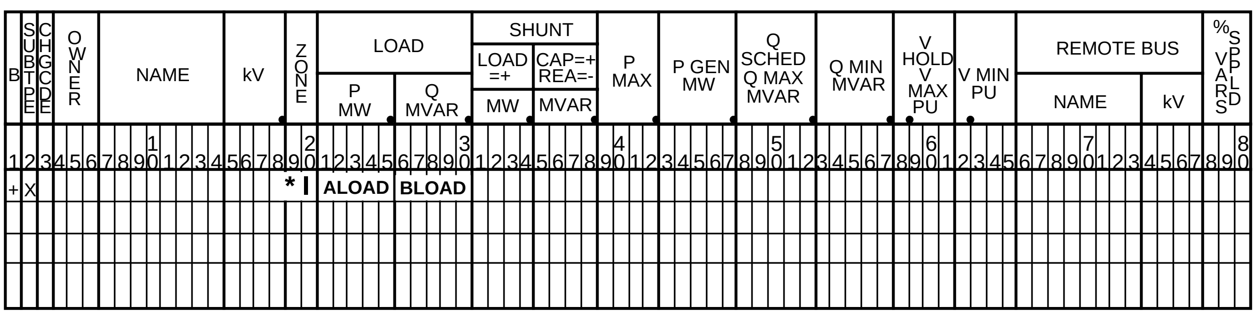


Figure 4-9 Original Continuation (+) Record

1. Remove `ALOAD` and `BLOAD` quantities from the `+X*I` record above. Note that these quantities are constant current. Convert them into constant power:

   ```
   PLOAD = ALOAD * %PL VOLTAGE
   QLOAD = BLOAD * %PL VOLTAGE
   ```

2. Calculate the following quantities:

```
P1 = PLOAD * %PL
Q1 = QLOAD * %QL
P2 = PLOAD * %PI  / VOLTAGE
Q2 = QLOAD * %QI / VOLTAGE
P3 = PLOAD * %PZ / VOLTAGE ** 2
Q3 = QLOAD * %QZ / VOLTAGE ** 2
```

3. Replace the load and shunt fields on the original + record and the load fields on the original type `+X` record.

Modified `+X*I` record and new `+A*P` record. See Figure 4-10.

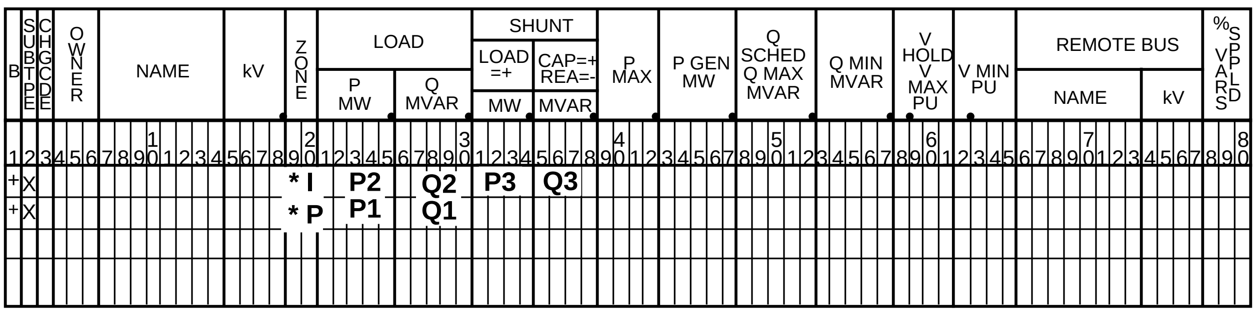


Figure 4-10 Modified Continuation (+) Record

4.27.6 Limitations, Restrictions, and Assumptions

The load distribution is presumed to apply to a solved base case. At the base solution, the total load in MWs and MVARs is unchanged after distribution. If the system is not otherwise changed, the solution should converge to the base solution.

Each nonzero load on a bus or continuation bus record generates an associated constant current and constant impedance load on an equivalent `+A*I` continuation bus record.

The continuation bus array is currently dimensioned for 3360 records.

The number of generated `+*I` and `+*P` records in a typical base case averages 400 (assuming one for each continuation bus) plus one for each number of nonzero load on the bus records.

BPA's Transient Stability Program in its present form cannot accommodate the Powerflow model of constant current loads.

4.28 LOAD_GE

`/LOAD_GE, FILE=<file_name>`

This command imports an ASCII coded GE-formatted network data file

4.28.1 LOAD_GE qualifiers.

`REFFILE=<reference_file_name>`

This qualifier introduces a reference base case from which to derive missing ownership and mileage information. The GE data set is potentially richer in content than IPF's base data file, but maybe incomplete if some optional data fields such as mileage or ownerships are omitted.

`VERSION=<nnn>`

This qualifier defines the version number of the input data. At present, only version 21 is recognized.

`RATINGS=(TX=AABC, LN=AAC)`

This option correlates the various GE branch ratings with the IPF branch ratings. Four GE transformer ratings (RATEA, RATEB, RATEC, RATED) can be assigned independently to the IPF transformer ratings in the following order -- Nominal, Thermal, Emergenty, and Bottleneck, Simarily, three GE line ratings (RATEA, RATEB, RATEC) can be assigned independently to the IPF line ratings in the following order -- Nominal, Thermal, and Bottleneck.

The default branch IPF ratings, shown in the example above, are assigned per Table 4-11 .

Table 4-11 Default Branch Rating Assignments

Branch	IPF Rating	GE Rating
Transformer	Nominal	RateA
	Thermal	RateA
	Emergency	RateB
	Bottlenect	RateC
Line	Nominal	RateA
	Thermal	RateA
	Bottlenect	RateC

`LTC=RANGE`

This option defines the remotely controlled bus' voltage assignments in the form of bus type and scheduled voltage. Table 4-12 describes all options.

Table 4-12 Remotely controlled bus assigned voltages

Type	Conditional bus type	Action taken
HIGH		vmax = vmax_ge vmin = vmax_ge Bb -> BT
AVERAGE		vmax = 0.5 * (vmax_ge + vmin_ge) vmin = 0.5 * (vmax_ge + vmin_ge) Bb -> BT
LOW	BQ	vmax = 0.5 * (vmax_ge + vmin_ge) vmin = 0.5 * (vmax_ge + vmin_ge)T
LOW	All other types	vmax = vmax_ge vmin = vmin_ge
RANGE	Bb	vmax = vmax_ge vmin = vmin_ge
RANGE	All other types	vmax = 0.5 * (vmax_ge + vmin_ge) vmin = 0.5 * (vmax_ge + vmin_ge)

4.29 LOAD_PTI

`/LOAD_GE, FILE=<file_name>`

This command imports an ASCII coded PTI-formatted network data file

4.29.1 LOAD_PTI qualifiers.

`REFFILE=<reference_file_name>`

This qualifier introduces a reference base case from which to derive missing ownership and mileage information.

`VERSION=<nnn>`

This qualifier defines the version number of the input data. At present, only version 3 and 4 are recognized.

`RATINGS=(TX=AABC, LN=AAC)`

This option correlates the various PTI branch ratings with the IPF branch ratings. Four PTI transformer ratings (RATEA, RATEB, RATEC, RATED) can be assigned independently to the IPF transformer ratings in the following order -- Nominal, Thermal, Emergenty, and Bottleneck, Simarily, three PTI line ratings (RATEA, RATEB, RATEC) can be assigned independently to the IPF line ratings in the following order -- Nominal, Thermal, and Bottleneck.

The default branch IPF ratings, shown in the example above, are assigned per Table 4-11 .

Table 4-13 Default Branch Rating Assignments

Branch	IPF Rating	PTI Rating
Transformer	Nominal	RateA
	Thermal	RateA
	Emergency	RateB
	Bottlenect	RateC
Line	Nominal	RateA
	Thermal	RateA
	Bottlenect	RateC

`LTC=RANGE`

This option defines the remotely controlled bus’ voltage assignments in the form of bus type and scheduled voltage. Table 4-12 describes all options.

Table 4-14 Remotely controlled bus assigned voltages

Type	Conditional bus type	Action taken
HIGH		vmax = vmax_pti vmin = vmax_pti Bb -> BT
AVERAGE		vmax = 0.5 * (vmax_pti + vmin_pti) vmin = 0.5 * (vmax_pti + vmin_pti) Bb -> BT
LOW		vmax = vmin_pti vmin = vmin_pti Bb -> BT
RANGE	Bb	vmax = 0.5 * (vmax_pti + vmin_pti) vmin = 0.5 * (vmax_pti + vmin_pti)
RANGE	All other types	vmax = 0.5 * (vmax_pti + vmin_pti) vmin = 0.5 * (vmax_pti + vmin_pti)

4.30 LOSS_SENSITIVITIES

`/ LOSS_SENSITIVITIES`

> *Note:* Three commands are dependent on the `SOLUTION` command. The commands are `CHANGE_PARAMETERS`, `LINE_SENSITIVITIES`, and `LOSS_SENSITIVITIES.` These three work correctly only if they immediately follow the `SOLUTION` command.

This feature provides valuable information concerning system losses with respect to scheduled active and reactive generation or loads, and to scheduled voltages. The command statement that invokes loss sensitivities is

```
/ LOSS_SENSITIVITIES,LTC=ON,   AI_CONTROL=CON, Q_SHUNT=ADJ, -
                         OFF,              OFF          FIXED

                    QGEN=ADJ, -
                         FIXED

                    AREAS=<area1,area2,...>,
                    ZONES=<zone1,...>
```

The top line depicts default quantities. The options `LTC`, `AI_CONTROL`, and `Q_SHUNT` pertain to LTC transformers, area interchange control, and B_shunt on type `BQ` buses.

Three loss sensitivities are computed: $dLoss/dP_i$, $dLoss/dQ_i$, and $dLoss/dV_i$.

These sensitivity computations are linearized about the solved case. For small changes, the sensitivities are extremely accurate. For larger changes, non-linearities redefine the problem. A rule of thumb is that the sensitivities are sufficiently accurate for a 0.5 per unit (p.u.) change in P_i or Q_i, and a 0.01 p.u. change in V_i.

Each sensitivity relates changes in the system losses to a hypothetical change of 1.0 p.u. in scheduled active generation P_i, reactive generation Q_i, or voltage V_i.

Ordinarily, a decrease in system losses is anticipated when P_i, Q_i, or V_i increases, that is, a negative loss sensitivity.

4.30.1 dLoss/dP$_i$

An exception often occurs for dLoss/dPi. Occasionally, $dLoss/dP_i > 0$, that is, increasing the generation P_i increases the losses!

Recall the constraint for `Area_i`:

Area export = Area generation - Area load - Area losses

(Any active bus shunt "G" is presumed to be accounted for in area losses.)

Within each area, the generation on the slack bus is adjustable and on all other generators is fixed. Thus, a change of 1.0 p.u. on generator "i" causes two changes in the area slack bus:

- An immediate transfer of -1.0 p.u. to balance the change in generation.
- An additional change to reflect the change in system losses, which are affected by the 1.0 p.u. generation transfer.

Note that the system slack bus or area interchange slack bus must pick up any deficit generation needed to supply loads and system losses. Thus, the sensitivity reflects the change in losses if 1.0 p.u. MW of generation is moved from bus "i" to the system or area slack bus. If the system or area slack bus is closer to the load center, the losses will decrease with the reallocation. Consequently, dLoss/Dpi < 0. Otherwise, the losses will increase.

4.30.2 dLoss/dQ$_i$

A change in reactive generation is quite different from a change in active generation. Changes in reactive generation strongly affect the voltage profile of the system adjacent to bus "i". Thus, a change in losses is due primarily to the change in voltage profile.

4.30.3 dLoss/dV$_i$

A change in scheduled voltage for types `BE`, `BS`, `BQ`, or `BG` buses directly affects the voltage profile of the system adjacent to bus "i". Thus, the change in voltages directly affects system losses. In general, higher voltages are accompanied with lower branch currents and hence, lower line losses. Exceptions may occur in cables where large amounts of inductive shunt are necessary to compensate for the capacitance in cable.

4.31 MERGE_OLD_BASE and MERGE_NEW_BASE

`/ MERGE_OLD_BASE` and `/ MERGE_NEW_BASE`

These subprocesses extract a subsystem from an old base file and merge it with another subsystem to generate a new system. The subsystems are defined by various qualifiers following the MERGE command.

```
/ MERGE_OLD_BASE,SUBSYSTEM_ID= <subsystem_label>,
  OLDBASE_FILE = <file_spec>
```

and

```
/ MERGE_NEW_BASE,SUBSYSTEM_ID = <subsystem_label>,
        BRANCH_DATA_FILE = <file_spec>, DATE = <myy>,
        R = <n>, BUS_DATA_FILE = <file_spec>
```

where:

- `file_spec` is the file specification for the pertinent file. If `file_spec` has the value `*` for either the `BUS_DATA_FILE` or `BRANCH_DATA_FILE`, the data is presumed to be the Powerflow command file.
- `subsystem_label` is the identifying label for the merged subsystem.
- `DATE` is the branch extraction date. Branches selected will have their energization date on or before `DATE` and a de-energization date after `DATE`.
- The month field (as a digit) also defines winter or summer extended ratings:

  `m = 1` selects winter peak ratings.
  `m = 8` selects summer peak ratings.

  See Table 4-11 for the complete listing.

- For other values, it is necessary to use an additional parameter `R` defined in the next section.
- `R` specifies extended ratings from the branch data file. See Table 4-15 and Table 4-16. Also, see Figure 4-11 and Figure 4-12. Two modes of operation are available:
  - Merge a subsystem from one `OLD_BASE` file with another subsystem from a different old base file.
  - Merge a subsystem from an `OLD_BASE` file with another subsystem which is newly created from bus and branch records.

The two merge control cards distinguish the source of the subsystem data. `/ MERGE_OLD_BASE` identifies an `OLD_BASE` file, and `/ MERGE_NEW_BASE` identifies the bus and branch records files from which a new subsystem will be constructed.

The `R` code indicates which extended ratings from the branch data file should be used. For example, the `R=2` code in the following card indicates that extra heavy ratings should be used.

```
/MERGE_NEW_BASE,SUBSYSID-BR_BUS,BRAN=BDCY89.DAT,DATE=196,R=2,BUSD=J96EH.BUS
```

Powerflow uses appropriate ratings from the branch data for the peak winter (`R=1`), peak summer (`R=8`), extra heavy (`R=2`), moderate cold (`R=3`), and spring (`R=4`) choices.

If the thermal or bottleneck rating on a branch is blank or zero in the columns for extra heavy or moderate cold ratings, the peak winter rating is used (if available). Similarly, if the thermal, bottleneck, or emergency rating on a branch is blank or zero in the columns for spring ratings, the peak summer rating is used (if available).

The chosen ratings are moved to columns 81 through 92 on the branch record in Powerflow.

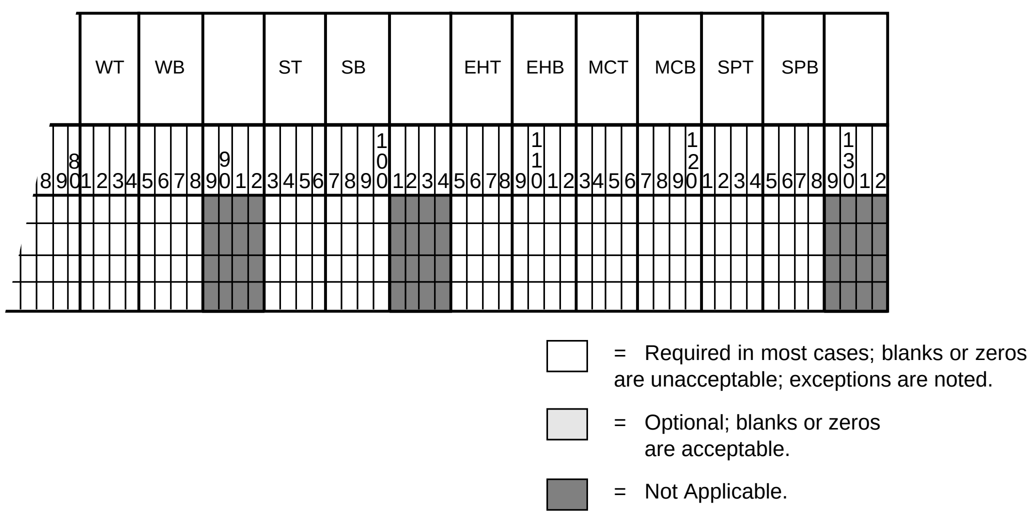


Figure 4-11 Extended Ratings Fields for L and E Records

Table 4-15 L and E Record Extended Fields Column Descriptions

Column	Rating ("R" Selection)	Field Description
81-84	1	Winter Thermal (WT)
85-88	1	Winter Bottleneck (WB)
89-92		(not used)

Table 4-15 L and E Record Extended Fields Column Descriptions (Continued)

Column	Rating (“R” Selection)	Field Description
93-96	8	Summer Thermal (ST)
97-100	8	Summer Bottleneck (SB)
101-104		(not used)
105-108	2	Extra Heavy Thermal (EHT)
109-112	2	Extra Heavy Bottleneck (EHB)
113-116	3	Moderate Cold Thermal (MCT)
117-120	3	Moderate Cold Bottleneck (MCB)
121-124	4	Spring Thermal (SPT)
125-128	4	Spring Bottleneck (SPB)

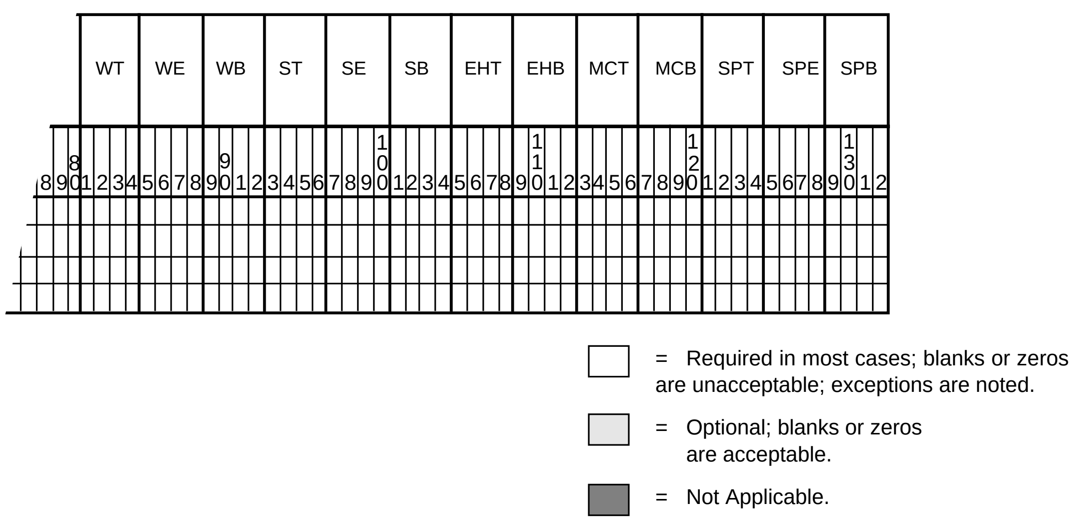


Figure 4-12 Extended Ratings Fields for T and TP Records

Table 4-16 T and TP Record Extended Fields Column Descriptions

Column	Rating (“R” Selection)	Field Description
81-84	1	Winter Thermal (WT)
85-88	1, 2, 3	Winter Emergency (WE)
89-92	1	Winter Bottleneck (WB)
93-96	8	Summer Thermal (ST)
97-100	8	Summer Emergency (SE)
101-104	8	Summer Bottleneck (SB)
105-108	2	Extra Heavy Thermal (EHT)
109-112	2	Extra Heavy Bottleneck (EHB)
113-116	3	Moderate Cold Thermal (MCT)
117-120	3	Moderate Cold Bottleneck (MCB)
121-124	4	Spring Thermal (SPT)
125-128	4	Spring Emergency (SPE)
129-132	4	Spring Bottleneck (SPB)

4.31.1 MERGE Qualifiers

`>EXCLUDE_BRANCHES`

Use this command to exclude from the subsystem branches following this statement. Each branch is identified with a separate `L`, `E`, or `T` formatted record.

`>INCLUDE_BUS`

Use this command to identify additional buses which are to be included in the selected subsystem. Each bus is identified with a separate `B` formatted record.

`>INTERFACE_BRANCHES`

Use this command to list individual interface branches. Each such interface branch is identified with a separate `L`, `E`, or `T` formatted record.

```
>INTERFACE_PREF=COMP
                REJECT
                ACCEPT
```

This command assigns preference weights on competing interface branches listed following the statement. Two subsystems to be merged are usually topologically complementary and have common branches. These branches are called interface branches. During merging, two sets of competing interface branches vie for selection in the final system. In the absence of any information supplied, the default decision is to select the interface branch with the most detail.

The command above allows the user to assign preferences for the interface branches for each system. Each such interface branch is identified on a standard `L`, `T`, or `E` formatted record. `ACCEPT` and `REJECT` must complement each other, or both sets of interface branches will be accepted or rejected.

`COMP` forces comparison of common interface branches from the two subsystems. Acceptance from one subsystem and rejection from the other is determined on the basis of matching bus and branch ownerships. The assumption is that the bus owner always has better branch data. For BPA users, WSCC data is accepted when branch ownerships cannot be determined from data.

```
>MERGE_RPT = SORTED
             UNSORTED
```

This command requests the specific level of merge report. This feature is not yet implemented.

```
>RENAME_BUS
```

This command provides a convenient way to resolve potential conflicts of identically named but topologically distinct buses. This command introduces `B`-formatted records with the old name in columns 7-18 and the new name in columns 20-31.

```
>SAVE_AREAS
```

Use this command to save areas of the subsystem listed following this statement. Each area is identified with a separate `A`-formatted area record.

```
>SAVE_BASES <list>
```

This command saves buses whose base kV's match the list. Elements of the list are separated by commas (`,`) and terminated by a period (`.`).

```
>SAVE_BUSES
```

This command saves listed buses of the subsystem. Saved buses are named on separate `B`-formatted bus records following.

```
>SAVE_ZONES <list>
```

This command saves listed zones of the subsystem. Elements of the list are separated with commas. Example: `> SAVE_ZONES NA, NB`

`>USE_AIC`

This command specifies that `A` records should be generated from the old base file defined by the `OLD_BASE` statement.

4.32 MVA_BASE

```
/ MVA_BASE =    100
               <number>
```

This command changes the base MVA from the default value of 100 MVA to an assigned value.

4.33 NETWORK_DATA

```
/ NETWORK_DATA ,FILE= *,              RXCHECK = ON
                      <filespec>,               OFF
```

This introduces network bus and branch data into the program. No old base case is in residence. `RXCHECK = ON` enables R/X ratios checking.

If the `FILE` parameter value is asterisk (`*`), then bus and branch data is assumed to immediately follow this command.

4.34 NEW_BASE

```
/ NEW_BASE , FILE = <filespec>
```

This command defines the name of the new base file to save the network solved by the case run. It may be the same as the old base file, if you want to overwrite it.

4.35 OI_LIST

```
/ OI_LIST = NONE
            TIELINE
            MATRIX
            FULL
```

This is used to list ownership interchange. Owners are listed using the expanded owner identifications hard-coded in the program. See Appendix D for the complete list.

4.36 OLD_BASE

```
/ OLD_BASE, FILE = <filespec>, REBUILD = OFF
                                         ON
```

This command specifies that a previously solved Powerflow case is to be loaded from the specified file and used as the base system for the current request.

`<filespec>` The file specification of the solved network to be re-solved.

The `REBUILD` switch causes the program to rebuild all of the tables and starts the solution with a "flat start."

4.37 OUTAGE_SIMULATION

```
/ OUTAGE_SIMULATION
```

This command simulates the effect of line outages, load dropping, generator outages, and generator rescheduling. It invokes a process which modifies the base case data in residence. For this reason, this process should not be used with any other process.

```
/ OUTAGE_SIM
> OLDBASE = filespec
 .......
  .......
  .......        Optional Outage Simulation Required Qualifiers
  .......
  .......
```

where:

`filespec` File specification for the base file to be loaded to begin the process.

4.37.1 OUTAGE_SIMULATION Qualifiers

```
>ANALYSIS = OFF, MINLOADING = 100
            ON                <num>
```

This command specifies the threshold loading of a line to be included as contingency-caused overloads. This threshold may be raised on individual branches to screen out base case overloads.

```
>COMMON_MODE, FILE = *
>COMMON_MODE_ONLY, FILE =*
```

These two commands introduce a script which defines one or more "common-mode" outages. The second form restricts the outage simulation study to include only common mode outages. In this case, it is still necessary to introduce an associated >OUTAGE record, but it is used only to define the zones and bases of interest.

The simulation and analysis of any common-mode outages complements in a seamless fashion that for the ordinary single-contingency branch outages. The script associated with the common mode study can be either in a separate file (in which case a file name would be specified) or in the input stream (in which case a file name "*" is specified).

Each common-mode outage consists of two parts: A common-mode identification record (>MODE) and the set of WSCC-formatted bus an/or branch changes which are associated with that common mode outage. It is useful and recommended to annotate this script with comment text. An example will illustrate all the points mentioned.

```
> MODE B/D DRISCOLT 230
```

```
B D   DRISCOLT 230
. Above common mode outage takes out the following lines:
.       DRISCOLT 230 ALLSTON  230
.       DRISCOLT 230 CLATSOP  230
.       DRISCOLT 230 DRISCOLL 230
.
```

Here, the name of the introduced common-mode outage is "B/D DRISCOLT 230". The name is arbitrary; it should be sufficiently distinct to contrast it with entities associated with ordinary single contingency branch outages. The name is 40-characters long, is defined in columns (7:47) on the > MODE records, and is truncated to 31 columns in certain Outage Analysis listings where it must compete with the single contingency branch outages. A maximum of 50 >MODE records are permitted.

Each >MODE record is accompanied with an set of arbitrary change records which specifically define all of the changes in the system that are effected by the common mode. If no change records are submitted, the >MODE record is meaningless, since it would not perturb the system in any manner.

The common mode changes permitted are restricted to the following:

- Bus deletion (D) and modification (M).
- Continuation bus deletion (D) and modification (M).
- Branch deletion (D).

The change methodology is identical with that used elsewhere. A bus deletion, for example, automatically deletes all components associated with it. Implementation, however, expedites the change, but in a manner designed to maximize the computational efficiency. The same bus deletion, to repeat the example, is effected by temporarily changing the impedance of all emanating branches to 10000.0 p.u. X, and preserving a small residual admittance for the bus.

With judicious selection of change records, it is possible to simulate complex scenarios such as the loss of switching CAPs followed with the loss of a transformer.

If the common mode changes isolate even a single bus in the system, the outage is skipped and the isolation is noted within the outage analysis reports.

Although every attempt was made to simulate common mode outages as efficiently as possible, the highly efficient line compensation schemes that were utilized in the single contingency branch outages could not be used here. Each common mode outage requires refactorization of the associated network matrices.

```
>DEBUG = OFF
         ON
```

This turns on debug dumps.

Note: Caution! These dumps can be enormous.

```
>DEFAULT_RATING
```

This command indicates that the following text is line default data. Branches in the specified areas of interest are examined for zero rating (which is an omission of data). If the base kVs of the terminals match the kV in the following default ratings, new ratings are assigned to their branches. They then become candidates for branch overload checking following an outage.

See Table 4-17 for the format of default ratings.

Table 4-17 Format of Default Branch Ratings

Column Position	Content
1-3	(blank)
4-7	Base kV
10-13	Base kV if transformer; blank or zero if line
16-19	Default rating (amps if line; MVA if transformer)

```
>ELIM_LINE_R
```

This command specifies that all line resistance in the eliminated system is replaced with equivalent current injection. The equivalent network, as modified by this option, is easier to solve.

```
>EXPAND_NET = 2
              <nn>
```

This command specifies that the border of the selected equivalent network should emanate outwards an additional number of buses. The expansion selected should be less than 100.

```
>GEN_OUTAGE = NONE
              <nn>
```

This command specifies the maximum number of generator outages for rescheduling.

```
>INCLUDE_CON = <filespec>
```

Use this command to divert the input stream to an auxiliary file that contains `/ OUTAGE_SIMULATION` text. This auxiliary file cannot contain a recursive `/ INCLUDE_CON` statement.

```
>LOW_VOLT_SCREEN = 80
                   <num>
```

This command specifies a contraction for overload values to compensate for effects of voltage changes. It lowers the threshold which tests for overloaded lines.

```
>MIN_EQUIV_Y = .02
               <num>
```

This command specifies minimum admittance of equivalent branches.

```
>NO_SOLUTION, ANGLE = 3.0, DELTA_V = .5
                      <num>         <num>
```

This command specifies conditions for no solution (or no convergence). `ANGLE` is the largest excursion angle (from one iteration to another) in radians relative to the slack bus.

```
   >OLD_BASE = <filespec>
```

`<filespec>` is file specification of the solved network to be re-solved.

Because `/ OUTAGE_SIMULATION` is a stand-alone process, it must begin by loading an old base file which is introduced using this command.

```
>OUTAGE, ZONES = *      BASES= *
                 <list>        <list>
```

This command specifies the ZONES and voltage levels where outages should be taken. Elements of the list should be separated by commas.

```
>OUTPUT_SORT , OVER_OUT
               OUT_OVER, OWNER
               BOTH
```

This command specifies the sort order for output listing in terms of overloads and associated outages. The `OWNER` option requests ownership-bus sort order.

```
>OVERLOAD, ZONES = *      BASES= *
                   <list>        <list>
```

To specify zones and voltage levels where overload should be monitored, use this command. Entities in list should be separated by commas.

```
>PHASE_SHIFT = FIXED_POWER
               FIXED_ANGLE
```

This command specifies phase-shifter representation constant branch power or constant phase shift angle.

```
>REACTIVE_SOL = ON
                OFF
```

This command invokes the reactive solution feature. Normally, only the P-constraints are held.

```
>REALLOCATE = NONE
              LOAD
              LOADGEN
```

This command specifies that load may be shed, generation changed, or both, in order to relieve overload.

```
>REDUCTION = NONE,REI=OFF
             SIMPLE   ON
             OPTIMAL
```

This command requests the reduction feature and specifies the type of reduction.

```
>REDUCTION_DEBUG = NONE
                   MINOR
                   MAJOR
```

This is used to request the debug feature.

```
>RELAX_BR_RATE = ON,PERCENT=5.0
                 OFF        <NUM>
```

This command requests that the branch ratings be relaxed by a certain percentage.

```
>SET_RATINGS, NOMINAL, FILE = <filespec>
              SUMMER
              WINTER
```

This command specifies the special ratings of branches that are used for overload determinations. The number of branches whose ratings are specified in `FILE` is given by a records parameter. Specification records follow this qualifier if the file parameter is omitted. Rating records are described in Table 4-18.

Table 4-18 Fields for Rating Records

Column Position	Content
7-15	bus name
16-19	base voltage
21-27	bus name
28-31	base voltage
32	parallel identification
34-37	nominal amps rating
39-42	summer amps rating
44-47	winter amps rating

```
>SOL_ITER, FIXED = 3
                  <nn>
```

This command sets the solution iteration limit per outage. Divergence is assumed when this limit is exceeded.

```
>TOLERANCE = .005
             <num>
```

This specifies the convergence tolerance in per unit power. Convergence is assumed when mismatch is less than this value. Larger values (0.05) yield fast, approximate solutions; smaller values yield slower, more exact solutions.

4.37.2 Debugging techniques.

The following method has proved to be a useful tool for debugging the Outage Simulation Program (OSP) interactively. In invoking this option, three events occur.

1. After the equivalent reduced system is established but before the individual branch outages are taken, the user interactively selects from the full set of branch outages one or more outages. The unselected outages will be ignored.
2. Debugging switches are turned on.
3. Salient process and status information about each outage is displayed on the screen.

This is most useful to confine the study to a single questionable outage which them will to be compared with the results of an IPF change case depicting the same outage.

To invoke this, enter the two following DCL commands in a terminal window.

```
$ DEBUG_OUTAGE_SIMULATION_STUDY :== ON
$ RUN IPF_EXE:FSTOUT.EXE_V321
```

The second command executes the OSP interactively. After responding to the prompted Power Flow Control file and waiting a few minutes, OSP’s special debugging in invoked.

```
 Enter outage range (n:m), 0=Save, -1=Cancel)
```

You must select the outage by trial and error using a binary search. Enter a candidate outage branch index (say 127). The dialog continues (using an actual case for an example).

```
127 outage BELNGM P 115.0 CARILINA 115.0 1 : Select? (Y or N)
```

Selecting "Y" will add this to the outage set’ "N" will ignore it. If the displayed outrage is alphabetically lower than the desired outage, respond with "N" and enter a higher outage number at the next prompt. If it is higher do the opposite. The dialog loops for additional selections or searches.

```
 Enter outage range (n:m), 0=Save, -1=Cancel)
```

Eventually, when the desired ouages(s) is (are) selected, the process is exited with either option ("0", saving the selection and continuing or "-1", ignoring the selection and continuing).

4.38 OVERLOAD_RPT

```
/ OVERLOAD_RPT, TX =        90.  , LINE = 90.
                           <num>         <num>
```

This command sets the percentage of line and transformer ratings above which line and transformer loadings are listed in the analysis report.

4.39 P_ANALYSIS_RPT

```
/ P_ANALYSIS_RPT , LEVEL =     2 , *
                               1   ZONES=<list>
                               3   OWNERS=<list>
                               4
```

Use this command to specify the printed analysis report.

When `<list>` is blank, asterisk or null, `ALL` is assumed unless limited by a preceding statement.

The level number determines the analysis summaries to be displayed.

For `LEVEL=1`, the following summaries are included:

- User-defined analysis (optional).
- Buses with unscheduled reactive.

For `LEVEL=2`, the following are displayed with summaries for `LEVEL=1`:

- Total system generations and loads by owner.
- System generations, loads, losses and shunts by zones.
- Undervoltage-overvoltage buses.
- Transmission lines loaded above XX.X% of ratings.
- Transformers loaded above XX.X% of ratings.
- Transformer excited above 5% over tap.
- Transmission system losses.
- BPA industrial loads.
- dc system.
- Shunt reactive summary.
- Summary of LTC transformers.
- Summary of phase-shifters.
- Summary of %Var-controlled buses.
- Summary of type BX buses.
- Summary of adjustable Var compensation.
- Transmission lines containing series compensation.

For `LEVEL=3,` the following is displayed in addition to the `LEVEL=2` output:

- Bus quantities.

For `LEVEL=4`, the following are displayed in addition to the `LEVEL=3` display:

- Spinning reserves.
- Transmission line efficiency analysis. Lines loaded above XX.X% of nominal ratings.
- Transformer efficiency analysis. Total losses above X.XX% of nominal ratings.
- Transformer efficiency analysis. Core losses above X.XX% of nominal ratings.

4.39.1 Example

```
/ F_ANALYSIS_RPT, LEVEL=4, OWNERS= BPA,PGE,PPL,WPS
/ P_ANALYSIS_RPT, LEVEL=1, ZONES = NA, NB, NC
/ F_ANALYSIS_RPT, LEVEL=4, *
/ P_ANALYSIS_RPT, LEVEL=1, ZONES = *
```

4.40 P_INPUT_LIST

```
/ P_INPUT_LIST , NONE
                 FULL,  ERRORS = NO_LIST
                                 LIST
                 ZONES = <list>
                 ZONES = ALL, FULL, or NONE
```

This command lists input data on `PAPER`. Output can be restricted to individual zones specified in `<list>`, which are separated with commas. Note that `FULL` or `NONE` may be specified in two forms.

The `ERRORS` options can be set to `NO_LIST` to suppress the input listing if any Fatal (F) errors are encountered.

Example:

```
PWRFLO case: 9BUS proj: TEST-CASE * * * INPUT LISTING * * * 9 BUSSES 8 EQUIVALENT BR PAGE 3 14-JUN-94

 BASIC NINE-BUS CASE
 FOR EXAMPLE REPORTS



BS GEN1 16.5 2 .0PL .0QL .0PS .0QS 240.0PM 306.2PG 150.0QH -100.0QL 1.040VH .0VL
 T 1 GEN1 HI 230.0 0 0 MVA 0 C .00000 R .05760 X .00000 G .00000 B 16.50 230.00 0 T 0 E 0 B 0IN
B GEN1 HI 230.0 2 .0PL .0QL .0PS .0QS .0PM .0PG .0QH .0QL .000VH .000VL
 T 2 GEN1 16.5 0 0 MVA 0 C .00000 R .05760 X .00000 G .00000 B 230.00 16.50 0 T 0 E 0 B 0IN
 L 2 STA A 230.0 0 0 AMP 0 C .01000 R .08500 X .00000 G .08800 B .0 MI 0 T 0 B 0IN
 L 1 STA B 230.0 0 0 AMP 0 C .01700 R .09200 X .00000 G .07900 B .0 MI 0 T 0 B 0IN
BQ GEN2 18.0 1 .0PL .0QL .0PS .0QS 180.0PM 163.0PG 120.0QH -80.0QL 1.025VH .000VL
 T 1 GEN2 HI 230.0 0 0 MVA 0 C .00000 R .06250 X .00000 G .00000 B 18.00 230.00 0 T 0 E 0 B 0IN
B GEN2 HI 230.0 1 230.0PL .0QL .0PS .0QS .0PM .0PG .0QH .0QL .000VH .000VL
 T 2 GEN2 18.0 0 0 MVA 0 C .00000 R .06250 X .00000 G .00000 B 230.00 18.00 0 T 0 E 0 B 0IN
 L 1 STA A 230.0 0 0 AMP 0 C .03200 R .16100 X .00000 G .15300 B .0 MI 0 T 0 B 0IN
BQ GEN3 13.8 2 .0PL .0QL .0PS .0QS 130.0PM 85.0PG 80.0QH -60.0QL 1.025VH .000VL
 T 1 GEN3 HI 230.0 0 0 MVA 0 C .00000 R .05860 X .00000 G .00000 B 13.80 230.00 0 T 0 E 0 B 0IN
B GEN3 HI 230.0 2 .0PL .0QL .0PS .0QS .0PM .0PG .0QH .0QL .000VH .000VL
 T 2 GEN3 13.8 0 0 MVA 0 C .00000 R .05860 X .00000 G .00000 B 230.00 13.80 0 T 0 E 0 B 0IN
 L 1 STA B 230.0 0 0 AMP 0 C .03900 R .17000 X .00000 G .17900 B .0 MI 0 T 0 B 0IN
 L 1 STA C 230.0 0 0 AMP 0 C .01190 R .10080 X .00000 G .10450 B .0 MI 0 T 0 B 0IN
B STA A 230.0 1 125.0PL 50.0QL .0PS .0QS .0PM .0PG .0QH .0QL .000VH .000VL
 L 1 GEN1 HI 230.0 0 0 AMP 0 C .01000 R .08500 X .00000 G .08800 B .0 MI 0 T 0 B 0IN
 L 2 GEN2 HI 230.0 0 0 AMP 0 C .03200 R .16100 X .00000 G .15300 B .0 MI 0 T 0 B 0IN
B STA B 230.0 2 90.0PL 30.0QL .0PS .0QS .0PM .0PG .0QH .0QL .000VH .000VL
 L 2 GEN1 HI 230.0 0 0 AMP 0 C .01700 R .09200 X .00000 G .07900 B .0 MI 0 T 0 B 0IN
 L 2 GEN3 HI 230.0 0 0 AMP 0 C .03900 R .17000 X .00000 G .17900 B .0 MI 0 T 0 B 0IN
B STA C 230.0 2 100.0PL 35.0QL .0PS .0QS .0PM .0PG .0QH .0QL .000VH .000VL
 L 2 GEN3 HI 230.0 0 0 AMP 0 C .01190 R .10080 X .00000 G .10450 B .0 MI 0 T 0 B 0IN

PWRFLO case: 9BUS proj: TEST-CASE * * * INPUT LISTING * * * 9 BUSSES 8 EQUIVALENT BR PAGE 3 14-JUN-94
```

4.41 P_OUTPUT_LIST

```
/ P_OUTPUT_LIST, NONE,  FAILED_SOL = FULL_LIST
                 FULL                PARTIAL_LIST
                 ZONES = <list>      NO_LIST
                 ZONES = ALL, FULL, or NONE
```

This command lists output on PAPER. Output can be restricted to individual zones specified in <list>, which are separated with commas. Note that FULL or NONE may be specified in two forms.

The FAILED_SOL option is set to override the output listing if a failed solution occurs. It defaults to a full listing. A PARTIAL_LIST observes zone lists.

Example:

```
PWRFLO case: 9BUS proj: TEST-CASE * * * * DETAILED OUTPUT LISTING * * * * PAGE 8 14-JUN-94

 BASIC NINE-BUS CASE
 FOR EXAMPLE REPORTS


A COMPLETE OUTPUT LISTING OF ALL BUSSES WILL BE GIVEN


GEN1    16.5   17.2KV/ .0 ZONE  2 306.2PGE  72.5QCOND  .0PLOAD    .0QLOAD     1.040PU KV     BUS TYPE S
    GEN1 HI  230.0             2 306.2PIN  72.5QIN    0.0PLOSS   52.7QLOSS      16.5/230.0
                                306.2PNET  72.5QNET                            0.0 SLACK ADJ

GEN1 HI   230.0  233.3KV/ -9.6 ZONE  2               .0PLOAD    .0QLOAD      1.014PU KV      BUS TYPE
   GEN1     16.5        2 -306.2PIN   -19.8QIN    0.0PLOSS   52.7QLOSS       230.0/ 16.5
   STA A    230.0       1  197.7      24.9       3.9       15.8
   STA B    230.0       2  108.5      -5.1       1.9       -5.5
                           0.0PNET    0.0QNET

GEN2     18.0   18.4KV/-20.4 ZONE  1  163.0PGE  36.4QCOND .0PLOAD  .0QLOAD      1.025PU KV    BUS TYPE Q
    GEN2 HI   230.0       1  163.0PIN    36.4QIN      .0PLOSS    16.6QLOSS       18.0/230.0
                             163.0PNET   36.4QNET

GEN2 HI   230.0  231.8KV/-26.1 ZONE  1            230.0PLOAD .0QLOAD     1.008PU KV    BUS TYPE
    GEN2     18.0        1 -163.0PIN   -19.8QIN     .0PLOSS   16.6QLOSS       230.0/ 18.0
   STA A   230.0        1   -67.0      19.8       1.8       -21.1
                          -230.0PNET    0.0QNET
                              .
                              .
                              .

 OUTPUT CHECK  ---  LINE EXPORT SUMS    LINE IMPORT SUMS      LINE LOSSES
                9.2    18.3       9.2    18.3       9.2    18.3
PWRFLO case: 9BUS proj: TEST-CASE * * * * DETAILED OUTPUT LISTING * * * * PAGE 9 14-JUN-94
```

```
PWRFLO case: 9BUS proj: TEST-CASE * * * * DETAILED OUTPUT LISTING * * * * PAGE  10 14-JUN-94

 BASIC NINE-BUS CASE
 FOR EXAMPLE REPORTS

                            SUMMARY OF SYSTEM TOTALS        (MW    (MVAR)

                            SYSTEM INJECTION:
                               GENERATION                  554.2    133.3
                               LOAD                       -545.0   -115.0
                               BUS SHUNT ADMITTANCE           .0       .0
                               UNSCHEDULED SOURCES            .0      0.0
                            SUBTOTAL (INJECTION)             9.2     18.3
                            SYSTEM LOSSES:
                               EQUIVALENT SHUNT ADMITTANCE    .0       .0
                               LINE AND TRANSFORMER LOSSES  -9.2    -18.3
                               DC CONVERTER LOSSES            .0       .0
                            SUBTOTAL (LOSSES)               -9.2    -18.3

                            NET SYSTEM EXPORT:               0.0      0.0


PWRFLO case: 9BUS proj: TEST-CASE * * * * DETAILED OUTPUT LISTING * * * * PAGE  10 14-JUN-94
```

4.42 REBUILD

```
/ REBUILD = OFF
            ON
```

This command requests that all internal data tables be rebuilt using the current specified `OLDBASE` file. This has the same effect in a case as the `REBUILD` parameter on the `/ OLD_BASE` statement.

4.43 REDUCTION

```
/ REDUCTION
```

This command reduces the network in residence to a desired size and solves the reduced network. It can be saved or processed further as an ordinary base case. For more detail on the methods used, see Chapter 5.

```
/ REDUCTION
.......
.......
.......     Optional Reduction Qualifiers
.......
.......
```

4.43.1 Reduction Qualifiers

```
>COHERENT_CLUSTERS, <name> <base kV>
```

This identifies row-coherent generators (or load) of an REI subsystem. The name must be unique, containing 1-7 characters without blanks and be left-justified. The REI components, which will have their generation and/or load transferred to the coherent generator, are identified with ordinary WSCC-formatted bus (Type B) records which follow.

The named constituent buses which comprise each coherent cluster may be either retained or eliminated buses. In either case, the constituent buses will be eliminated.

Special codes on each bus permit individual dispositions of generator and load quantities. Generation and/or load may be converted to constant current, constant admittance, or converted to an REI coherent unit. The codes are show in Table 4-19.

Table 4-19 Reduction Qualifier Codes

Column	Value
3 (Generation)	0 - Constant Current
3 (Generation)	1 - Constant Admittance
3 (Generation)	Blank or 2 - REI
4 (Load)	0 - Constant Current
4 (Load)	1 - Constant Admittance
4 (Load)	Blank or 2 - REI

```
>DEBUG = NONE
         MINOR
         MAJOR
         ORDERING
```

Use this to request the debug feature.

Table 4-20 Reduction Debug Codes

Debug	Effect
Minor	Minimal debug.
Major	Includes dump of intermittent reduction steps.
Ordering	Includes full dump of reordering arrays during each nodal elimination step.

```
>ELIM_MODE, GEN = CURRENT, LOAD = CURRENT, SHUNT_Y = ADMITT
                  ADMITT          ADMITT             CURRENT
                  REI,PMIN=<n>    REI                REI
```

This command determines how the nodal generation, load, and shunt admittance on eliminated nodes is to be processed. It does not affect the original quantities of the interior or envelop (border) nodes. The disposal options are to convert selected quantities to nodal current, to nodal shunt admittance, or to append them to an REI node.

```
>ENVELOPE_BUSES = BE
```

This command, when elected, changes the subtypes of all envelope node to type BE. Its primary merit is to secure the voltages of the terminal buses at their base case values an improve the solvability of the reduced equivalent system. The default option is to leave the envelope buses in their original subtype.

```
>EXCLUDE_BUSES
```

This command excludes from the retained network the buses listed on the bus-formatted records following this statement. Its purpose is to allow more flexibility in the definition than allowed with a simple `SAVE_BASES` or `SAVE_ZONES`. Obviously, the retained system must already be defined by a prior `SAVE_BASES` or `SAVE_ZONES` command.

```
>INCLUDE_BUSES
```

This command includes in the retained network additional buses listed on the bus-formatted records following this statement. Its purpose is to allow more flexibility in the definition than allowed with a simple SAVE_BASES or SAVE_ZONES. Obviously, the retained system must already be defined by a prior SAVE_BASES or SAVE_ZONES command.

```
>INCLUDE_CON = <filespec>
```

Use this command to include a set of user-specified default command qualifiers, which is stored in a file. Such a default command file should not contain this / INCLUDE_CON statement.

```
>KEEP_AI_SYS = ON
               OFF
```

This command requests that the equivalent network will retain all of the attributes of area interchange control. This includes all area slack nodes and all tie line terminal nodes.

```
>MIN_EQUIV_Y = .02
               <num>
```

This command specifies the minimum admittance of equivalent branches that are retained. Its purpose is to reduce the large number of equivalent branches which are generated, some of which have such large impedances that their contribution to the flows are marginal. A smaller value of 1.0 is recommended. Equivalent branches which have lower admittances (or what is the same, higher impedances) will be replaced with equivalent shunt admittances at both terminals.

```
>OPTIMAL_REDU = ON
                OFF
```

This command switches the optimal network determination feature, which precedes the actual network reduction. When the optimal network selection is ON, it may enlarge the user-specified retained system with optimally selected nodes such that the overall size of the reduced system will be minimized. In essence, it expands the boundary into the eliminated system in a manner which will topologically result in an equivalent network having more buses but fewer branches overall. Thus, the user defines a fuzzy retained system containing the minimum desired configuration, and the optimal network selection will enlarge the network if feasible.

```
>RETAIN_GEN = OFF, PMIN = 100.0
              ON          <num>
```

This command selected all generators with generation > PMIN to be in the retained network.

```
>REI_CLUSTERS, VOLT_DIFF =.25, ANGLE_DIFF = 20.
                          <num>            <num>
```

This command works in conjunction with the REI option on the ELIM_MODE command. An attempt is made to automatically consolidate REI clusters which may have only a single node. However, their consolidation may result in an equivalent REI node whose voltages are too bizarre. It is electrically correct, but may cause solution problems since voltages are initialized about 1.0. By restricting the voltage differences of REI consolidation candidates to those whose voltage differences are less than the user-prescribed value, the resultant consolidated REI cluster will have a more feasible voltage.

```
>SAVE_BASES = <list>
```

This command defined the retained network as consisting of those buses which have the base kvs in `list`. Elements of `list` are separated with commas (`,`).

```
>SAVE_BUSES
```

This command defines the retained network as consisting of all buses identified on the following bus-formatted records. It is a brute force method to define the retained network. It cannot be used in conjunction with `SAVE_ZONES` or `SAVE_BASES`. See `INCLUDE_BUSES`.

```
>SAVE_ZONES = <list>, BASES = <list>
```

This command defines the retained network as consisting of those buses which have zones in the first list, with the optional, additional provision that their base kvs must be in the second list. Elements of the list are separated with commas (,).

```
>STARTING_VOLTAGES = FLAT
                     HOT
```

This command defines the starting voltages which will be used in the ensuing rebuilding and solution of the reduced equivalent base. The default is FLAT, meaning that the solution will use flat starting voltages. There are two separate applications for this option.

The first application is to verify the integrity of the equivalent bus and branch data structures from the complex reduction processing. When used in conjunction a another solution option

```
/ SOLUTION
> BASE_SOLUTION
```

the ensuing convergence checks performed in output report independently verify the validity of the reduced bus and branch data.

The second application is to assist in a solution of a reduced equivalent system if such assistance becomes necessary.

```
>ULT_MODE, GEN = CURRENT, LOAD = CURRENT,SHUNT_Y = ADMITT
                 ADMITT          ADMITT            CURRENT
                 POWER           POWER             POWER
```

This command defines the ultimate form which the currents distributed from the eliminated nodes to the border nodes will attain. It affects only the border nodes. Note that before the elimination, the generation, load, and shunt of each eliminated node is disposed as defined by the command

`ELIM_MODE`. Those quantities, which were distributed as three separate current vectors during the network reduction, are now to be transformed into their ultimate form. The distributed currents (generation, load, and shunt) will be encoded into special types of +A continuation buses with ownership "***".

Table 4-21 Ultimate Form of Distributed Currents

Option	Meaning	Code year	Comment
CURRENT	Constant current model	01	The load fields are interpreted as constant current, constant power factor
ADMITT	Constant admittance	01	The shunt fields are interpreted in the ordinary manner.
POWER	Constant MVA	02	The generation fields are interpreted in the ordinary manner.

It should be noted that the special continuation records +A with ownership "***" will always be generated to hold the equivalent shunt admittance which results from the admittance to ground in the eliminated system.

4.44 RPT_SORT

```
/ RPT_SORT = BUS
             ZONE
             AREA
             OWNER
```

This command sorts output information of a solved network by bus, zone, area, or ownership. The area sort is by `AO` records, not by `A` records. See section Area Output Sort in Chapter 3.

4.45 SAVE_FILE

```
/ SAVE_FILE, TYPE = WSCC_ASCII,  FILE = <filespec>
                    WSCC_BINARY

/ SAVE_FILE, TYPE = NEW_BASE, FILE = <filespec>

/ SAVE_FILE, TYPE = NETWORK_DATA, FILE = <filespec>,
             DIALECTS = BPA,
                        WSCC,
                        WSCC1,
                        PTI,
             SIZE = 120,
                    80,
             RATINGS = EXTENDED
                       MINIMUM
                       NOMINAL

/ SAVE_FILE, TYPE = CHANGES, FILE = <filespec>
```

These commands request that the identified file type be written to the named file.

Type = WSCC_ASCII or type = WSCC_BINARY writes an interface file which can be read by the WSCC Stability Program (version 9 or greater) in lieu of an IPS history file. The filename must be specified. The file can be written in either formatted ASCII or unformatted binary format. The binary format is more compact, but the ASCII file can be freely transferred between platforms with unlike hardware and/or operating systems. The file contains only that powerflow information which is required by the Stability Program; it is not a complete base case.

Type = NEW_BASE is identical in function to the command /NEW_BASE, file = <filename>

Type = NETWORK_DATA writes the complete network data file in various WSCC-formatted dialects.

- The BPA dialect writes the network data in the form most identical to its originally submitted form.
- The WSCC dialect ignores Interarea "I" records, consolidates all "+" bus records (with the exception of +A INT records) with the associated B-record; writes types L,E,T,TP,LM, and RZ branch records in the order of their original submittal; writes type R records in the order adjustable tap side to fixed tap side, or hi-low; writes type LD records in the order rectifier-inverter; writes all branch data with a minimum of X = 0.0005 p.u.; sets Vmin on bus types BV, BX, BD, and BM to 0.0, sets non-zero Qmin on bus types B , BC, BV, and BT to zero; changes type BE buses with non-zero Q-limits to type BQ; and changes zero Qmin and Qmax on type BE buses to type B.

- The WSCC1 dialect includes all of the WSCC dialect mentioned above, and includes consolidating all branches consisting of sections into a single equivalent branch.
- The PTI dialect ignores Interarea "I" records, consolidates all "+" bus records with the associated B-record; sets Vmin on bus types BV, BX, BD, and BM to 0.0, sets non-zero Qmin on bus types B , BC, BV, and BT to zero; changes type BE buses with non-zero Q-limits to type BQ; and changes zero Qmin and Qmax on type BE buses to type B.writes types L, E, T, TP, and RZ (ignores type LM) branch records in the order of their original submittal; writes type R records in the order adjustable tap side to fixed tap side, or hi-low; writes type LD records in the order rectifier-inverter.

In addition, type = NETWORK_DATA writes the MINIMUM or NOMINAL branch current rating in the NOMINAL field if that option is selected; the EXTENDED ratings are written to columns 81:92 only if the BPA dialect, the EXTENDED rating, and the 120-character record size are all selected (all are defaults).

Type = CHANGES writes the complete set of network changes to the named file.

4.46 SOLUTION

```
/ SOLUTION
```

This command enables solution options and special post-solution processes.

```
>AI_CONTROL = CON
              MON
              OFF
```

This command sets the switches for area interchange to `CONtrol`, `MONitor`, or `OFF`.

The alternate voltages and LTC taps are encoded on type `B` and `T` records. See Figure 4-13 and Figure 4-14.

4.46.1 SOLUTION Qualifiers

```
>BASE_SOLUTION
```

This command completely bypasses the solution routine and uses the base voltages in residence. It is useful for debugging purposes, such as validating Network Reduction, or for examining the actual old solution quantities directly from a base case.

```
>DEBUG,TX=OFF,BUS=OFF,AI=OFF,DCMODEL=OFF
          ON      ON     ON          ON
```

This command turns on the following various program debug switches. See Table 4-22.

Table 4-22 Debug Switches

Switch	Meaning
TX:	LTC
BUS:	Bus Switching
AI:	Area Interchange
DCMODEL:	dc Modeling

```
>LIMITS, QRES= 0.10 ,PHA= 45.001,DEL_ANG= 1.000, DEL_VOLT= .150
               <num>      <num>            <num>            <num>
```

To set limits, the statement `>LIMITS` may be used as many times as is needed.

QRES p.u. MVAR by which a BQ, BG, or BX bus must be perturbed to revert from a state of Q-max control to a state of V control.

PHA Minimum angle in degrees for which fixed-tap phase shifters are modeled as ideal (no loss) devices in the decoupled starting routine.

DEL_ANG Maximum angle adjustment in radians permitted in one Newton-Raphson iteration.

DEL_VOLT Maximum voltage adjustment in per unit permitted in one Newton-Raphson iteration.

```
> LOAD_SOLUTION,  VOLTAGES =RECTANGULAR, FILE = file_name
                            POLAR
                  DEBUG =  OFF, SOLUTION = BASE
                           ON                HOTSTART
```

>LOAD_SOLUTION loads an alternate set of voltages and LTC taps for either the base solution (SOLUTION = BASE) or for a hot start (SOLUTION = HOTSTART). The purpose of this command is to validate other Powerflow programs (PTI, SVSPP) using similar base case data or to assist difficult solutions by providing an alternate starting point.

The contents of data in file_name are shown below.

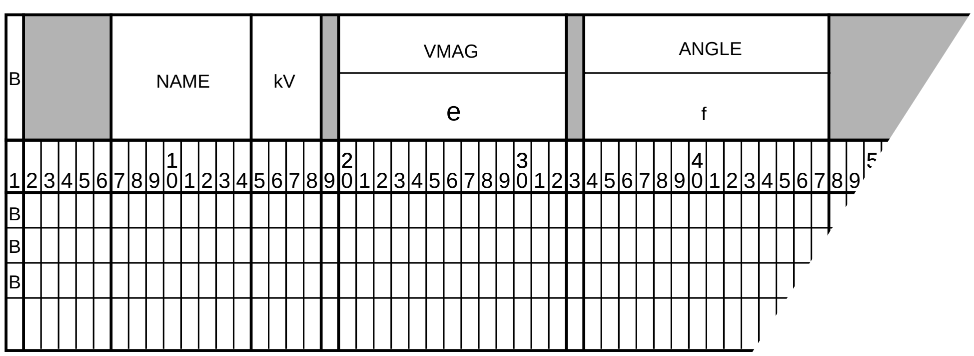


Figure 4-13 Alternate Voltages and LTC Taps for B Records

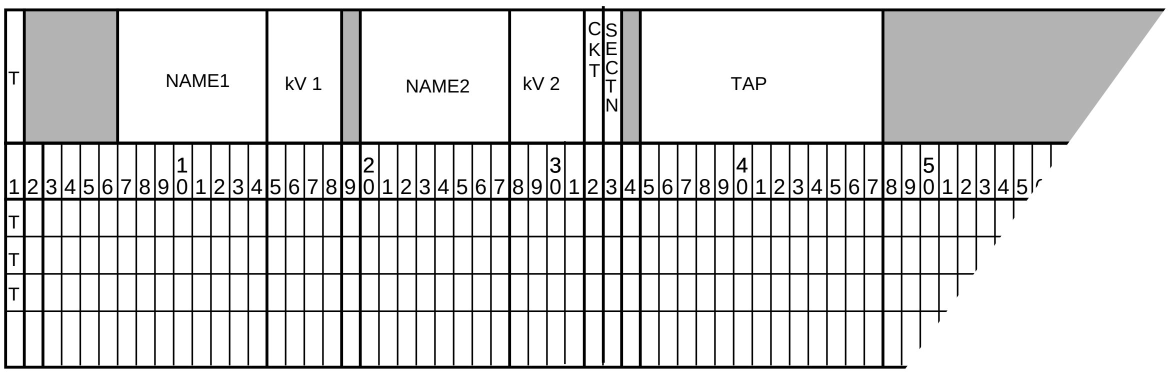


Figure 4-14 Alternate Voltages and LTC Taps for T Records

The formats of the voltages and taps are "free-field," meaning that the information must begin at least in the column noted and that additional entities are separated with a blank space.

On the `T` record, `tap` is in per unit `(TAP1/BASE1)/(TAP2/BASE2)` or in radians for an LTC phase shifter.

Restrictions

The following restrictions apply:

- All sets of `B` records must include all buses.
- The voltages must be within global limits.
- Only LTC transformers can have tap changes.
- The taps must be within LTC tap limits.

```
>LTC = ON
       ON_NV
       ON_NPS
       OFF
       ON_DCONLY
```

This is used with the following to set the control of LTC transformers.

`ON` Full LTC control.

`ON_NV` Partial LTC control (P and Q only).

`ON_NPS` Full LTC voltage control, no LTC phase shifter control.

`OFF` No LTC control.

`ON_DCONLY` No LTC control (except for dc commutating transformer).

Note: To obtain meaningful results with the options `ON_NV`, `ON_NPS`, or `ON_DCONLY`, the taps of the other LTC's should not change. Recall that normally with a flat start (`VFLATSTART=ON`) all LTC's, including those turned off, start at the mid tap value. To represent this action, invoke the additional command:

```
>MISC_CNTRL, VFLATSTART =ON, DCLP = ON, X_BUS = BPA, -
                         OFF        OFF         WSCC
                         ITER_SUM = OFF, TSTART =0.5  -
                                    ON
                        NUMVSTEPS = 3  -
                        PHASE_SHIFTER_BIAS = BPA -
                                            WSCC
                        BRIDGE_CURRENT_RATING = ON
                                                OFF
```

These commands and options set the solution controls.

```
X_BUS        = BPA
               VMAX
               WSCC
```

Solution option for type `BX` buses. The `BPA` option accepts any discrete reactance step on a BX bus when its solution voltage V lies in the range of `Vmin ≤ V ≤ Vmax`. The `VMAX` option attempts to find the switched reactance step on each BX such that its solution voltage is the largest voltage `V ≤ Vmax`. The `WSCC` option adjusts discrete steps on a BX bus (using as an initial value the `B_shunt` entered on the input record) only when the voltage violates the limits `Vmin` or `Vmax`.

`DCLP` dc solution technique for multi-terminal dc lines. `OFF` uses old version. `ON` uses linear programming (LP) routines — default is `ON`, and it should not be changed except in extraordinary circumstances.

`VFLATSTART` = `ON`
`OFF`

Starting option. `ON` = flat start. Initialization under flat start invokes the following conditions.

- All voltages are set V+j0 where V is either the controlled voltage or a value between V_{min} and V_{max}.
- All special bus types `BV`, `BQ`, `BG`, and `BX` are in nominal state. (See

options `X_BUS`.)

- All LTCs are set to a uniform starting value. All LTS phase shifters are set to a value closest to zero, but within top limits. (See option `TSTART`.)
- All dc quantities invoke ac terminal conditions.

`TSTART = 0.50`

This sets the LTC transformer starting tap. The starting tap is based on this value together with the relative magnitude of the variable-tap side and fixed-tap side base kVs.

If `Base_varible_tap_side < Base_fixed_tap_side` then

`Tap = (1-TSTART) *` T_{min} `+ TSTART *` T_{max}

otherwise, it is

`Tap < TSTART *` T_{min} `+ (1-TSTART) *` T_{max}

```
ITER_SUM          = OFF
                    ON
```

This switch controls printout of the solution iteration detail report.

`OFF` = Print out report only if a failed solution occurs.

`ON` = Print out report unconditionally.

```
PHASE_SHIFTER_BIAS        = BPA
                            WSCC
```

This switch determines the phase shifter angle bias for type RM phase shifters. The BPA option biases the angle to zero degrees (in recognization that non-zero degree phase shifts cause real-power loop flow and that biasing the angle to zero effectively bias the system to lower losses since the additional loses in the loop are minimized). The WSCC option biases the angle to the original angle specified on the TP record)

```
BRIDGE_CURRENT_RATING = ON
                        OFF
```

This switch determines whether the converter bridge current rating is applied to the d-c circuit rating. ON implies that the bridge current rating does apply; OFF implies that it doesn't.

```
>SOL_ITER, DECOUPLED = 2, NEWTON = 30
                      <n>         <nn>
```

This command sets the solution and iteration limits with the following:

`DECOUPLED` Uses decoupled method to iterate from flat start. `INITIAL` prefixes the solution iteration count.

`NEWTON` Uses Newton-Raphson method. At least three iterations must be specified. This is the final solution.

```
>TOLERANCE, BUS = 0.001 ,AIPOWER = 0.001, TX = 0.001, Q = 0.001
                  <num>            <num>       <num>      <num>
             V = 0.001
                 <num>
```

This command sets the tolerances in per unit (p.u.) for convergence testing. BUS pertains to both Pnet and Qnet (in per unit), AI_POWER to net area interchange export (in per unit), TX to Pkm for type RP or RM LTC phase shifters or for Qkm for type RQ and RN LTC transformers, Q to the violation of Qmax or Qmin for special bus types BQ, BG, and BX, and V to the desired controlled voltage by type BG buses or by type R transformers.

4.47 SORT_ANALYSIS

```
/ SORT_ANALYSIS , OVERLOAD = < BUS >, OVERVOLTAGE = < BUS >
                             < OWNER >               < OWNER >
                             < ZONE >                < ZONE >
                             < AREA >                < AREA >
```

This controls the sort order of selected analysis listings:

- Overloaded transmission lines.
- Overloaded transformers.
- Undervoltage/overvoltage buses.

The defaults are determined by `RPT_SORT` options:

- Sort by `<ZONE>` if `RPT_SORT` = `<ZONE>`.
- Sort by `<AREA>` if `RPT_SORT` = `<AREA>`.
- Sort by `<OWNER>` if `RPT_SORT` is defaulted.

4.48 TRACE

```
/ TRACE, REORDER = OFF, X_REF = OFF, AUTO = OFF, Y_MATRIX = OFF, -
                   ON           PART        ON               ON
                                FULL

               OUTPUT = OFF, MERGE = OFF, CHANGE = OFF
                  ON           ON             ON
```

Use this command to monitor data used by the program in various functional applications. This is an aid to user data verification.

4.49 TRANSFER_SENSITIVITIES

```
/ TRANSFER_SENSITIVITIES
  > OUTAGE
  L  ...
  E  ...  1 to 100 branch records in WSCC format identifying outages
  T  ...
  > OVERLOAD
  L  ...
  E  ...  1 to 100 branch records in WSCC format identifying lines
  T  ...  checked for overloads.
  > TRANSFER
  I  ...
  I  ...  1 to 100 intertie records identifying transfer between
  I  ...  two areas which will alleviate any line overloads.
  I
```

This feature is similar to the outage simulation analysis, but with an important difference. Each overloaded line resulting from a contingency is quantified as to the amount of area transfer (shifting of generation from one area to another) that is necessary to alleviate the overload.

Because the problem contains three nested loops (contingency loop, line overload monitoring loop, and inter-area transfer loop), the inter-area transfer loop is restricted to user-specified sets of transfers. Even with the present limits, the number of transfers can be large (100 outages * 100 overloads * 100 transfers = 1,000,000).

Limitations and restrictions.

- Each `/ TRANSFER_SENSITIVITIES` must include all three components:

  `> OVERLOAD`
  `> OUTAGE`
  `> TRANSFER`

- Each `> OVERLOAD`, `> OUTAGE`, and `> TRANSFER` component must be followed with relevant branch records of type `L`, `E`, or `T`, or relevant intertie records of type `I`.

  The individual limits are:

  Limit of `OUTAGE` branches: 100
  Limit of `OVERLOAD` branches: 100
  Limit of inter-area `TRANSFER`: 100

- Lines monitored for overload must have rating (nominal) > 0.0. Extended ratings are not used.
- Lines that are candidates for overloads or outages must have `R < X`.

4.50 TX_EFF

```
/ TX_EFF, TOTAL_LOSS = <0.04>, CORE_LOSS = <0.02>, OWNERS = < BPA >
                       <nn>                <nn>              < list >
```

Use this command to compare total and core transformer losses. The output can be filtered by owners. "BPA" is the default if no owners are specified.

4.51 USER_ANALYSIS

```
/ USER_ANALYSIS, FILE = <file_name>, DEBUG = OFF, OUTPUT = <filename>
                                             ON
```

This command generates customized analysis listings.

USER_ANALYSIS provides a simple macro-like programming language to perform algebraic operations involving quantities available or used in the base case in residence. This capability is not related in any way to the CFLOW programming library, which is much more powerful and flexible. However, USER_ANALYSIS provides an easy way to generate simple reports without C programming.

If FILE in the above command is omitted, or <file_name> is *, the user-defined text follows in the input stream. Otherwise, the named file becomes the input stream for this command.

DEBUG enables the debug switch. Its output appears in an output file with the suffix PFD.

OUTPUT = <filename> places a copy of the user defined output into the file selected in <filename>.

The following quantities are available from the solved base case in residence:

- Line flows, P_in or Q_in, measured at either bus1 or bus2 terminal.
- Intertie flows, P_in or Q_in, measured at metering points.
- Scheduled intertie flow, P_sched.
- Losses by Zones, Ownerships, Areas or system totals.
- All bus quantities: P_gen, P_max, Q_gen, Q_max, Q_min, P_load, Q_load, Caps_scheduled, Caps_used, Reactors_scheduled, Reactors_used, Susceptance_used, Susceptance_scheduled, Q_unscheduled. Voltage in per unit or in kV.

4.51.1 Example

A simple example illustrates this concept. The records following the / USER_ANALYSIS have not been introduced. However, the scheme is simple, and the purpose of the records is fairly obvious.

In the example, it is desired to list the sums (P_in and Q_in) of two selected branches.

```
/ USER_ANALYSIS, FILE = *
.
. The following symbols define P_in.
.
> DEFINE_TYPE BRANCH_P
 LET A1 = ELDORADO 500*LUGO        500 1
```

```
 LET A2 = MOHAVE   500*LUGO        500 1
> DEFINE_TYPE FUNCTION
 LET S1 = A1 + A2
.
.The following symbols define Q_in.
.
> DEFINE_TYPE BRANCH_Q
 LET B1 = ELDORADO 500*LUGO        500 1
 LET B2 = MOHAVE   500*LUGO        500 1
> DEFINE_TYPE FUNCTION
 LET S2 = B1 + B2
H
C Branch                       P_in    Q_in
C                              (MW)    (MVAR)
C
C ELDORADO/LUGO        500. 1 = $A1     $B1
C MOHAVE  /LUGO        500. 1 = $A2     $B2
C
C Total                       = $S1     $S2
```

Notice that this example contains two types of data: definitions and comments.

The definitions `> DEFINE_TYPE BRANCH_P`, `> DEFINE_TYPE BRANCH_Q`, and `> DEFINE_TYPE FUNCTION` identify the type of symbols that follow.

The symbols `A1`, `A2`, `S1`, `B1`, `B2`, and `S2` are assigned to specific quantities in the network. They are evaluated after the case is solved.

In the analysis phase, the user-defined report is compiled first. The report consists of a single pass through the comment text, substituting symbols for evaluated quantities before the line is printed. The symbols are identified with a leading `$` followed by a valid symbol name.

Let us make the assumption that the symbols above are evaluated as follows:

```
A1 = 859.2
A2 = 901.8
S1 = 1761.0
B1 = 245.1
B2 = 254.2
S2 = 499.3
```

Immediately before printing, these values are encoded into the symbol fields into the comment text. Their default format is F6.0. The output report appears as follows.

```
Branch                        P_in    Q_in
                              (MW)   (MVAR)

ELDORADO/LUGO   500. 1 =    859.    245.
```

```
MOHAVE   /LUGO   500. 1 =    902.    254.

Total                   =   1761.    499.
```

Three types of text follow the `/ USER_ANALYSIS` record: pagination specifications, symbol definitions, and user-defined comment text. They are described in more detail in the following sections and are then illustrated with a second example.

4.51.2 Symbol Definitions

Symbol definitions have either a one-line or multiple-line format.

The one-line format is:

```
> DEFINE_TYPE <symbol_type><symbol_name>=<id_of_computed_quantity>
```

The multiple-line format is:

```
> DEFINE_TYPE <symbol_type>
<symbol_name> = <id_of_computed_quantity>
<symbol_name> = <id_of_computed_quantity>
<symbol_name> = <id_of_computed_quantity>
```

Some simple rules must be followed:

- All `> DEFINE_TYPE` data is free-field. Blanks and commas are delimiters. If a blank character is part of a name, substitute a pound sign (#).

  Example: `JOHN DAY 500.0 --> JOHN#DAY 500.0`

  A blank circuit ID in a multicircuit line must also be entered as a pound sign (#).

  Example: `B = ELDORADO 500 LUGO 500 #`

- All `> DEFINE_TYPE` data is case-insensitive. No distinction is made between upper and lower case symbol characters. The case, however, is preserved in the analysis report as it was entered.
- The symbol names are limited to six characters.
- The symbol quantities are encoded with a default format of F6.0. The field begins in the column position of the `$` and continues the necessary field width (default is six) as specified by the format. This default format may be changed by appending the new format to the symbol name using the FORTRAN convention, as shown below.

  ```
  C Total                  = $S1/F8.1 $S2/F8.1
  ```

4.51.3 >DEFINE_TYPE BRANCH_P and >DEFINE_TYPE BRANCH_Q

This defines line flows, both `P_in` and `Q_in`, computed at the `bus1` terminal (default) or at `bus2` if an asterisk (`*`) immediately follows the base kV. Below, square brackets “[” and “]” denote enclosed optional quantities.

```
>DEFINE_TYPE BRANCH_P            (Branch flow in MW)
 LET P1 = BUS1 BASE1[*] BUS2 BASE2[*] ID
 LET P2 = BUS3 BASE3[*] BUS3 BASE4[*] ID
...
 LET PN = BUSM BASEM[*] BUSN BASEN[*] ID
>DEFINE_TYPE BRANCH_Q            (Branch flow in MW)
 LET Q1 = BUS1 BASE1[*] BUS2 BASE2[*] ID
 LET Q2 = BUS3 BASE3[*] BUS3 BASE4[*] ID
...
 LET QN = BUSM BASEM[*] BUSN BASEN[*] ID
```

4.51.4 >DEFINE_TYPE INTERTIE_P or DEFINE_TYPE INTERTIE_Q

This defines the area interchange flow, either `P_in` (MW) or `Q_in` (MVAR). Either quantity is computed at the tie-line metering points.

```
>DEFINE_TYPE INTERTIE_P          (Interchange flow in MW)
 LET I1 = AREA_1 AREA_2
 LET I2 = AREA_3 AREA_4
...
 LET IN = AREA_M AREA_N

>DEFINE_TYPE INTERTIE_Q          (Interchange flow in MVAR)
 LET J1 = AREA_1 AREA_2
 LET J2 = AREA_3 AREA_4
...
 LET JN = AREA_M AREA_N
```

4.51.5 > DEFINE_TYPE INTERTIE_P_SCHEDULED

This defines the scheduled area intertie flow (`I` records) as `P_in` (MW).

```
>DEFINE_TYPE INTERTIE_P_SCHEDULED       (Scheduled Interchange flow in MW)
 LET I1 = AREA_1 AREA_2
 LET I2 = AREA_3 AREA_4
...
 LET IN = AREA_M AREA_N
```

4.51.6 >DEFINE_TYPE OWNER_LOSS, LET O1 = BPA, O2 = PGE, etc. >DEFINE_TYPE AREA_LOSS, LET A1 = NORTHWEST, etc. >DEFINE_TYPE ZONE_LOSS, LET Z1 = NA, Z2 = NB, etc. >DEFINE_TYPE SYSTEM_LOSS, LET SYSTOT

This defines losses by Area, Zone, Ownership, or total system.

4.51.7 >DEFINE_TYPE FUNCTION

This defines the following records as containing algebraic operators:

+, -, *, /, **, <, >, (, and).

```
>DEFINE_TYPE FUNCTION
 LET T1 = (Z1 ** 2 + Z2 ** 2 ) ** 0.5
 LET T2 = (Z1 > 1200.0) * 100.0
```

`T1` evaluates as the square root of the sum of the squares `Z1` and `Z2`. `T2` evaluates as 100 times the excess of `Z1` over 1200.0.

Some simple rules must be followed:

- All symbols referenced on the right-hand side must be defined prior to reference.
- Parentheses can be nested to any level. Operation begins inside the innermost level.
- A single function is limited to 30 symbols and operators.
- Operators have the following precedence (highest to lowest):

```
**
*,/
>,<
+,-
```

`FUNCTION` admits simple trigonometric (and one absolute value) functions where the relevant arguments or returned values are expressed in radians:

```
sin(), cos(), tan(), arcsin(), arccos(), arctan(), and abs().
```

Here is an example: compute the voltage angle difference between two buses, `KEELER 500` and `PAUL 500`.

```
> DEFINE_TYPE BUS_INDEX
  LET A = KEELER  500
  LET B = PAUL       500
> DEFINE_TYPE FUNCTION
  LET DIF = 57.29578 * (ARCTAN(A.VI/A.VR) - ARCTAN(B.VI/B.VR))
```

Here, A.VR and A.VI are the real and imaginary components to the per unit voltage at KEELER 500. Similarly, B.VR and B.VI for PAUL 500. The ARCTAN function returns the angle in radians. The difference is then converted to degrees.

4.51.8 >DEFINE_TYPE OLDBASE

This defines pertinent information from the retrieved OLD_BASE data file. An example will demonstrate the use of these symbols.

```
>DEFINE_TYPE OLDBASE
 LET A = DISK
 LET B = DIR
 LET C = FILE
 LET D = CASE
 LET E = DATE
 LET F = TIME
 LET G = DESC
 LET H = PFVER
 LET I = USER

C OLD_BASE CASE =      $D/A10
C DESCRIPTION          $G/A20
C
C GENERATED ON         $E/A10          $F/A10
C OWNER                $I/A10
C POWERFLOW VERSION    $H/A10
```

4.51.9 > DEFINE_TYPE BUS_INDEX

This defines the following records as bus indices. This index is used in conjunction with a coded suffix to obtain specific bus quantities.

Valid suffixes and their associated bus quantities are shown in Table 4-23.

Table 4-23 Suffixes for Bus Quantities

Suffix	Quantity
.PL	P_load in MW
.QL	Q_load in MVAR
.PG	P_gen in MW
.PM	P_max in MW
.QG	Q_gen in MVAR

Table 4-23 Suffixes for Bus Quantities (Continued)

Suffix	Quantity
.QM	Q_max in MVAR
.QN	Q_min in MVAR
.RKK	Real part of driving point admittance (YKK=RKK+jXKK). Also known as short circuit admittance.
.XKK	Imaginary part of driving point admittance (YKK=RKK+jXKK). Also known as short circuit admittance.
.V	V in per unit
.VA	Voltage angle in degrees
.VR	V in per unit, real component
.VI	V in per unit, imaginary component
.VK	V in kV
.VM	V_max in per unit
.VN	V_min in per unit
.C	Q_caps used in MVAR
.CM	Q_caps scheduled in MVAR
.R	Q_reactors used in MVAR
.RM	Q_reactors scheduled in MVAR
.QU	Q_unscheduled in MVAR
.DVQ	dV/dQ sensitivity kV/MVAR
.DVP	dV/dP sensitivity in kV/MW.
.S	Total reactive used (Capacitors or Reactors) in MVAR.
.SM	Total reactive available (Capacitors or Reactors) in MVAR.

An example will demonstrate these concepts.

Compute the generator current (in amps) of Paul 500.0.

```
> DEFINE_TYPE BUS_INDEX
  LET A = PAUL 500.0
> DEFINE_TYPE FUNCTION
  LET B = (A.PG ** 2 + A.QG ** 2) ** 0.5
  LET C = 1000.0 * B / (3.0 ** 0.5 * A.VK)
```

Here symbol `B` contains the generation in MVA, and `C` contains the current in amps.

4.51.10 > DEFINE_TYPE BRANCH_INDEX

This defines the following records as branch indices. This index is used in conjunction with a coded suffix to obtain specific branch quantities.

Valid suffixes and their associated branch quantities are shown in Table 4-23.

Table 4-24 Suffixes for Branch Quantities

Suffix	Quantity
.TAP1	Tap1 in kV for a T or in degrees for a TP record
.TAP2	Tap2 in kV for a T or TP record
.TAP	The discrete tap number (lowest tap = 1) for an LTC transformer.
.TAPS	The total number of discrete taps for a LTC transformer.

An example will demonstrate these concepts.

Show the tap, the discrete tap number, and the number of discrete taps for a transformer FRANKLIN 115/230

```
>DEFINE_TYPE LINE_INDEX
LET FR = FRANKLIN 115.0 FRANKLIN 230.0
C  TX AT     TAP         TAP #        # OF TAPS
C FRANKLIN $FR.TAP2/F7.3  $FR.TAP/F3.0  $FR.TAPS/F3.0
```

Here symbol `B` contains the generation in MVA, and `C` contains the current in amps.

4.51.11 > DEFINE_TYPE ZONE_INDEX

This defines the following records as zone indices. This index is used in conjunction with a coded suffix to obtain specific zone quantities.

Valid suffixes and their associated zonal quantities are shown in Table 4-25.

Table 4-25 Suffixes for Zonal Quantities

Suffix	Zonal Quantity
.PG	P_gen in MW
.QG	Q_gen in MVAR
.PL	P_load in MW
.QL	Q_load in MVAR
.PLS	P_loss in MW
.QLS	Q_loss in MVAR
.PSH	Installed (Scheduled) P_shunt in MW
.QSH	Installed (Scheduled) Q_shunt in MVAR
.SCAP	Installed (Scheduled) Q_cap in MVAR
.SREK	Installed (Scheduled) Q_reactors in MVAR
.UCAP	Used Q_cap in MVAR
.UREK	IUsed Q_reactors in MVAR

The following example illustrates these concepts.

```
> DEFINE_TYPE ZONE_INDEX
  LET  ZA = NA
     LET  ZB = NB
  LET  TP = ZA.PLS + ZB.PLS
  LET TQ = ZA.QLS + ZB.QLS
C
C Zone        Ploss       Qloss
C             (MW)       (MVAR)
C
C NA        $ZA.PLS   $ZA.QLS
C NB        $ZB.PLS   $ZB.QLS
C- - - - - - - - - - - - - - - - - - - - - - - - - -
C Total      $TP        $TQ
C
```

The symbol `ZA.PLS` contains the losses in MWs for zone NA.

4.51.12 > DEFINE_TYPE OWNER_INDEX

This defines the following records as owner indices. This index is used in conjunction with a coded suffix to obtain specific owner quantities.

Valid suffixes and their associatedownership quantities are shown in Table 4-25.

Table 4-26 Suffixes for Ownership Quantities

Suffix	Onwership Quantity
.PG	P_gen in MW
.QG	Q_gen in MVAR
.PL	P_load in MW
.QL	Q_load in MVAR
.PLS	P_loss in MW
.QLS	Q_loss in MW
.PSH	Installed (Scheduled) P_shunt in MW
.QSH	Installed (Scheduled) Q_shunt in MVAR
.SCAP	Installed (Scheduled) Q_cap in MVAR
.SREK	Installed (Scheduled) Q_reactors in MVAR
.UCAP	Used Q_cap in MVAR
.UREK	IUsed Q_reactors in MVAR

The following example illustrates these concepts.

```
> DEFINE_TYPE OWNER_INDEX
  LET  ZA = BPA
       LET  ZB = PPL
  DEFINE_TYPE FUNCTION
  LET TP = ZA.PLS + ZB.PLS
  LET TQ = ZA.QLS + ZB.QLS
C
C Onwer       Ploss       Qloss
C            (MW)       (MVAR)
C
C BPA       $ZA.PLS   $ZA.QLS
C PPL       $ZB.PLS   $ZB.QLS
C- - - - - - - - - - - - - - - - - - - - - - - - -
```

```
C Total      $TP        $TQ
C
```

The symbol `ZA.PLS` contains the losses in MWs for owner BPA.

There are three remaining types of indices:

```
> DEFINE_TYPE SYSTEM
> DEFINE_TYPE INTERTIE_INDEX
> DEFINE_TYPE AREA_INDEX
```

These commands define following records as system, intertie, and area indices, respectively. Their use is similar to the bus and zone indices. (*Not available*.)

4.51.13 > DEFINE_TYPE TRANSFER_INDEX

This defines the following records as transfer indices. This index is used in conjunction with a coded suffix to obtain specific transfer quantities.

Valid suffixes and their associated transfer quantities are shown in Table 4-23.

Table 4-27 Suffixes for Branch Quantities

Suffix	Quantity
.RKM	Real part of transfer impedance (p.u.)
.XKM	Imaginary part of transfer impedance (p.u.)
.DVP	Sensitivity $d(V_1-V_2)/dP$ in kV/MW
.DVQ	Sensitivity $d(V_1-V_2)/dQ$ in kV/MVAR
.DTP	Sensitivity $d(\theta_1 - \theta_2)/dP$ in degrees/MW

The transfer impedance is the point-to-point impedance between two buses. It would represent the incremental (complex) voltage change due to a 1.0 p.u. current injection into bus1 in conjunction with a -1.0 injection out of bus2. It represents the impedance of the entire network with respect to the two terminal nodes.

The transfer sensitivity is the sensitivity of the voltage or angle difference between two buses with respect to a 1 MW or MVAR change in injection between two buses.

The following example obtains the transfer impedance and transfer sensitivities between COULEE 2 13.8 - JOHN DAY 500 and between JOHN DAY 500 - MALIN 500.

```
> DEFINE_TYPE TRANSFER_INDEX
  LET TX1 = COULEE   500 JOHN#DAY  500
  LET TX2 = JOHN#DAY 500 MALIN     500
C
C TRANSFER IMPEDANCES       R (P.U.)        X (P.U.)
C
C COULEE   500 JOHN DAY 500 $TX1.RKM/E12.5  $TX1.XKM/E12.5
C JOHN DAY 500 MALIN    500 $TX2.RKM/E12.5  $TX2.XKM/E12.5
C
C TRANSFER SENSITIVITIES    dV/dP (kV/MW)   dV/dQ (kV/MVAR) dT/dP (deg/MW)
C
C COULEE   500 JOHN DAY 500 $TX1.DVP/E12.5  $TX1.DVQ/E12.5  $TX1.DTP/E12.5
C JOHN DAY 500 MALIN    500 $TX2.DVP/E12.5  $TX2.DVQ/E12.5  $TX1.DTP/E12.5
```

4.51.14 Pagination Specifications

Pagination specifications pertain to headers and subheaders. The Header record is the most important record. It has an `H` in column 1.

Each user-defined report must begin with a separate header record. The contents of this record become the first subheader. Additional subheaders can be appended to the report.

The header and subheaders are listed at the top of each page on the user-defined analysis report.

Following the header and optional subheader records are 120-character user-formatted comment text, identified with a `C` in column 1. These records define the user-defined analysis report.

Only columns 3-120 are used. Column 1 (containing the `C`) is ignored in the report, while column 2 is interpreted as FORTRAN carriage control:

`" "` = single line spacing

`"0"` = double line spacing

Symbols whose character fields are to be encoded with numerical values computed from the solved case in residence are prefixed with a `$` and suffixed optionally with a format specification.

Examples

```
C WEST-OF-RIVER FLOW/NORTH= $T1/F8.0   WEST-OF RIVER FLOW/SOUTH= $T2/F8.0
C -----------------------              -----------------------
C ELDORADO/LUGO    500. 1 = $A1/F8.0   PALOVRDE/DEVERS  500. 1 = $A9/F8.0
```

There are two symbol substitutions in the first comment line: `T1` and `T2`. Both elect an optional format, which is `F8.0`. By coincidence, the symbol field with `$T1/F8.0` is eight characters, the same as the Format specification. If the Format was larger, substitution would overwrite additional columns on the right. If the format was smaller, only the left-most characters would be used with a blank fill on the remaining (unused) field.

The second comment line has no substitution. The third has two symbol substitutions, similar to the first comment line.

If no format specification is used, the default (F6.0) is used. In this instance, it would be plausible to use five-character symbol names. When the `$` is included, the substituted text is the same field width as the original text. The program limits are 500 comment lines including headers and subheaders. No symbol substitution occurs on headers or subheaders.

If a comment refers to an undefined symbol, a warning is issued, with the questionable fields flagged with a string of `??????`s. The limits are 500 lines of symbol definition and 1000 symbols. Comment text ("`.`" in column 1) is excluded.

CHAPTER 5

ADVANCED FEATURES

5.1 NETWORK REDUCTION

This section gives a detailed description of the network reduction method and solution options.

5.1.1 Method of Reduction

This program reduces a large sparse network into a smaller equivalent network by Gaussian decomposition. The original network is linearized about the operating point and is expressed by the current equation:

$$\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} Y_{11} & Y_{12} \\ Y_{21} & Y_{22} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix} \qquad \text{Eq. 5.1}$$

where: I is the complex current net injection matrix, Y the complex nodal admittance matrix, and V the complex nodal voltage matrix. The subscripts 1 and 2 pertain to the eliminated and retained portions of the network, respectively. For simplicity, the matrix is reordered as shown. We may separate the partitioned matrix equations in Eq. 5.1.

$$[I_1] = [Y_{11}][V_1] + [Y_{12}][V_2] \qquad \text{Eq. 5.2}$$

$$[I_2] = [Y_{21}][V_1] + [Y_{22}][V_2] \qquad \text{Eq. 5.3}$$

We may solve for $[V_1]$ from Eq. 5.2.

$$[V_1] = [Y_{11}]^{-1}[I_1] - [Y_{11}]^{-1}[Y_{12}][V_2]$$

and then substitute the expression into Eq. 5.3.

$$\left[I_2\right] = \left[Y_{21}\right]\left[\left[Y_{11}\right]^{-1}\left[I_1\right] - \left[Y_{11}\right]^{-1}\left[Y_{12}\right]\left[V_2\right]\right] + \left[Y_{22}\right]\left[V_2\right]$$

$$= \left[Y_{21}\right]\left[Y_{11}\right]^{-1}\left[I_1\right] - \left[Y_{21}\right]\left[Y_{11}\right]^{-1}\left[Y_{12}\right]\left[V_2\right] + \left[Y_{22}\right]\left[V_2\right]$$

Rearranging terms, we have

$$\left[I_2\right] - \left[Y_{21}\right]\left[Y_{11}\right]^{-1}\left[I_1\right] = \left[\left[Y_{22}\right] - \left[Y_{21}\right]\left[Y_{11}\right]^{-1}\left[Y_{12}\right]\right]\left[V_2\right]$$

or

$$\left[I_2\right]eq = \left[Y_{22}\right]eq\left[V_2\right] \qquad \text{Eq. 5.4}$$

where:

$$\left[I_2\right]eq = \left[I_2\right] - \left[Y_{21}\right]\left[Y_{11}\right]^{-1}\left[I_1\right] \qquad \text{Eq. 5.5}$$

$$\left[Y_{22}\right]eq = \left[Y_{22}\right] - \left[Y_{21}\right]\left[Y_{11}\right]^{-1}\left[Y_{12}\right] \qquad \text{Eq. 5.6}$$

The matrix operations in Eq. 5.5 and Eq. 5.6 have the following interpretation:

Equivalent injection = original injection + distributed injection
Equivalent admittance = Original admittance + distributed admittance + equivalent branches

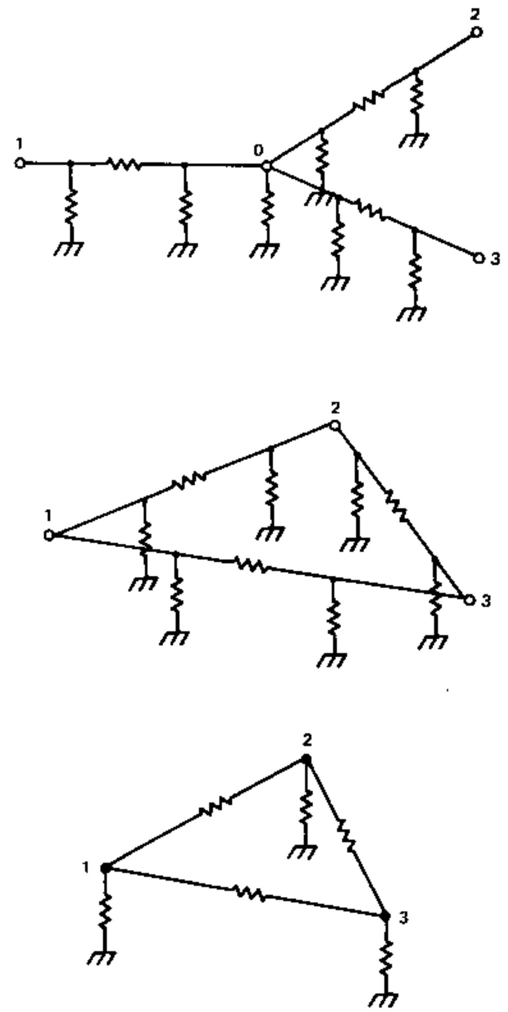
Equations Eq. 5.5 and Eq. 5.6 have interesting topological interpretations. Some notation is necessary so the following definitions apply:

Envelope node	A retained node with at least one adjacent node in the eliminated system.
Internal node	A retained node with all adjacent nodes in the retained network.
Equivalent branch	A fictitious branch between two envelope nodes which effectively represents the reduced network as seen from those nodes.

Inherent in the reduction is the connectedness of the network and the preserved identity of the current equations. An eliminated node is connected (not necessarily directly) to several envelope nodes. Any injected current on that node becomes branch current in the eliminated system. After deducting losses, it finally reaches the envelope nodes and is reconverted into an equivalent injection. The distribution of eliminated injections is determined by the admittance of the eliminated system. By superposition, the injections from all eliminated nodes are distributed to the envelope nodes. This reflects the second term on the right side of equation Eq. 5.5. This does not imply, however, that the equivalent injections are identical to the branch currents and could also be obtained by arbitrary cutting of the network. The reasons will be explained in examples to follow.

The equivalent branches introduced between the envelope nodes after reduction reflect the admittance seen from the envelope nodes and into the eliminated network and finally to other envelope nodes. It is similar to the delta branches introduced in a wye-delta conversion. The value of the equivalent branches is found in the second term in the right side of equation Eq. 5.6.

The branch data is originally submitted in the form of equivalent pi's which are used to construct the nodal admittance matrix Y. In general, the reverse process is not unique. Figure 5-1 illustrates the form of the equivalent pi-branches obtained.



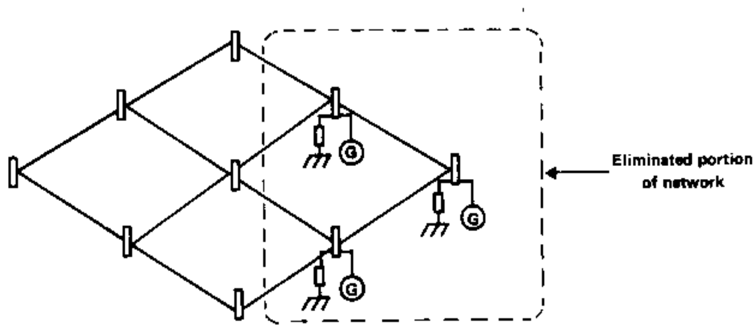
a) Original four-node network

b) Equivalent reduced network
(node 0 eliminated)

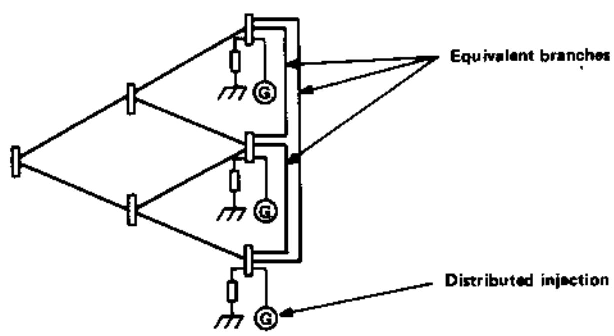
c) Actual representation
or equivalent pi-branches:
legs-to-ground consolidat-
ed with nodal suscep-
tance.

Figure 5-1. Equivalent Pi-Branches

In Figure 5-2 below, a nine-node network is reduced. The distributed injections and equivalent branches introduced are emphasized.



a) Original network



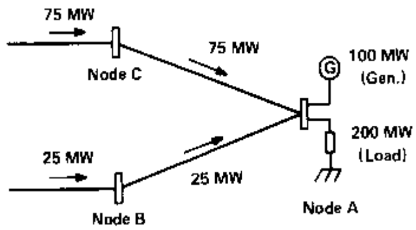
b) Reduced network

Figure 5-2. Network Reduction

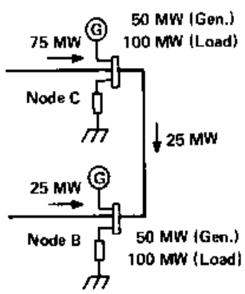
Three options are available for disposal of the generation and load of eliminated nodes:

1. Generation and load assumed constant current.
2. Generation assumed constant current, load assumed constant admittance.
3. Generation and load assumed constant admittance.

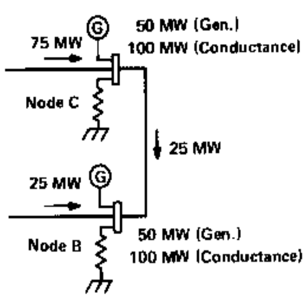
These options are illustrated by the examples in Figure 5-3. For simplicity, losses are ignored and a dc model is used.



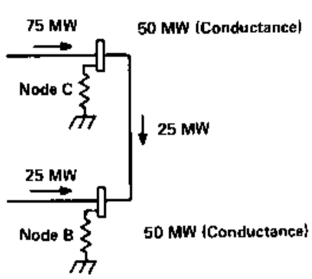
a) Original network



b) Network with node A eliminated with option 1 assuming equal branch admittance



c) Network with node A eliminated with option 2 (loads replaced with distributed bus susceptance)



d) Network with node A eliminated with option 3 (net load and generation replaced with distributed bus susceptance

Figure 5-3. Eliminated Node Generation and Load Disposal

In all examples, the equivalent branch flow represents the sum of three components:

1. The power looping into the eliminated system and back out to the retained system.
2. The flow of generation within the retained system through an envelope node to the distributed loads of the equivalent system.
3. The flow of distributed generation on the envelope nodes to loads within the retained system.

The difference between network reduction and network cutting is seen in component 1 above. This component is found by assuming all generations and loads within the eliminated system are identically zero. Thus, in equation Eq. 5.5 , $I_1 = 0$ and

$$\left[I_2\right]eq = \left[I_2\right] \qquad \text{Eq. 5.7}$$

The branch flow in this case is strictly due to the differences of voltages between envelope nodes, i. e., looping. This is the important distinction between reduction and cutting.

5.1.2 Description of Reduction

The nodal admittance matrix is retrieved from the base file and selective elimination is performed first upon all eliminated nodes and then partially upon the retained nodes.

A complete pass merges the data from the reduced current matrix and the reduced admittance matrix with the system data from the base file. Eliminated data is purged and equivalent branches and distributed injections are added to the data. Concurrent with this pass, a simple injection check is performed on the envelope nodes. The net injection of the nodes is compared with the original values. Any mismatches are errors and will be flagged.

Special consideration is given to the distributed shunt admittances. The envelope nodes which receive these admittances may be subtype Q. In such a case, this portion of the shunt admittance is not adjustable for voltage control. To accomplish this, a special continuation bus subtype, +A, was created, to which all distributed injections and shunt admittances are added. In the power flow output listings, this portion of the admittance is flagged "EQUIVALENT" to confer distinction over other adjustable susceptances.

Upon completion of the reduction, all equivalent branches and injections are added to the system data and all data in the eliminated system is permanently deleted. A new base case is created, updated, and must be solved. Thus, a `/SOLUTION` and `/NEW_BASE` command must follow any network reduction. If desired, subsequent changes could be applied.

An example deck setup for network reduction is shown in Appendix A.

The program is written such that the method of determining the base case is irrelevant to the options that may be performed. Once a base case is defined and solved, any of the options for a base case may be exercised. Thus, further network reduction could be performed upon the already reduced system. Proper position of the appropriate control cards give the user complete flexibility.

5.1.3 Program Control Options

There are seven options that the user may exercise; they are all specified by qualifiers within the `/REDUCTION` command set.

1. Admittance cutoff (`MIN_EQUIV_Y`).
2. Disposition of injections (elimination mode: `ELIM_MODE`, final mode: `ULT_MODE`).
3. Retain generators by "REI"scheme (`REI_CLUSTERS, ELIM_MODE`).
4. Retain area interchange nodes (`KEEP_AI_SYSTEM`).
5. Retain all generators (`RETAIN_GEN`).
6. Optimal network determination (`OPTIMAL_REDU`)
7. Minimum generator cutoff for "REI" equivalent (`ELIM_MODE`).

These options are discussed in the following paragraphs.

Admittance Cutoff

Assume that the retained network has n nodes in which m (m<n) nodes define the envelope. Assume furthermore that there is a path from any envelope node into the eliminated network and back to any other envelope node. Then, inherent in the reduction, there will result an equivalent branch between any pair of envelope nodes. The total equivalent branches added will be

$$\frac{m\,(m-1)}{2}$$

This total can become large. Many equivalent branches added between the most relatively remote pair of envelope nodes will have a branch impedance excessively large and presumed negligible. The admittance cutoff is a parameter that the user may choose in eliminating these branches from the generated reduced system data. It is defined as

$$\text{Admittance cutoff} = \left|\frac{1}{R + jX \text{ equivalent}}\right|$$

For example, the value 0. 001 will exclude all equivalent branches with an equivalent impedance of 1000 p. u. ohms or more.

Disposition of Injections

The disposition of injections of eliminated nodes has, in all, 12 different combinations of options. Each combination is unique with its inherent advantages and disadvantages.

The injections are divided into three parts: (1) generation, (2) load, and (3) shunt admittance. Each of these injections has two modes of disposition during reduction and three additional modes ultimately. The transition of a single injection is shown in Figure 5-4.

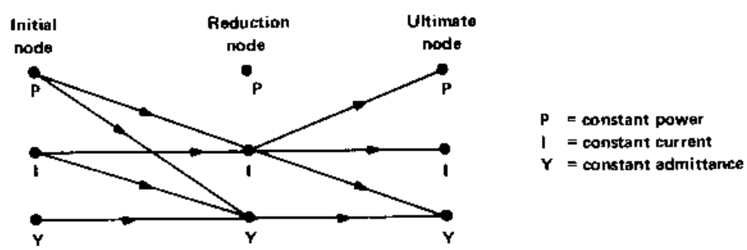


Figure 5-4. Injection Disposition of Eliminated Nodes

Reduction Mode

The two possible modes of disposition during reduction are constant current and constant admittance. A summary of each option with its inherent characteristics follows:

Generation:

- *Constant current* has improved convergence characteristics; retains identity as generation.
- *Constant admittance* appears as fictitious negative impedance; has major effect on passive equivalent network.

Load:

- *Constant current* retains identity of load
- *Constant admittance* has slightly better convergence characteristics; has major effect on passive equivalent network.

Shunt admittance:

- *Constant current* avoids negative impedances in the equivalent network.
- *Constant admittance* preserves the identity of the passive network.

Ultimate Mode

After equation Eq. 5.4 has been solved for $I_2\ eq$ and $Y_{22}\ eq$, the question arises: How should the separate components of $I_2\ eq$ be disposed to their ultimate state?

From Figure 5-4 we have three options to dispose *I*; namely *P*, *I*, or *Y*. A summary of each is described below.

Generation and load:

- *Constant power* is typical and preserves the identity of generation or load.
- *Constant current* is preferred and has superior convergence characteristics.
- *Constant admittance* is the least preferred and has poor accuracy.

Shunt admittance:

- *Constant power* is atypical and is available for compatibility only.
- *Constant current* is the same as constant power.
- *Constant admittance* is preferred and is most realistic to a passive network.

Summary

The recommended disposition is therefore summarized in Table 5-1.

Table 5-1. Disposition of Components

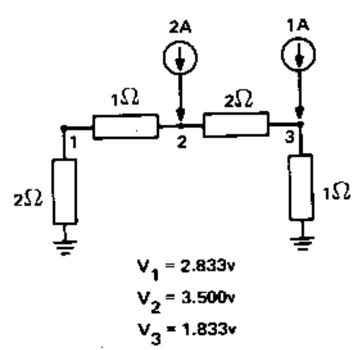
Quantity	Reduction Mode	Ultimate Mode
Generation	I	I
Load	I	I
Shunt Admittance	Y	Y

5.1.4 REI Equivalent

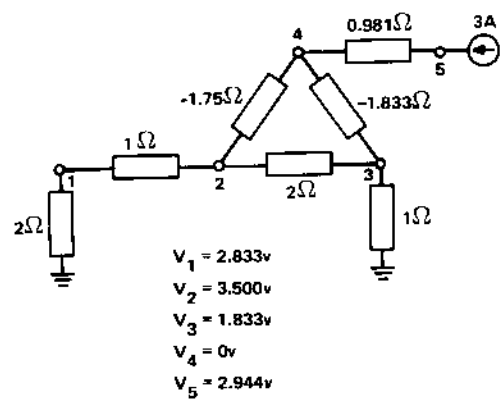
One disadvantage inherent in reduction involves the properties of eliminated generators. The power injections are converted into current injections using the steady-state solution voltages. Every eliminated generator therefore becomes identical to a bus with fixed real and reactive injection, but without fixed voltages typical of BQ nodes with reactive inequality constraints. Consequently, the eliminated system loses its voltage regulation capacity. System changes near the border nodes of reduced equivalent systems often converge to voltage profiles quite different from the full system. The obvious remedy is to reinstate these generators or, alternately, to preserve their regulating characteristics.

The normal option of retaining generators has been unsatisfactory. A network having 1600 nodes that is reduced to a system of 600 nodes may also include about 200 retained generators and an extremely disproportionate number of equivalent branches. The reduced equivalent system is typically about 75 percent of the size of the full network and nearly defeats any merits gained in reduction.

The "REI" equivalent is an innovative alternate to preserving eliminated generators directly. The initials mean Radial Equivalent Independent. It is a simple scheme in which several eliminated generators are connected to a common ground node having zero voltage but isolated from the ground of the rest of the system. This ground node is then tied directly to an equivalent generator. The branch admittance from the ground node to all the generators and to the equivalent node are determined such that no real or reactive power is gained or lost. A simple resistive network as shown in Figure 5-5 demonstrates the procedure.



a) Network having current sources at nodes 2 and 3



b) REI network in which the equivalent currents are coalesced into a single node

Figure 5-5. Example of Network and Its REI Equivalent

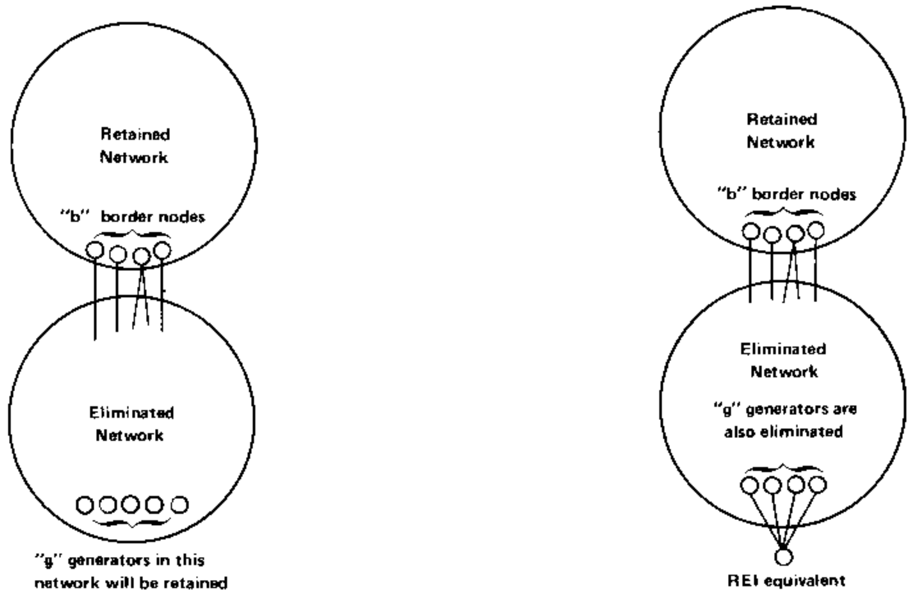
The example in Figure 5-5 has moved the current injections at nodes 2 and 3 in (a) back to an equivalent node 5, which has 3A injection. The current flowing from 4 to 2 is 2A; from 4 to 3 is 1A. The power loss in the branches is

$$P = I_{42}^2 R_{42} + I_{43}^2 R_{43} + I_{54}^2 R_{54}$$

$$= 2^2 (-1.75) + 1^2 (-1.833) + 3^2 (0.981) = 0 \text{ watts}$$

This zero power loss is deliberate. It is termed the zero power balance. Introduction of the REI system has not changed the total system losses.

Although this example demonstrates the procedure involved, it does not illustrate the merits in preserving sparsity. Only in large networks does this become apparent. Consider the network in Figure 5-6.



(a) Direct

Network schematic in which the eliminated network contains "g" generator nodes. These generators will be excluded from eliminated network and therefore be appended into the retained network.

(b) Indirect

Same network as (a) except the "g" generator nodes will be tied to one REI equivalent. The equivalent node will be appended to the retained network and the "g" generators will be eliminated.

Figure 5-6. Direct and Indirect Generator Preservation in Eliminated Network

The letter *b* in Figure 5-6 is the number of border nodes in the network. The letter *g* is the number of generators in the eliminated network. If they are saved directly and the rest of the network is eliminated, the number of equivalent branches is at worst.

$$N_{br} = \frac{g(g-1)}{2} + gb + \frac{b(b-1)}{2}$$

However, if an REI equivalent is obtained instead, g = 1 and

$$N'_{br} = b + \frac{b(b-1)}{2}$$

Typical numerical values are g = 10, b = 15. Then N_{br} = 225 and N'_{br} = 120. This is nearly a 50 percent reduction in the number of equivalent branches.

5.1.5 REI Clusters

In Figure 5-6, all of the border nodes will be normally fully interconnected. The total number of branches is easily computed by b(b-1)/2 where b is the number of border nodes. If b is large, say 50, then 50*49/2 = 1225 equivalent branches will result during this elimination. (The same number would occur without the REI equivalents.) However, if the area interchange system is retained, the eliminated system becomes clustered with a dramatic reduction in the number of equivalent branches.

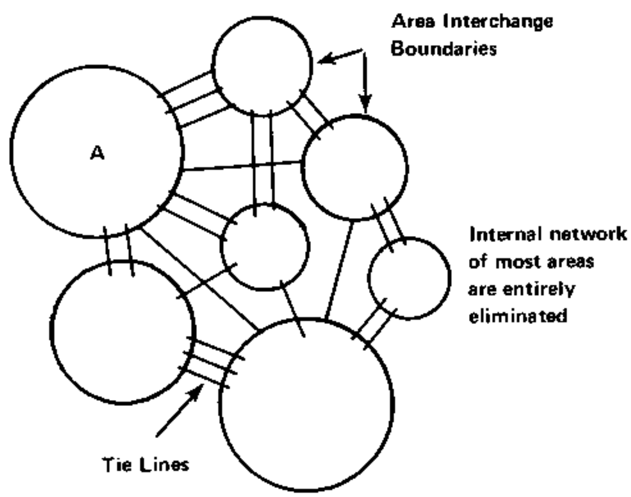


Figure 5-7. Small System Network (Areas and Tie Lines Shown)

A typical equivalent of Figure 5-7 might normally retain area A in full detail, and would include all the tie line nodes and area slack buses of the remaining system. The rest of the system is replaced with an equivalent. This area interchange system permits the eliminated system to be assigned clusters (a minimum of one cluster per area). Each cluster is assigned an “REI” equivalent generator to replace all the eliminated generators.

Defining clusters does not decrease the number of eliminated generators nor decrease the number of border nodes. However, it isolates the interconnections from one REI equivalent to another. For example, suppose that the previous example was split into two clusters defined with the following bus counts:

$$= 5 \qquad g_2 = 5 \qquad g_1 + g_2 = 1$$

$$= 7 \qquad b_2 = 8 \qquad b_1 + b_2 = 1$$

$$N'_{br} = \left(b_1 + \frac{b_1 (b_1 - 1)}{2} \right) + b_2 + \left(\frac{b_2 (b_2 - 1)}{2} \right) = 64$$

Comparing this with the previous example of 10 generators and 15 border nodes, this is nearly a 50 percent reduction in the number of equivalent branches from the REI equivalent without clusters.

5.1.6 Coherency Clusters

In some applications, the generators equivalenced by the area interchange clustering may not be the desired grouping. Specifically, if the reduced network is to be used with a transient stability program, the coherent groups may be determined by other factors such as size or voltage level. In this application, the coherent groups can be specified individually by additional data as shown in Figure 5-8. The data may either supplement or complement the normal REI clustering.

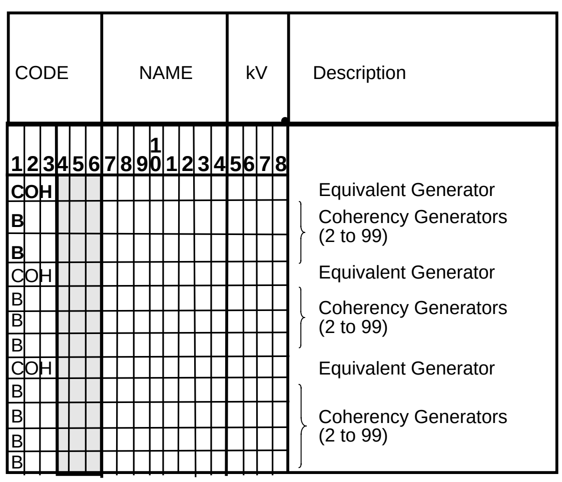


Figure 5-8. General Data Used to Define or Modify REI Clusters

The set of data cards illustrated in Figure 5-8 follow immediately the control card "`SAVE_BUSES`" or after the last bus following the control cards “`INCLUDE_BUSES`” or “`EXCLUDE_BUSES`”. The name of the equivalent generator (coherent equivalent) must be unique; i. e., it cannot be any bus already in the system. The names of the coalesced generators may be any bus already defined in the network. It may be eliminated or retained (in which case elimination will become mandatory). It may also be already assigned to another REI equivalent cluster. Any errors encountered will be described with diagnostics and the program will exit.

5.1.7 Using REI Equivalents

The `ELIM_MODE` command requests REI equivalencing of eliminated generators. An additional parameter specifies the minimum PGEN for a bus to be normally coalesced. Larger values of PGEN will exclude the smaller generators from being coalesced. Care should be exercised when requesting coalesced generators, since table overflow will occur if more than 99 generators are coalesced into a single equivalent.

The equivalent generators are made type BQ with a scheduled voltage computed for zero power balance. Names such as “EQUIV 1” are program generated and pertain to the clusters in which they reside. However, if "COH" data is submitted, the generator names are as specified in the data. The zone of an equivalent generator is randomly selected to be any zone of one of the coalesced generators.

5.1.8 Optimal Network Determination

When not using the REI equivalent, the number of equivalent branches may become excessively large and compromise any advantages obtained by network reduction, unless the retained network is judiciously chosen. If the optimal feature is selected using the `OPTIMAL_REDU` command, the retained network specified by the input data will be interpreted as the “minimum” retained system. Nodes selected for actual elimination will contribute to a definite reduction in system size. Thus, the optimal feature will expand the retained system if necessary to minimize the network size.

5.1.9 REDUCTION Command

This control card requests a network reduction to be performed on the base case or change case that has been defined. It generates an unsolved, reduced equivalent base case. Other commands must eventually follow to obtain the new solution and any desired outputs. However, system data could follow the `/REDUCTION` to update the reduced case.

The reduced system is composed of internal and enveloping retained nodes. The internal nodes undergo no change during the reduction. The enveloping nodes are those which have branches into the reduced system. However, these branches are replaced with equivalent branches connected to other enveloping nodes which simulate the reduced system. In addition, any nodal injection is distributed to the enveloping nodes in the form of continuation bus data.

All distributed injections and equivalent branches are flagged with the ownership code ***. This emphasizes their fictitious nature; however, they are valid system data and should be treated as such.

Note: "Default" means a blank entry. Zero entries and blank entries are distinct. If the default value is non-zero and the zero option is desired, a zero must be punched.

5.2 RETAINED NETWORK DEFINITION

The network to be reduced is obtained from a solved base case. The retained system is defined by the user in the INPUT file. Five options are available to the user as shown in Figure 5-9.

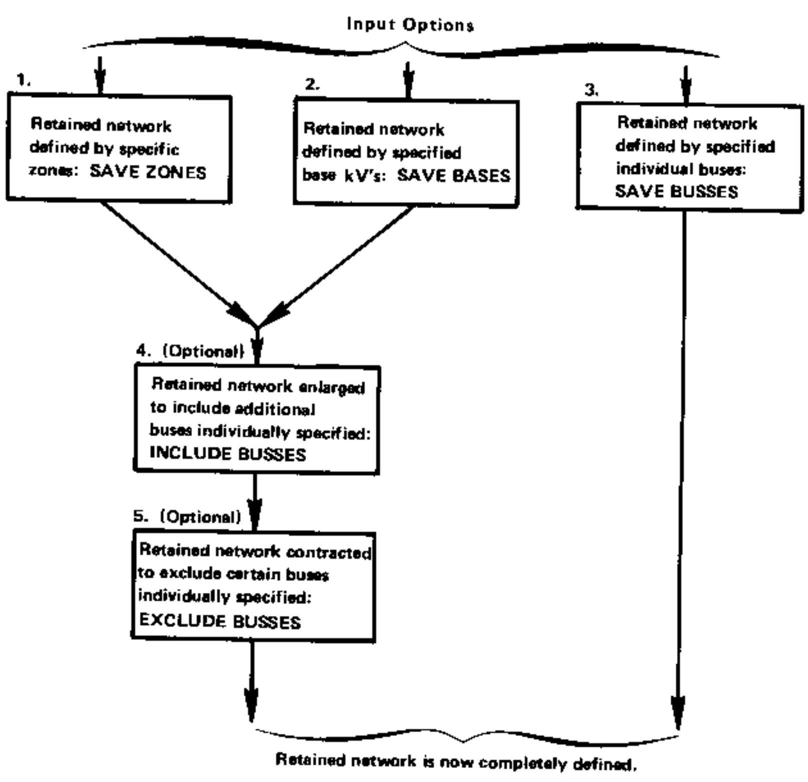


Figure 5-9. Retained Network Input Options

Each of the options 1 through 5 are affected by the unique control cards described in upper case characters in the blocks in Figure 5-9. Their formats are described in the following paragraphs.

5.2.1 Reduction Cards

The reduction cards specify the retained systems. There are several options available.

1. Zone Selection. The zones which normally define geographical areas may be used to define the retained system. All buses within these zones are then retained.

   The format is essentially "free-field". Commas separate the different zones and a period terminates the list. Any blanks are ignored unless immediately preceded by a comma or a period.

   The command `>SAVE_ZONES` must begin in column 1. If the zone list is too long to be contained on a single card, continuation cards must be used, in which a blank appears in column 1 and the zone list continued.

2. Base kV Selection. The retained system may be selected as the set of all buses with base kV's matching the specified set.

   As with the previous card, the format is essentially free-field. However, decimal points may be part of the base kV, necessitating a double period to terminate the list.

   The command `>SAVE_BASES` must begin in column 1. Continuation cards are permitted. If they are used, a blank must appear in column 1 as the base kV list continues.

3. Zone Selection Subjected to Base kV's. This is a combination of steps 1 and 2 described previously. Each of the zones selected is further stipulated to certain base kV's. Recognition is acknowledged that different zone/base kV combinations may be desirable, and several zone-base KV cards are permitted.

   The format is similar to steps 1 and 2 above. The difference is that the last zone (there may be only one) is followed by a comma and the words `>SAVE_BASES`. Continuation cards are permitted.

4. Inclusion and Exclusion of Buses to Retained System. The general criteria of saved zones, saved bases, or both is recognized as too general to adequately define all retained systems. Provisions permit the system thus defined to be enlarged or contracted by specifying individual buses which are to be included into or excluded from the retained system.

   The retained system is expanded with the control card.

   ```
   >INCLUDE_BUSES
   ```

   beginning in column 1 and followed with separate bus cards. The bus card need only contain the B in column 1, and the bus name and base kV in columns 7-18. All other fields are ignored. The list of included buses is terminated when a card without a B in column1 is encountered.

The retained system is contracted with the control card

```
>EXCLUDE_BUSES
```

beginning in column 1 and followed with separate bus cards as described previously.

5. Individual Bus Selection. In lieu of options 1. through 4.described previously, the retained system could be identified by individually specified bus cards. This request is initiated with the control card

   ```
   >SAVE_BUSES
   ```

   beginning in column 1. Each retained bus is then individually specified with a bus card. Only the bus identification fields need be specified, that is, the B in column 1 and the bus name and base kV in columns 7-18. All other fields will be ignored. The list continues until a card without a B in column1 is encountered.

5.2.2 Input Listings

Following the program control card and subsequent reduction cards, the retained system is defined and two listings are produced. The first listing defines the retained network. Each bus name will be preceded with one or two of the following characters:

Blank	Retained bus is internal and unchanged.
E	Retained bus is an envelope node and will receive distributed injections and equivalent branches.
X	Retained bus is also an envelope node. However, everyone of the adjacent nodes is eliminated. This is acceptable but may not be intentional and is intended as an informative diagnostic.
*	Retained bus is selected by the optimal feature.
P	Retained bus is a generator.

The second listing defines all eliminated nodes.

APPENDIX A

PROGRAM CONTROL EXAMPLES

A.1 INTRODUCTION

This appendix gives several typical examples of PGM_CONTROL files. Details of database creation, Program Control Language (PCL) and standard database record formats can be found in Chapters 2 and 3. A series of examples of control files are given to demonstrate typical control setups for the Powerflow Program.

A.2 BASE CASE EXAMPLE

Purpose of Case: To solve a basic powerflow that contains all data in the control file.

```
(  POWERFLOW,CASEID=TEST1.DAT,  PROJECT = EXAMPLES  )
/ HEADER
H    WSCC Nine Bus Base Case
/ COMMENT
C
C  CASEB-1_  NINE-BUS CASE, ON CARDS, THAT IN ADDITION TO TESTING
C             THE FEATURES OF CASE A-1, ALSO FEATURES_TRANSFORMERS
C            AND SUBTYPE "E" BUSES.
C
/ P_INPUT_LIST,FULL
/ P_OUTPUT_LIST,FULL
/ AI_LIST=NONE
/ P_ANALYSIS_RPT,LEVEL = 4
/ F_ANALYSIS_RPT,LEVEL = 1
/ NEW_BASE, FILE = NINEBUS.BSE
/ NETWORK_DATA
B     GEN1 HI    230  2  -0.0  -0.0  0.0  0.0     -0.0 -0.0 -0.0
B     GEN2 HI    230  1  -0.0  -0.0  0.0 0.0      -0.0 -0.0 -0.0
B     GEN3 HI   230   2  -0.0  -0.0  0.0 0.0      -0.0 -0.0 -0.0
B     STA A        230   1125.0  50.0  0.0 0.0    -0.0 -0.0 -0.0
B     STA B        230  2  90.     30.
B     STA C        230  2100.0   35.0 0.0 0.0     -0.0 -0.0  -0.0
BS   GEN1       16.5  2 -0.0    -0.0   0.0 0.0     71.6 -0.0 -0.01040
BE   GEN2       18 1   -0.0      -0.0  0.0 0.0    163.0 -0.0 -0.01025
BE   GEN3       13.8  2 -0.0    -0.0   0.0 0.0     85.0 -0.0 -0.01025
L     GEN1 HI    230 STA B       230  1        1700  9200        7900
L     GEN1 HI    230 STA B       230  2        1700  9200        7900
L     GEN1 HI    2302STA A      230           1        85              88
L     GEN3 HI    230 STA B       230            39       17              179
L     STA C        230 GEN3 HI   230            1190  10080   10450
L     STA A        230 GEN2 HI   230             32      161            153
```

```
L     GEN2 HI   2302STA C       230              85       72            745
T     GEN1 HI   230 GEN1        16.5                 5760  23000 1650
T     GEN2 HI   230 GEN2           18                  6250  23000 1800
T     GEN3 HI   230 GEN3        13.8                   5860 23000 1380
(STOP)
```

A more convenient method to perform the preceding setup is to use a `NETWORK_DATA` file.

```
(  POWERFLOW,CASEID=TEST1.DAT,  PROJECT = EXAMPLES  )
/ HEADER
H      WSCC Nine Bus Base Case
/ COMMENT
C
C  CASEB-1_  NINE-BUS CASE, ON CARDS, THAT IN ADDITION TO TESTING
C            THE FEATURES OF CASE A-1, ALSO FEATURES TRANSFORMERS
C            AND SUBTYPE "E" BUSES.
C
/ NEW_BASE, FILE= NINEBUS.BSE
/ INCLUDE_CONTROL,FILE = CONFILE.CTL
/ NETWORK_DATA, FILE = BASE.DAT
(STOP)
```

Where `CONFILE.CTL` contains:

```
/ P_INPUT_LIST,FULL
/ P_OUTPUT_LIST,FULL
/ AI_LIST=NONE
/ P_ANALYSIS_RPT,LEVEL = 4
/ F_ANALYSIS_RPT,LEVEL = 1
```

and `BASE.DAT` contains:

```
B     GEN1 HI   230  2  -0.0  -0.0 0.0 0.0    -0.0 -0.0 -0.0
B     GEN2 HI   230  1  -0.0 -0.0 0.0 0.0     -0.0 -0.0 -0.0
B     GEN3 HI   230  2  -0.0 -0.0 0.0 0.0     -0.0 -0.0 -0.0
B     STA A       230 1125.0 50.0 0.0 0.0     -0.0 -0.0 -0.0
B     STA B       230 2 90.    30.
B     STA C      230 2100.0  35.0 0.0 0.0    -0.0 -0.0 -0.0
BS    GEN1    16.5  2  -0.0  -0.0 0.0 0.0     71.6 -0.0 -0.01040
BE    GEN2        18 1 -0.0   -0.0 0.0 0.0   163.0 -0.0 -0.01025
BE    GEN3     13.8 2 -0.0   -0.0 0.0 0.0     85.0 -0.0 -0.01025
L     GEN1 HI  230 STA B     230 1      1700  9200        7900
L     GEN1 HI  230 STA B     230 2      1700  9200        7900
L     GEN1 HI  2302STA A    230        1     85          88
L     GEN3 HI  230 STA B     230        39   17          179
L     STA C    230 GEN3 HI   230        1190 10080  10450
L     STA A    230 GEN2 HI   230        32   161         153
L     GEN2 HI  2302STA C   230         85   72          745
T     GEN1 HI  230 GEN1    16.5               5760            23000 1650
T     GEN2 HI  230 GEN2      18                6250            23000 1800
T     GEN3 HI  230 GEN3    13.8               5860            23000 1380
```

A.3 CHANGE CASE EXAMPLE

Purpose of Case: To load a system from a solved old base, and make data changes, and save a new base.

```
( POWERFLOW, CASEID = TEST-CHG,  PROJECT = TEST-WSCC-DATA)
/ NEW_BASE, FILE = 9BUSNEW.BSE
/ COMMENTS
C  CASEB-1_  NINE-BUS CASE, ON CARDS, THAT IN ADDITION TO TESTING THE
C             FEATURES OF CASE A-1, ALSO FEATURES  TRANSFORMERS AND
C             SUBTYPE "E" BUSES.
C                THE BUS_BRANCH FILE AND THE CHANGE FILE ARE REMOTE
/ INCLUDE_CONTROLS, FILE = TESTCONT.CTL
/ OLD_BASE, FILE= NINEBUS.BSE
/ CHANGES, FILE = CHANG.DAT
( STOP - END OF TEST )
```

Note: Commands are not performed in the order they are encountered, but in the order the program decides is logical.

A.4 MERGE CASE EXAMPLE 1

Purpose of Case: To merge two systems defined from separate solved old base files.

```
( POWERFLOW, CASEID = TEST-MERGE, PROJECT = TEST-MERGE_OLD_BASE )
/COMMENTS
C  CASE 2 - TEST BASE MERGE BY MERGING TWO IDENTICAL BASE SYSTEMS.
C           TWO MUTUALLY EXCLUSIVE SUBSYSTEMS ARE INTEGRATED TO
C           REGENERATE THE ORIGINAL SYSTEM.
C
C    EACH SYSTEM IS BUILT FROM DIFFERENT AREAS OF THE SAME OLDBASE
.
.     control options
.
/ P_INPUTLIST,FULL
/ F_INPUTLIST,NONE
/ P_OUTPUTLIST,FULL
/ F_OUTPUTLIST,NONE
/ AILIST=FULL
.
/ NEW_BASE, FILE = MERGOLD.BAS
.
.      DEFINE SUBSYSTEM "AREA 1"
.
/ MERGE_OLD_BASE, SUB_SYSTEM_ID = AREA-1, OLD_BASE = TESTDC.BAS
> USE_AIC
> SAVE_AREAS
A  AREA 1
.
.      DEFINE SUBSYSTEM "AREA 2"
```

```
/ MERGE_OLD_BASE, SUB_SYSTEM_ID = AREA-2,OLD_BASE = TESTDC.BAS
> SAVE_ AREAS
A  AREA 2
.
.      SUBSYSTEMS ARE NOW MERGED
.
.      ( CHANGES ) may now follow
.
( STOP )
```

A.5 MERGE CASE EXAMPLE 2

Purpose of case: To merge two topologically overlapping networks into one consolidated network and solve the network, creating a new base to be called `J86JFY82`. Each of the original networks is to be appropriately modified before the merger. The first network is a WSCC base case saved as `86J201.BSE` which must be modified by saving areas, excluding bases, renaming buses and excluding certain branches. The second network is the BPA system which will be extracted from the branch file `BDFY82W` using the extraction date Jan 1986.

```
(POWERFLOW, CASEID = J86FY82, PROJECT = BASEMERGE)
/NEWBASE FILE = [APF]J86FY82.BSE
.
.Note:  composite network will be solved with defaults.
.
/MERGE_OLD_BASE,SUBSYSID = WSCC_NETWORK,OLD_BASE=86J201.BSE
>SAVE_AREAS
.....
..... "A" - records - name fields only
.....
>EXCLUDE_BUSES
.....
..... "B" - records - name fields only
.....
>RENAME_BUSES
.....
..... rename table
.....
>EXCLUDE_BRANCHES
.....
..... "L" - records - name fields only
.....
/MERGE_NEW_BASE,SUBSYSID = BPA_NETWORK,BRANCH_DATA=BDFY84,DATE=186
.....
..... "B" - records for BPA system
.....
/CHANGES
.....
..... change records
.....
(STOP)
```

A.6 REDUCTION CASE EXAMPLE

Purpose of Case: To reduce an existing network to a desired size and solve the reduced network. Reduction is achieved by retaining only specified zones from the original system. Produce full input/output listings on microfiche. Partial input/output listings (restricted to certain specified zones) will be printed on paper. Give full analysis report on both paper and fiche. In solving the network, regulating transformers will be activated and area-interchange control will be switched to control mode. Provide full listing of area interchange flows.

```
(POWERFLOW, CASEID = A86FY81RED, PROJECT = SAMPLE_PCL)
/OLDBASE, FILE = A8601FY81.BA2
/REDUCTION
>SAVE_ZONES,NA,NB,NC,ND,NE,NF,NG,NH,NI,NJ,NR
>SAVE_ZONES 19,17,20,08,PR,27,16
/P_INPUT_LIST, ZONES=NA,NB,NC,ND,NE,NF,NG,NH,NI,NJ,NK
/P_INPUT_LIST, ZONES = 19,17,20,08,PR
/P_OUTPUT_LIST, ZONES= NA,NB,NC,ND,NE,NF,NG,NH,NI,NJ,NK
/P_OUTPUT_LIST, ZONES= 19,17,20,08,PR
/LTC = ON
/AI_CONTROL = CON
/AI_LIST = FULL
/P_ANALYSIS_RPT, LEVEL = 4
(STOP)
```

APPENDIX B

TYPICAL APPLICATION EXAMPLES

B.1 INTRODUCTION

Some typical power system design application examples are given in this appendix to demonstrate possible applications of the Powerflow program. Each example indicates possible uses of the program relative to some stated network planning objectives.

B.2 SETTING UP A NETWORK DATA FILE

Use the following values for this four-bus network:

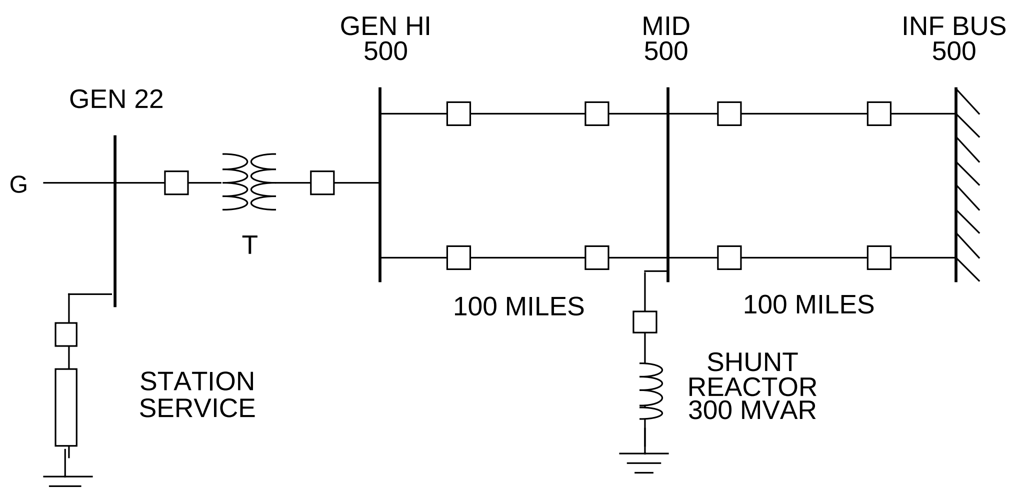


Figure B-1 Four Bus Network

Line Data

- Use 100 MVA, 500 kV base.
- X = .525 ohm/mile, X/R = 18.
- B/2 = .01024 pu/mile, where B is the total line charging and B/2 is equal to B_{pi}, if long-line effect is ignored.
- Current Rating is 3000 amps.

Transformer Data

- X = 20% (0.20 pu) on 525 kV, 1770 MVA base.
- Transformer Taps = 22 kV, 525 kV.

Generator Data for Power Flow.

- P(max) = 1770MW, P(g) = 1680 MW.
- Q(lim) = +/- 521MVAR.
- Type G bus controlling voltage of GEN HI to 1.08 pu.

Station Service Load

- 190 + j 95 (constant power for stability).

Approach

The preparation of the network data will be presented in the following steps:

1. Prepare the bus data group.

   Define the following buses:

   ```
   GEN 22
   GEN HI 500
   INF BUS 500
   MID 500
   ```

   a. Data for GEN 22

   ```
   Record Type:     B
   Sub Type:        G
   Change Code:     blank
   Owner:           blank (not specified)
   Name:            GEN
   KV:              22
   Zone:            blank (not specified)
   Load P MW:       190
   Load Q MVAR:     95
   ```

```
Shunt Load MW:   blank (or zero)
Shunt Load MVAR: blank (or zero)
P MAX:           1770
P GEN MW:        1680
Q MAX MVAR:      521
Q MIN MVAR:      -521
V MAX PU:        blank (not specified)
V MIN PU:        blank (not specified)
Remote Bus Name: GEN HI
Remote Bus kV:   500
% VARS Supplied: blank (defaults to 100)
```

b. Data for GEN HI 500

```
Record Type:     B
Sub Type:        C  (remotely controlled)
Change Code:     blank
Owner:           blank
Name:            GEN HI
kV:              500
Zone:            blank
Load P MW:       blank  (or zero)
Load Q MVAR:     blank  (or zero)
Shunt Load MW:   blank
Shunt Load MVAR: blank
P MAX:           blank
P GEN MW:        blank  (or zero)
Q MAX MVAR:      blank
Q MIN MVAR:      blank
V Hold PU:       1.08
V MIN PU:        blank  (not used)
Remote Bus Name: blank (none)
Remote Bus kV:   blank (none)
% VARS Supplied: blank (not applicable)
```

c. Data for INF BUS 500

```
Record Type:     B
Subtype:         S
Change Code:     blank
Owner:           blank
Name:            INF BUS
kV:              500
Zone:            blank
Load P MW:       blank
Load Q MVAR:     blank
Shunt Load MW:   blank
Shunt Load MVAR: blank
P MAX:           blank
P GEN MW:        blank
Q SCHED MVAR:    blank
Q MIN MVAR:      blank
```

```
V Hold PU:       1.05
V MIN PU:        blank
Remote Bus Name: blank
Remote Bus kV:   blank
% VARS Supplied: blank
```

d. Data for MID 500

```
Record Type:      B
Sub Type:         blank
Change Code:      blank
Owner:            blank (not known)
Name:             MID
KV:               500
Zone:             blank
Load P MW:        blank (zero)
Load Q MVAR:      blank (zero)
Shunt Load MW:    blank (zero)
Shunt React MVAR: -300
P MAX:            blank
P GEN MW:         blank
Q MAX MVAR:       blank (fixed)
Q MIN MVAR:       blank (fixed = Q MAX)
V MAX PU:         blank (defaults to global limit)
V MIN PU:         blank (defaults to global limit)
Remote Bus Name:  blank
Remote Bus kV:    blank
% VARS Supplied:  blank (not applicable)
```

Note: A bus can only be of one subtype. The subtype of a bus is suggested by information given about the bus. Therefore, the user should try to be familiar with various bus subtypes and when and how they are indicated by descriptive information given.

2. Prepare the branch data group.

```
Transformer:  GEN 22                 GEN HI 500
Line:         GEN HI 500             MID 500 circuit 1
Line:         GEN HI 500             MID 500 circuit 2
Line:         INF BUS 500            MID 500 circuit 1
Line:         INF BUS 500            MID 500 circuit 2
```

Note: 1 and 2 designations are arbitrary identifications for parallel branches. Letters A-Z and digits 0-9 are acceptable.

a. Data for Transformer GEN 22 GEN HI 500

```
Record Type:      T
Sub Type:         blank
Change Code:      blank
Owner:            blank (not known)
Name 1:           GEN
KV 1:             22
Meter:            blank
Name 2:           GEN HI
KV 2:             500
ID:               blank
Section:          blank
Total MVA RATE:   1770
No of CKT:        blank
Zpi
Rpu(100MVA):  blank (or zero)
Xpu(100MVA):  .01246
Ypi
Gpu(100MVA):  blank (or zero)
Bpu(100MVA):  blank (or zero)
Tap 1 kV:         22
Tap 2 kV:         525
Date In:          blank (in)
Date Out:         blank (not out)
```

b. Data for Line GEN HI 500 MID 500 circuit 1

```
Record Type:      L
Sub Type:         blank
Change Code:      blank
Owner:            blank (not known)
Name 1:           GEN HI
KV 1:             500
Name 2:           MID
KV 2:             500
ID:               1
Section:          blank
Total AMP RATING: 3000
No of CKT:        blank (means 1)
Zpi
Rpu:          .00117
Xpu:          .02100
Ypi
Gpu:          blank (zero)
Bpu:          1.024
Miles:            100
DESC DATA:        blank
Date In:          blank (in)
Date Out:         blank (not out)
```

c. Data for Line GEN HI 500 MID 500 circuit 2

```
Record Type:      L
Sub Type:         blank
Change Code:      blank
Owner:            blank (not known)
Name 1:           GEN HI
KV 1:             500
Meter:            blank
Name 2:           MID
KV 2:             500
ID:               2
Section:          blank
Total AMP RATING: 3000
No of CKT:        blank (means 1)
Zpi
Rpu:          .00117
Xpu:          .02100
Ypi
Gpu:          blank
Bpu:          1.024
Miles:            100
DESC DATA:        blank
Date In:          blank (in)
Date Out:         blank (not out)
```

d. Data for Line INF BUS 500 MID 500 circuit 1

```
Record Type:      L
Sub Type:         blank
Change Code:      blank
Owner:            blank (not known)
Name 1:           INF BUS
KV 1:             500
Meter:            blank
Name 2:           MID
KV 2:             500
ID:               1
Section:          blank
Total AMP RATING: 3000
No of CKT:        blank (means 1)
Zpi
Rpu:          .00117
Xpu:          .02100
Ypi
Gpu:          blank (zero)
Bpu:          1.024
Miles:            100
DESC DATA:        blank
Date In:          blank (in)
```

```
Date Out:         blank (not out)
```

e. Data for Line INF BUS 500 MID 500 circuit 2

```
Record Type:      L
Sub Type:         blank
Change Code:      blank
Owner:            blank (not known)
Name 1:           INF BUS
KV 1:             500
Meter:            blank
Name 2:           MID
KV 2:             500
ID:               2
Section:          blank
Total AMP RATING: 3000
No of CKT:        blank (means 1)
Zpi
Rpu:          .00117
Xpu:          .02100
Ypi
Gpu:          blank (zero)
Bpu:          1.024
Miles:            100
DESC DATA:        blank
Date In:          blank (in)
Date Out:         blank (not out)
```

Note: The most difficult task in setting up branch data is determining the per unit (pu) values of R, X, G and B.

Note: In this example, some preliminary information has been furnished on a per-mile basis. We have multiplied the per-mile quantities by the line lengths in order to obtain the data entered in the record. The reader should generally use detailed line constant calculation procedures to obtain more accurate values for high-voltage long lines. At 500 kV, 100 miles should be considered a long line. Energy conservation analysis is sensitive to the accuracy of high-voltage long-line branch data and transformer branch data.

Derivation of Transformer Xpu on 500kV, 100 MVA:

$$\begin{aligned}(\text{Xpu on 500kV 100 MVA}) &= (\text{Xpu on 525kV 1770 MVA}) \times \frac{525 \times 525}{500 \times 500} \times \frac{100}{1770} \\ &= 0.20 \times \frac{525 \times 525}{500 \times 500} \times \frac{100}{1770} \\ &= 0.012458\end{aligned}$$

Derivation of Line Xpu on 500 kV, 100 MVA:

All four lines are the same:

$$\text{Base inpedance in ohms} = \frac{\text{Base kV} \times \text{Base kV}}{\text{Base MVA}}$$

$$= \frac{(500)\ (500)}{100}$$

$$= 2500\,\text{ohms}$$

Ignoring long-line effect:

$$\text{Reactance for 100-mile line is 52.2 ohms} = \frac{52.5}{2500}\ \text{pu}$$

$$= 0.02100\ \text{pu}$$

Derivation of Line Rpu on 500 kV, 100MVA:

All four lines are the same:

$$\text{Rpu} = \frac{\text{Xpu}}{(\text{Xpu}) / (\text{Rpu})}$$

$$= \frac{0.02100}{18}$$

$$= 0.00117$$

Derivation of Line B/2pu on 500kV, 100 MVA:

All four lines are the same:

$$\text{Bpi (pu)} = \left[\frac{\text{'B}}{2}\ \text{pu/mile}\right] \times (\text{miles})$$

$$= (0.01024)\ (100)$$

$$= 1.024$$

Again long-line effect is ignored.

Derivation of Line Gpu on 500kV, 100 MVA:

All four lines are the same:

Gpu is negligible when long-line effect is ignored.. Zero is assumed for this case.

B.3 NEW FACILITIES

The purpose of this example is to provide facilities to serve the growing loads near the town of Keller and Mount Tolman.

B.3.1 Proposed New Facility

The proposed facility includes a new substation at NEW SUB, a 21-mile 230 kV line tapped from the A SUB - B SUB No. 2 line and another line to D SUB tapped from A SUB - NEW SUB line but which will be built and owned by another utility. The equipment at NEW SUB substation will include a 25 MVA transformer with protective equipment serving a 34.5 kV load. In the diagram on the following page, starred or dotted lines are the proposed facility while the dashed lines indicate existing facility. This proposed facility may be one among other possible alternatives. Each alternative, and modifications thereof, will be considered a case and submitted to the Powerflow program for analysis and report.

B.3.2 Possible Uses of Powerflow

The Powerflow program will be used to study the power flows, voltage regulation and reliability of service utilizing the proposed facility.

.

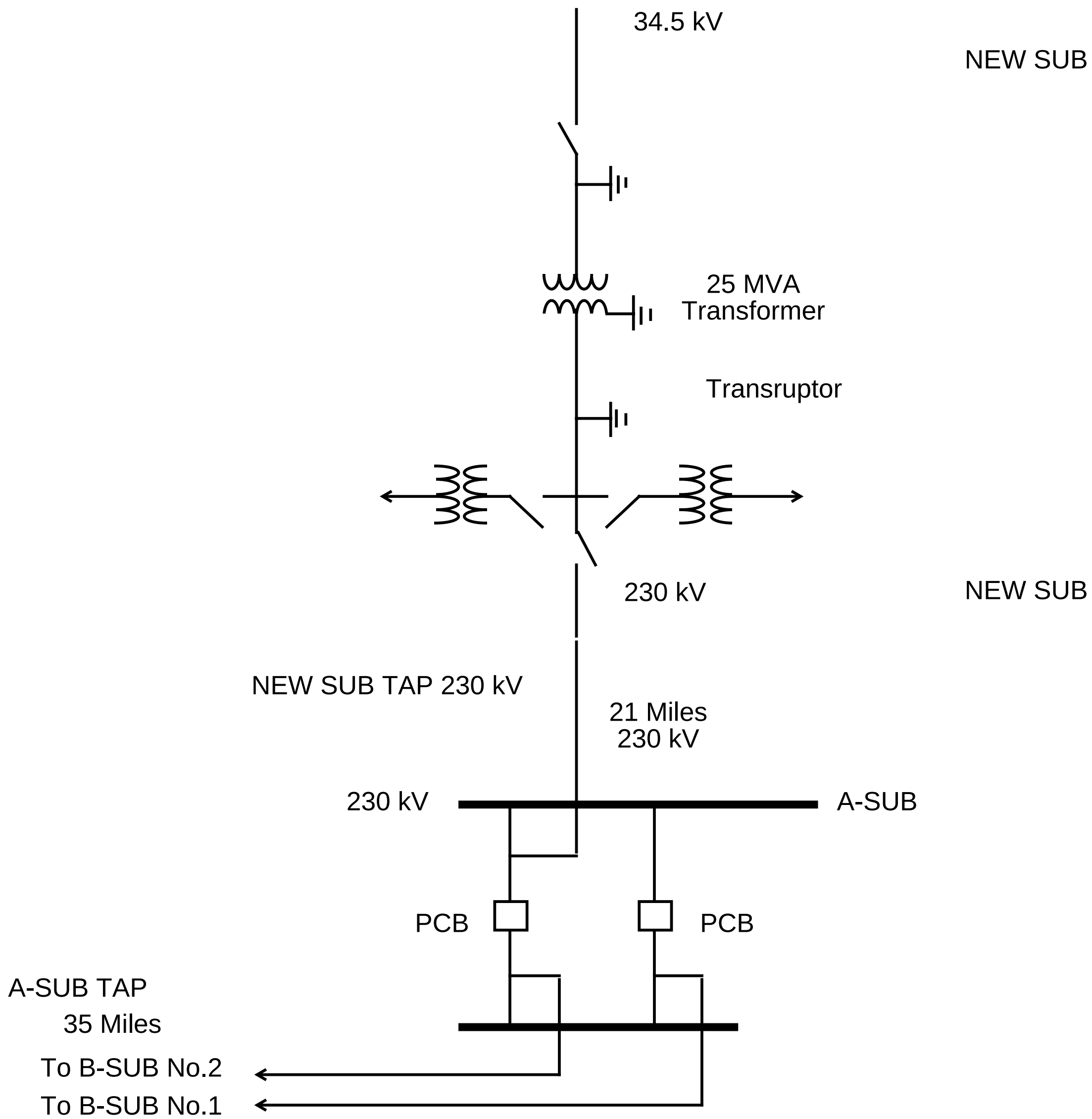


Figure B-2 A-SUB - New SUB 230 KV Line

The processes (`POWERFLOW`) and (`OUTAGE_SIM`) will be used to check power flow as well as reliability. Refer to Chapter 4, *Program Control and Database Files*, for a description of these processes.

Suppose the base network which the proposed new facility will amend has been described in an old base file named `BASENET.BSE`. The following program control file can be built for this case:

```
(POWERFLOW, CASEID = EXAMPLE1, PROJECT=KELLER-SUB)
/OLDBASE FILE = BASENET.BSE\
/NEWBASE = EXAMPLE1.CAS\
....
....  Optional Network Solution Qualifiers Listed Under
....                 (POWERFLOW)
/CHANGES
B - record for NEW SUB 34.5
B - record for NEW SUB 230
B - record for NEW SUB Tap 230
B - record for D SUB 230
B - record for A SUB TAP 230
L - record to delete A SUB 230 B SUB 230  2
L - record for A SUB 230 A SUB Tap 230
L - record for A SUB Tap 230 B SUB 230
T - record for NEW SUB 230 NEW SUB 34.5
. The above record formats are described
. Under appropriate Heading starting with the key letter
(POWERFLOW, CASEID=EXAMPLE1, PROJECT=NEW-SUB)
/OLDBASE FILE=EXAMPLE1.CAS
/OUTAGE_SIM
....
....  Optional Qualifiers Listed Under /OUTAGE_SIM
....
(STOP)
```

The output listings from this case will be inspected to make sure no overloads occur during normal operation as well as during the outages of key lines.

Special environmental concerns may suggest evaluation of alternatives to the river crossing indicated in the exhibit. Conductor sizing may also be influenced by energy conservation (loss-reduction) considerations. The effect of each alternative can be determined from the network solution output listing.

In this example, the major point to monitor is the impact of tapping lines since segments of a tapped line perform differently from the untapped line.

B.4 RECONDUCTORING

The purpose of this example is to cure poor voltage regulation at delivery point C occurring when lines AB, BC or DE are out of service, and to improve energy conservation.

B.4.1 Proposed New Facility

Lines AB, BC and DE will be reconductored to reduce series impedances using higher capacity lines. The higher capacity lines will give rise to acceptable voltages and save energy otherwise lost in transmission.

B.4.2 Possible Uses of Powerflow

The Powerflow program can be used to study the power flows, voltage regulation and reliability of service utilizing the proposed facility. In reference to the Program Control Language:

1. The base case is run to determine power flows, voltage levels and transmission losses.
2. The change case is run to modify the data for lines AB, BC and DE reflecting the new conductors used. Power flows, voltages and losses will again be reviewed.
3. The outage simulations case is run to verify the effect of certain lines being out of service on power flows, voltage levels, line loading and line losses. If the base network to be amended by the proposed new facility is described in an old-base file named `BASENET.BSE`, the program control file following the diagram of the reconductoring can be built for this project.

```
( POWERFLOW, CASEID = EXAMPLE30, PROJECT = RECONDUCT )
/ OLD_BASE, FILE = BASENET.BSE
. . .
. . .  Optional network solution qualifiers.
. . .
( NEXTCASE, CASEID = EXAMPLE31, PROJECT = RECONDUCT )
/ NEW_BASE, FILE = EXAMPLE31.CAS
. . .  Optional qualifiers to override options
. . .  already selected above.  This should be
. . .  an empty set.
/ CHANGES
L - record to modify line AB
L - record to modify line BC
L - record to modify line DE
( NEXTCASE, CASEID = EXAMPLE32, PROJECT = RECONDUCT )
/ OUTAGE_SIM
. . .
. . .  Optional simulation qualifiers.
. . .
( STOP )
```

B.5 SERIES COMPENSATION

The purpose of this example is to add series compensation to existing parallel lines so as to cause more power to be shifted to these lines from lines with less loss-reduction.

B.5.1 Proposed New Facility

A 540 MVAR series capacitor at Station C is installed (270 MVAR per line), along with additional control and protective equipment. Station C is sited 72 miles from Station A and 102 miles from Station B.

B.5.2 Possible Uses of Powerflow

The Powerflow program will be used to study the power flows utilizing the proposed facility.

If the base network amended by the proposed new facility is described in an old-base file named `BASENET.BSE`, then the following program control file can be built for this case:

```
( POWERFLOW, CASEID = EXAMPLE4, PROJECT = SERIES COMP )
/ OLD_BASE, FILE = BASENET.BSE
. . .
. . .  Optional solution qualifiers.
. . .
/ CHANGES
L - record to delete line AB circuit 1
L - record to delete line AB circuit 2
L - record to add Ckt circuit 1 section 1 (line AC)
L - record to add Ckt circuit 1 section 2 (capacitor)
L - record to add Ckt circuit 1 section 3 (line CB)
L - record to add Ckt circuit 2 section 1 (line AC)
L - record to add Ckt circuit 2 section 2 (capacitor)
L - record to add Ckt circuit 2 section 3 (line CB)
( STOP )
```

APPENDIX C

DC LINE MODELING

The following describes the data representation of a dc line as used in the Powerflow program. A typical configuration of the network is shown

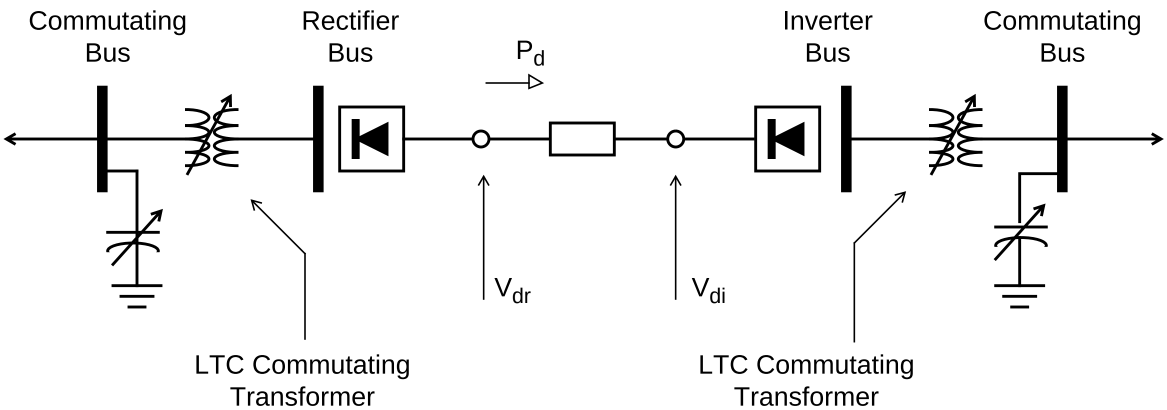


Figure C-1 Two Pole, Two Terminal dc Line Configuration

Each dc line requires two dc buses, a single dc line and two commutating buses, each of which is connected to the dc bus with a commutating transformer.

Representation of the commutating transformer conforms to the ac network; one transformer is required for each bridge. They are parallel connected in the ac network, necessitating either separate transformer data records or an equivalent transformer which has the correct parallel impedance and MVA rating. As shown in the diagram, the commutating transformers must be LTC, specifically type `R`, subtype blank, controlling the dc bus, and oriented such that the tap range encompasses the commutating bus base kV. The magnitude of the dc bus voltage to be controlled is automatically determined from the dc line parameters.

Assuming nominal taps, the dc no-load voltage V_{do} available from each converter bridge is approximated by the formula

$$V_{do} = 1.35 * E_v * \cos \alpha$$

where α is the firing angle at the rectifier and the extinction angle at the inverter. V_{do} is the no-load direct voltage and E_v is the effective voltage at the dc bus. The actual voltage is a chopped sinusoid.

The full load direct voltage will be less. Normal representation of the dc line usually models the positive and negative poles as separate but parallel dc lines. This scheme permits asymmetrical operation of the dc line. For example, one bridge may temporarily be out of operation. In this case, one pole may have three bridges while the other has only two.

With this scheme, the model may be as shown as follows.

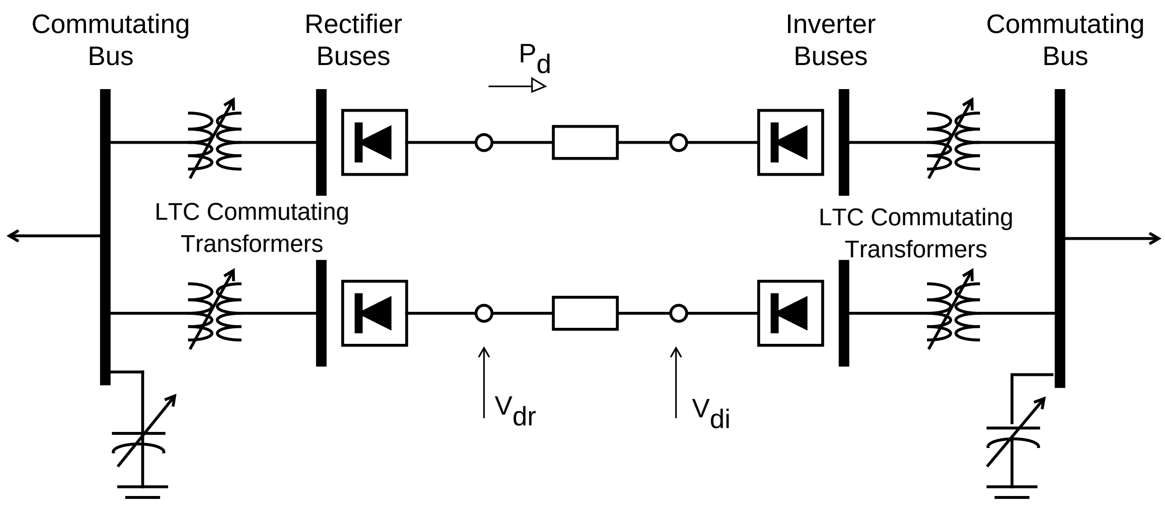


Figure C-2 Single Pole, Two Terminal dc Line Re

In the former scheme the dc line quantities are pole-to-pole. In the latter scheme, the quantities are pole-to-neutral. However, the direct voltage must always be positive on the line data record.

When using the pole-to-neutral scheme, the direct voltage of each pole must correspond to the number of bridges in operation. It is recommended that the allocation of the total dc power to each pole should result in no net neutral current, that is, the current in each pole must be equal but opposite.

An example will clarify this. Assume that the normal direct voltages is 800 kV pole-to-pole with six bridges in operation, or 133 kV/bridge. It is desired to find the voltage and power in each pole required to transport 600 MW with one negative bridge out of operation. This situation is shown as follows

Positive pole line voltage	= 3 * 133 kV	= 400 kV dc
Negative pole line voltage	= 2 * 133 kV	= 267 kV dc
Total voltage (pole-to-pole)		= 667 kV dc

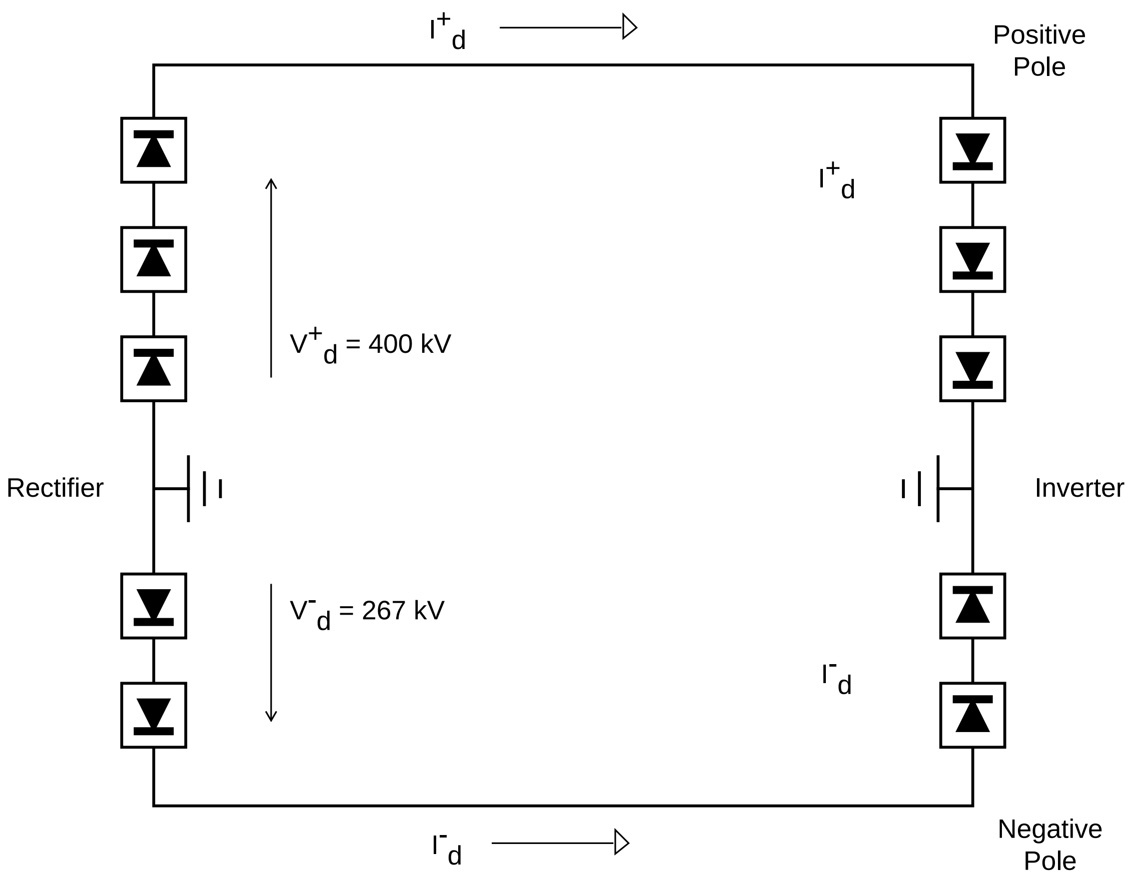


Figure C-3 One Negative Bridge Out of Operation

For zero neutral current, $I^{+}_{d} = I^{-}_{d}$ (with positive values assigned in the direction shown)

$$I_d = \frac{p_{dc}}{V_{dc\text{pole-to-pole}}} = \frac{600 \text{ MW} \times 1000 \text{ kV/MW}}{667 \text{ kV}} = 900 \text{ amps}$$

$$P^+_{dc} = V^+_{dv} \times I^+_{dc} = 400 \text{ kV} \times 900 \text{ amps}$$

$$= 360,000 \text{ kW} = 360 \text{ MW}$$

$$P^-_{dc} = V^-_{dv} \times I^-_{dc} = 267 \text{ kV} \times 900 \text{ amps}$$

$$= 240,000 \text{ kW} = 240 \text{ MW}$$

Assuming the dc line was modeled for six-bridge operation, the only changes required to take a bridge out of service would be modification of the following quantities:

- Positive and negative pole dc line power on the `LD` record.
- Negative pole dc line voltage on the `LD` record.
- Delete one of the parallel commutating transformers at each end of the negative pole dc line.
- Change the number of bridges for both converter buses.

APPENDIX D

OWNERSHIP CODES

The following ownership codes and expanded names are hard-coded into the Powerflow program, and are used only by the `/OI_LIST` command.

Ownership Code	Ownership Name
AAC	ANACONDA ALUMINUM COMPANY
AEC	ATOMIC ENERGY COMMISSION
AEP	ARIZONA ELECTRIC POWER COOPERATION
ALA	ALABAMA POWER COMPANY
ALC	ALUMINUM COMPANY OF AMERICA
APS	ARIZONA PUBLIC SERVICE COMPANY
ARL	ARKANSAS POWER AND LIGHT COMPANY
ARR	ARROWHEAD ELECTRIC COOPERATIVE, INC.
AVC	AMARGOSA VALLEY COOPERATIVE INC.
BBE	BIG BEND ELECT. COOP
BCH	BRITISH COLUMBIA HYDRO AND POWER AUTHORITY
BEC	BASIN ELECTRIC POWER COOP.
BEP	BASIN ELECTRIC COOPERATIVE
BHP	BLACK HILLS POWER AND LIGHT COMPANY
BPA	BONNEVILLE POWER ADMINISTRATION
BPD	BENTON CO. PUD
BRE	BENTON REA
CAL	CALIFORNIA DEPARTMENT OF WATER RESOURCES
CCC	COOS CURRY ELECTRIC COOP
CCP	COWLITZ COUNTY PUBLIC UTILITY DISTRICT NO.1
CCS	CITY OF COLORADO SPRINGS
CE1	DEP. OF ARMY CORPS OF ENGINEER (REGION 1 AREA)
CE2	DEP. OF ARMY CORPS OF ENGINEER (REGION 2 AREA)
CE3	DEP. OF ARMY CORPS OF ENGINEER (REGION 3 AREA)
CE4	DEP. OF ARMY CORPS OF ENGINEER (REGION 4 AREA)
CE5	DEP. OF ARMY CORPS OF ENGINEER (REGION 5 AREA)
CE6	DEP. OF ARMY CORPS OF ENGINEER (REGION 6 AREA)
CE7	DEP. OF ARMY CORPS OF ENGINEER (REGION 7 AREA)
CEC	COMMONWEALTH EDISON COMPANY (ILLINOIS)
CED	COMMONWEALTH EDISON COMPANY OF INDIANA, INC.
CEN	CENTRAL POWER ELECTRIC COOP., INC. (N. DAKOTA
CIP	CENTRAL IOWA POWER COOPERATIVE
CIS	CENTRAL ILLINOIS PUBLIC SERVICE COMPANY
CLA	CLALLAM PUD
CLK	CLARK COUNTY PUBLIC UTILITY DISTRICT NO. 1
CLP	CENTRAL LINCOLN PUD
CLT	CLATSKANIE PUD
CMS	CHICAGO, MILWAUKEE, ST.PAUL AND PACIFIC R.R. CO.
CNP	CENTRAL NEBRASKA PUBLIC POWER AND IRRIGATION DIST.

COB	CORN BELT POWER COOPERATIVE, INC.
COE	DEP. OF ARMY CORPS OF ENGINEERS
COR	CITY OF RICHLAND
CPA	COOPERATIVE POWER ADMINISTRATION
CPD	CHELAN COUNTY PUBLIC UTILITY DISTRICT NO. 1
CPI	CONSUMERS POWER INC.
CPL	CALGARY POWER LIMITED
CPN	C P NATIONAL
CPP	CONSUMERS PUBLIC POWER DISTRICT (NEBRASKA)
CPS	COMMUNITY PUBLIC SERVICE CO.
CPU	CALIFORNIA PACIFIC UTILITIES COMPANY
CRP	COLUMBIA RIVER PUD
CU	COLORADO-UTE ELECTRIC ASSOCIATION
DPC	DAIRYLAND POWER COOPERATIVE (WISC., MINN.)
DPD	DOUGLAS COUNTY PUBLIC UTILITIES DISTRICT
EEQ	EASTERN EQUIVALENT
EIL	EASTERN IOWA LIGHT AND POWER COOPERATIVE
ELE	EL PASO ELECTRIC COMPANY
ELP	EL PASO ELECTRIC COMPANY
EMP	EMERALD PUD
EPE	EL PASO ELECTRIC
ERP	EAST RIVER ELECTRIC POWER COOP.,INC.(S. DAKOTA)
EWE	EUGENE WATER AND ELECTRIC BOARD (OREGON)
FRC	FALL RIVER ELEC. COOP
FRK	FRANKLIN CO. PUD
GH	GRAYS HARBOR COUNTY PUBLIC UTILTIY DISTRICT
GPD	GRANT COUNTY PUD NO.2 (WASHINGTON)
GSU	GULF STATE UTILITIES COMPANY (TEXAS, LOUISIANA)
HAR	HARNEY ELECTRIC COOP
HEA	HIGHLINE ELECTRIC ASSOCIATION
HPL	HOUSTON POWER AND LIGHT COMPANY
IDP	IDAHO POWER COMPANY
IEL	IOWA ELECTRIC LIGHT AND POWER
IGE	IOWA ILLINOIS GAS AND ELECTRIC COMPANY
IID	IMPERIAL IRRIGATION DISTRICT (CALIFORNIA)
IIG	IOWA-ILLINOIS GAS & ELECTRIC CO.
ILL	ILLINOIS POWER COMPANY
ILM	ILLINOIS AND EASTERN MISSOURI
IME	INDIANA AND MICHIGAN ELECTRIC COMPANY
INL	INLAND POWER AND LIGHT
INP	INLAND POWER AND LIGHT COMPANY
IPC	IDAHO POWER COMPANY
IPL	IOWA POWER AND LIGHT COMPANY
IPS	IOWA PUBLIC SERVICE COMPANY
IPU	IOWA SOUTHERN UTILITIES CO.
ISP	INTERSTATE POWER COMPANY
ISU	IOWA SOUTHERN UTILITIES COMPANY
KCP	KANSAS CITY POWER AND LIGHT COMPANY
KGE	KANSAS GAS AND ELECTRIC COMPANY
KPL	KANSAS POWER AND LIGHT COMPANY
LA	CITY OF LOS ANGELES DEPARTMENT OF WATER AND POWER

LCR	LOWER COLORADO REGION WESTERN AREA POWER ADMIN.
LEC	LANE CO. ELEC.COOP.
LES	LINCOLN ELECTRIC SYSTEM
LEW	LEWIS CO. PUD.
LPL	LOUISIANA POWER AND LIGHT COMPANY
LSD	LAKE SUPERIOR DISTRICT POWER COMPANY
LVP	LOWER VALLEY POWER AND LIGHT
MAI	MAIN-MID-AMERICA INTERPOOL NETWORK
MCM	MCMINNVILE, CITY OF
MDU	MONTANA-DAKOTA UTILITIES COMPANY
MFR	MILTON-FREEWATER
MH	MANITOVA HYDRO ELECTRIC BOARD
MIN	MINNKOTA POWER COOPERATIVE, INC.
MLC	MISSOURI POWER AND LIGHT COMPANY
MLE	MOON LAKE ELECTRIC ASSOCIATION, INC.
MN1	MASON COUNTY PUD #1
MN3	MASON COUNTY PUD #3
MPC	MONTANA POWER COMPANY
MPL	MINNESOTA POWER AND LIGHT COMPANY
MPO	MISSISSIPPI POWER AND LIGHT COMPANY
MPR	MID PACIFIC REGION - USBR
MPS	MISSOURI PUBLIC SERVICE COMPANY
MPW	MUSCATINE POWER AND WATER
MWD	METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA
NEP	N.W. ELECTRIC POWER COOP., INC. (MISSOURI,ARK.)
NGT	NEBRASKA ELECTRIC GENERATING AND TRANSMISSION COOP
NIP	NORTHWEST IOWA POWER COOPERATIVE
NLI	NORTHERN LIGHTS,INC.
NPC	NEVADA POWER COMPANY
NPP	NEBRASKA PUBLIC POWER SYSTEM
NPR	NORTH PACIFIC REGION - USBR
NSC	NORTHERN STATES POWER COMPANY, (WISCONSIN)
NSP	NORTHERN STATES POWER COMPANY, (MINN.,N.D.,S.D.)
NWA	NORTHERN WASCO PUD
NWP	NORTHWESTERN PUBLIC SERVICE COMPANY (S. DAKOTA)
OGE	OKLAHOMA GAS AND ELECTRIC COMPANY
OKP	OKANOGAN CO. PUD
OPD	OMAHA PUBLIC POWER DISTRICT
OPP	OMAHA PUBLIC POWER DISTRICT
OTC	OREGON TRAIL COOP
OTP	OTTER TAIL POWER COMPANY
OWI	OROVILLE-WYANDOTTE IRRIGATION DISTRICT, (CALIF.)
PAN	PORT ANGELES
PDO	PEND OREILLE PUD
PEG	PLAINS ELECTRIC G AND T COOP(NEW MEXICO)
PEN	PENINSULA LT. CO.
PG	PORTLAND GENERAL ELECTRIC COMPANY
PGE	PACIFIC GAS AND ELECTRIC COMPANY
PGT	PLAINS ELECTRIC G AND T COOP., (NEW MEXICO)
PNM	PUBLIC SERVICE COMPANY OF NEW MEXICO
PPL	PACIFIC POWER AND LIGHT COMPANY

PPW	PACIFIC POWER AND LIGHT - WYOMING
PRP	PLATTE RIVER POWER AUTHORITY
PSC	PUBLIC SERVICE COMPANY OF COLORADO
PSI	PUBLIC SERVICE COMPANY OF INDIANA
PSO	PUBLIC SERVICE COMPANY OF OKLAHOMA
PSP	PUGET SOUND POWER AND LIGHT COMPANY
R1	WESTERN AREA POWER ADMIN. REGION 1
R2	WESTERN AREA POWER ADMIN. SACRAMENTO AREA
R3	WESTERN AREA POWER ADMIN. REGION 3
R4	WESTERN AREA POWER ADMIN. SALT LAKE CITY AREA
R5	WESTERN AREA POWER ADMIN. REGION 5
R6	WESTERN AREA POWER ADMIN. BILLINGS AREA
R7	WESTERN AREA POWER ADMIN. DENVER AREA
RCP	RURAL COOPERATIVE POWER ASSOCIATION, (MINNESOTA)
RFT	RAFT RIVER RURAL ELECTRIC COOP
SC	SOUTHERN CALIFORNIA EDISON COMPANY
SCE	SOUTHERN CALIFORNIA EDISON COMPANY
SCL	SEATTLE CITY LIGHT COMPANY
SCP	SOUTHEAST COLORADO POWER ASSOCIATION
SDG	SAN DIEGO GAS AND ELECTRIC COMPANY
SJL	SAINT JOSEPH LIGHT AND POWER COMPANY
SMD	SACRAMENTO MUNICIPAL UTILITIES DISTRICT
SPA	SOUTHWESTERN POWER ADMIN.
SPC	SASKATCHAWAN POWER COMPANY
SPD	SNOHOMISH COUNTY PUBLIC UTILITIES DISTRICT
SPP	SIERRA PACIFIC POWER COMPANY
SPS	SOUTHWESTERN PUBLIC SERVICE COMPANY
SRP	SALT RIVER POWER DISTRICT
SUB	SPRINGFIELD UTILITY BOARD
SWP	SOUTHWESTERN POWER ADMINISTRATION
SWR	SOUTHWEST REGION - USBR
TCE	TRI-COUNTY ELECTRIC ASSOCIATION, INC. (WYOMING)
TCL	TACOMA CITY LIGHT COMPANY
TEP	TUSCON ELECTRIC POWER COMPANY
TES	TEXAS ELECTRIC SERVICE COMPANY
TGE	TUCSON GAS AND ELECTRIC COMPANY
TIL	TILLAMOOK PUD
TPL	TEXAS POWER AND LIGHT COMPANY
TRI	TRI-STATE GENERATION AND TRANSMISSION ASSOC.
TSG	TRI-STATE GENERATION AND TRANSMISSION ASSOC.
TVA	TENNESEE VALLEY AUTHORITY
UEC	UNION ELECTRIC COMPANY (IOWA,MISSOURI,ILLLINOIS)
UPA	UNITED POWER ASSOCIATION, INC. (NORTH DAAKOTA)
UPL	UTAH POWER AND LIGHT COMPANY
USN	U.S.NAVY
WAP	WESTERN AREA POWER ADMINISTRATION-BILLINGS AREA
WEP	WISCONSIN ELECTRIC POWER COMPANY
WIS	WISCONSIN PUBLIC SERVICE CORP.
WKP	WEST KOOTENAY POWER AND LIGHT COMPANY, LTD.
WMP	WISCONSIN MICHIGAN POWER COMPANY
WPD	WHATCOM COUNTY PUD

WPS	WASHINGTON PUBLIC POWER SUPPLY SYSTEM
WRP	WISCONSIN RIVER POWER COMPANY
WRE	WELLS RURAL ELECTRIC CO.
WST	WESTERN POWER AND GAS COMPANY (COLORADO)
WWP	WASHINGTON WATER POWER COMPANY
YWE	YUMA WRAY ELEC.ASSN.,INC.

APPENDIX E

GLOBAL VOLTAGE LIMITS AND STARTING VOLTAGES

The following table allows you to find global and starting voltages for a bus given the base kV and zone. These values are hard-coded in the program and cannot be altered by the user.

Table E-1 Global Voltage Limits and Starting Voltages

Base KV From	Range To	Zone Restrictions	Global V Limits		Starting V	
			V_min (p.u.)	V_max (p.u.)	Gen Buses (40%)	Load Buses (20%)
0.1	6.5		0.950	1.052	1.011	1.032
6.6	6.6	M1	0.950	1.065	1.019	1.042
6.6	49.9		0.950	1.052	1.011	1.032
50.0	50.0	16	1.100	1.200	1.160	1.180
50.0	59.9		0.950	1.052	1.011	1.032
60.0	60.0	17	0.950	1.100	1.040	1.070
60.0	62.9		0.950	1.052	1.011	1.032
63.0	63.0	20	0.930	1.080	1.020	1.050
63.0	99.9		0.950	1.052	1.011	1.032
100.0	100.0	16 M5	1.100	1.200	1.160	1.180
100.0	100.0	M4	0.950	1.070	1.022	1.046
100.0	114.9		0.950	1.052	1.011	1.032
115.0	115.0	M4	0.950	1.070	1.022	1.046
115.0	131.9		0.950	1.052	1.011	1.032
132.0	161.0	17 20	0.950	1.090	1.034	1.062
132.0	199.9		0.950	1.052	1.011	1.032
200.0	200.0	16	1.100	1.200	1.160	1.180

Table E-1 Global Voltage Limits and Starting Voltages (Continued)

Base KV From	Range To	Zone Restrictions	Global V Limits		Starting V	
			V_min (p.u.)	V_max (p.u.)	Gen Buses (40%)	Load Buses (20%)
200.0	229.9		0.950	1.052	1.011	1.032
230.0	230.0	17 20	0.950	1.070	1.022	1.046
230.0	499.9		0.950	1.052	1.011	1.032
500.0	500.0		1.000	1.100	1.060	1.080
500.1	1099.9	1	0.950	1.052	1.011	1.032
1100.0	1100.0	1	1.000	1.100	1.060	1.080
1100.1	9999.9	1	0.950	1.052	1.011	1.032

E.1 TABLE NOTES

1. Twenty percent (20%) and forty percent (40%) starting voltages are the percentages from V_max to V_min:

   ```
   V_start = V_max * (1 - %pct)  + V_min * %pct
   ```

   ```
   "0%" starts at V_max; "100%" starts at V_min.
   ```

   Ideal starting percentages would be a value which lies closest to the final voltages. For peak load cases, a generator percentage of 30% is better; for light loads, 50% is better. The current 40% is a trade-off.

2. Zone restrictions mean that base kV's are also subject to zones. If the zone restriction list has nonblank entities, only base kV's within the range and zone list zones apply. Conversely, if the zone restriction list is blank, then there are no zone restrictions: all base kV's within the range apply.

3. To find global and starting voltages for a bus with Base XXX and Zone ZZ, proceed as follows:

   a. Find the encompassing base kV:

      ```
      From_base  <= XXX <= To_base
      ```

      There will be one or more such ranges. Zone restrictions may qualify the base range.

b. If zone restrictions apply, check whether zone ZZ qualifies. If true, then the pertinent entity has been located.

   If false, proceed to the next encompassing base kV and repeat step b. All encompassing base ranges terminate with an inclusive blank zone list, which ultimately defaults to “no restrictions”.

APPENDIX F

AUXILIARY POWERFLOW PROGRAMS

Some auxiliary Powerflow programs extend the capabilities of IPF proper. With these programs, you can run cases in batch mode, do plots in batch mode, do a save of network data in batch mode, perform a “cut” of a solved base case, etc. Some of these auxiliary programs are briefly described here.

F.1 IPFCUT

The stand-alone program that cuts out a subsystem from a solved base case file is called `IPFCUT`. The full system resides in a base case file; the cut system is a card image BUS/BRANCH data file. Flows at the cut branches are converted into equivalent generation or load on specially formatted `+A` continuation bus records. An ensuing Powerflow run should solve with internal branch flows and bus voltages which are identical to those quantities in the original base case.

- Several methods are available to define the cut system: specifying individual buses, zones, base kVs, or individual branches.
- A pi-back feature replaces selected buses with a passive-node sequence (lines consisting of sections) with the original loads, generation, and shunts, pi-backed in proportion to the line admittances.

The function of `CUTTING` and `REDUCTION` are similar, but their methodologies are different. Both generate subsystems whose internal composition and characteristics are identical to that of the base case. `REDUCTION` generates equivalent branches, shunt admittances, and injections such that internal nodes still “see” the full system. `CUTTING` generates equivalent shunt admittances and injections such that internal nodes can determine that the boundary has changed and the external system has been cut out, even though the internal flows and nodal voltages are identical.

The `CUTTING` program mandates that the flow into the cut-out system is constant. This is valid for eliminating radial feeder circuits, but not for eliminating a strongly interconnected external network. In the latter case, `REDUCTION` yields a more responsive equivalent.

A simple criterion can be used to determine whether `CUTTING` or `REDUCTION` is more appropriate.

- Will a line outage or other major perturbation near the boundary of the retained subsystem and eliminated system significantly alter the flow between the two systems?

If the answer is *no*, the flow will not be significantly altered, then `CUTTING` is acceptable. (It is the author's opinion that `REDUCTION` is always superior.)

The `CUTTING` program is initiated by entering `IPFCUT` at the keyboard after the computer displays the system prompt.

From this point on the operation is interactive. You should respond to the questions as they are asked.

F.1.1 Cutting Methodologies

Two simple techniques are employed. Both may be used.

- **Cutting the eliminated branches.** In cutting, the active and reactive power flowing into a cut branch is replaced with an equivalent but fictitious load, which is appended to the terminal bus with continuation buses (+A).
- **Pi-backing loads of retained buses.** In pi-back, the loads and shunt susceptances on selected pi-back buses are distributed to neighboring terminal buses in proportion to their branch admittances. Only branch transfer susceptance is used (a good approximation when X >> R). Also, the pi-back bus may contain at most two branches. This corresponds with early reduction schemes. The quantities pi-backed are appended to the terminal buses on specially coded continuation cards (`+A ***`).

F.1.2 Input Commands

The syntax of CUT commands conform to the convention that has been adopted for the Powerflow program.

```
[FICHE, copies=n]
(CUTTING, Project=name, case ID=name)
```

The qualifiers that select the subsystem and enable special options are listed below:

```
>DEBUG<
>EXCLUDE_BUSES<
>INCLUDE_BUSES<
>PI_BACK_BUSES<
>SAVE_BUSES...<
>CUT_BRANCHES<
>SAVE_ZONES...,SAVE_BUSES...<
>WSCC<
```

`>WSCC<` Enables the WSCC option. The default is no WSCC. Special processing is effected with this option:

1. Active power flowing from a cut branch into a bus is treated as a bus load under the WSCC option. Otherwise, it is treated as a load or generation depending upon the sign of the quantity.
2. Base kV fields omit the decimal point without the WSCC option. For example, a 115.0 KV appears as “115”. Under the WSCC option, the same field

appears as "115.". The WSCC Powerflow program interprets the base fields as character instead of decimal, and those two fields are unique! Lane 115. is in New Mexico but LANE 115 is in Oregon!

3. Line sections created from pi-back are consolidated into a single equivalent pi branch with the WSCC option enabled. Otherwise, the branch records are preserved (with the necessary name changes). There is one exception: If a step-up/step-down transformer-line transformer occurs, the branch is unconditionally made into an equivalent section.
4. Any branch in the cut list that has an INT in the ownership field has its flow transferred to a +A INT continuation bus instead of a +A *** bus.

>DEBUG<

Opens the program debug file. Output appears on a file with subtype .PFD. This is used only by the program developers.

>SAVE_ZONES...,SAVE_BUSES...<

Defines the retained network as all buses whose bases and zones *both* match the specified list. If SAVE_BUSES is null or omitted, only zones are considered. Continuation cards begin with a "+" in column 1.

For example: >SAVE_ZONES NA,NB,NC,ND,NE,NF,NG,NH, NI,NJ,NK,RM<

Any number of >SAVE_ZONE...SAVE_BASE< commands may be submitted. >SAVE_BASES...< defines the retained network as all bases whose buses match the specified list. It is not necessary to type a decimal part unless it is part of the base kV, for example, 13.8 but not 3.46. Continuation cards begin with a "+" in column 1.

The system is initialized as an eliminated network. The following commands define the composition of the retained system. With the exception of >CUT_BRANCHES<, the effect of the commands may be repeated in any order. Their effects are overlaid.

>INCLUDE_BUSES<
>EXCLUDE_BUSES<
>SAVE_BUSES<

These commands introduce buses that are specified on bus records that follow (B in column 1).

>SAVE_BUSES is used to specify the entire cut system, bus by bus.

>INCLUDE_BUSES is used to expand the cut system with individually named buses. This is used in context with >SAVE_ZONES or >SAVE_BUSES to provide more flexibility in the cut system.

>EXCLUDE_BUSES is used to contract the cut system with individually named

buses. This is used in context with >SAVE_ZONES or >SAVE_BUSES to provide more flexibility in the cut system.

A maximum of 1000 records are permitted. In the unlikely event that this is insufficient, the above command(s) may be simply repeated with an additional block of bus records.

>CUT_BRANCHES<

This command introduces branches that are specified on line records that follow (L,T, or E in column 1). A maximum of 500 cut branch records is permitted.

The CUT_BRANCHES are oriented in the following order: retained bus, cut bus.

The cut system is defined in the following manner. Starting from the set of all cut branches, each bus on the cut side, which is in the eliminated system, is expanded one-adjacent by examining each branch connected to that bus. All branches that are not connected to any bus on the retained bus side are in the cut system. Those terminal buses are eliminated.

The first pass determines all buses 1-adjacent that are in the cut system. The process is repeated, starting with all buses 1-adjacent to the cut boundary to find all buses 2-adjacent. This process is repeated until no further expansion occurs in either system. The major advantage of this approach is that any incomplete cut enclosure is properly diagnosed near the missing branch.

If the WSCC qualifier is selected, any branch in the cut list that has an INT in the ownership field will have its flow transferred to a +A INT continuation bus instead of a +A *** bus. This is done so that if this cut system is to be reintegrated into another system the cut points can be easily identified and discarded.

Unlike other >...< commands, CUT_BRANCH cannot be repeated.

>PI_BACK_BUSES<

This process replaces a bus having one or two branches with an equivalent consisting of bus generation, load, and shunt admittances on the adjacent terminal buses.

If the bus originally had two branches, the new system has the following changes:

- The buses' generation, load, and shunt admittance are proportioned by the branch admittance to each terminal node.
- The bus is eliminated.
- The subsystem consisting of a bus and two branches is replaced with a sin-

gle branch spanning the two terminal buses.

If the bus originally had one branch, the new system has the following changes:

- The buses' generation, load, and shunt admittance are transferred to the terminal node.
- The bus and its branch are eliminated.

In essence, a pi-backed bus becomes a passive node in a branch that now consists of sections. Since the quantities are pied-back in proportion to their branch admittances, the redistribution approximates the effects of `REDUCTION`. A maximum of 1000 pi-back records may follow. If this limit is insufficient, the remaining pi-back records may follow another `>PI_BACK<` command.

F.1.3 Interactive Execution

The following is an example of the dialogue that occurs during an interactive execution. User responses are bold.

```
* command file is: J8301FY84.CUT
ENTER NAME for BUS/BRANCH output file > J83CUT.DAT
ENTER file name for OLD_BASE > A8301FY84.BSE
```

F.2 IPFNET

The GUI allows you to save a network data file describing the case you currently have loaded. The batch program, `bpf`, has no command to do this. If you want a netdata file produced in batch mode, use the `netdata` program. It loads a saved base case (.bse) file and writes it out in an ASCII network (.net) file.

Both programs generate a WSCC-formatted network data file in any of the following dialects: BPA, WSCC1, or PTI. “Dialects” means that although the file is still WSCC format, the data is generated with special processing or restrictions and is destined for use with other programs. In the case of the PTI dialect, that data is intended to be processed by the PTI-proprietary conversion program WSCFOR.

This program extracts network data from a Powerflow “old base” history file. Table F-1 below summarizes the effects of each dialect.

Table F-1 Effect of Dialects on Network Data File

Record or Field	Dialect	Effects
Header comments	PTI	Three header records: “<case_name> “ “<case_name> “ “<case_name> “
	BPA, WSCC, WSCC1	“./CASE_ID = <case_name> “./CASE_DS = <case_description> “./H1 <header 1 text (auto-generated)> “./H2 <header 2 text (user input)> “./H3 <header 3 text (user input)> “./C001 <comment 1 text> ... “./Cnnn <comment nnn text>
Area “A” records	BPA, PTI	Encode zones 1-10 in “A” record, zones 11-20 in “A1” record, etc. Note: Voltage limits on “A” records are not encoded.They are specified by a default array that establishes limits using base kV and zones.
	WSCC, WSCC1	Encode only “A” record (any zones 11-50 will be lost). Note; Voltage limits on “A” records are not encoded.They are specified by a default array that establishes limits using base kV and zones.
Intertie “I” records	BPA, PTI	Single entry (low alpha to high alpha) associated “I” records follow each “A record.

Table F-1 Effect of Dialects on Network Data File (Continued)

Record or Field	Dialect	Effects
	WSCC, WSCC1	No "I" records encoded.
Default percentages on type BG buses	BPA	BG percentages are not changed.
	PTI, WSCC, WSCC1	BG percentages are calculated if their default value is invalid.
Continuation "+" bus records	BPA	"+" records are encoded.
	PTI, WSCC, WSCC1	"+" records are consolidated with "B" records.
Reactive capability "Q" records	BPA	"Q" records are encoded.
	PTI, WSCC, WSCC1	"Q" records are not encoded.
Minimum branch impedance	BPA, PTI	Branch impedances are not changed.
	WSCC, WSCC1	Minimum branch impedances are set to 0.0003 p.u.
Branch ratings	BPA	Options: 1. Use extended ratings (120-character records). 2. Replace nominal rating with minimum (Emergency, Thermal, or Bottleneck). 3. Use nominal rating only.
	PTI, WSCC, WSCC1	Options: 1. Replace nominal rating with minimum (Emergency, Thermal, or Bottleneck). 2. Use nominal rating only.
Branch sections	BPA	Encode as originally submitted.
	PTI, WSCC	Encode all branch sections in a consistent orientation.
	WSCC1	Consolidate all sections into an equivalent branch
Regulating "R" records	BPA	Encode as originally submitted.
	PTI, WSCC	1. Encode as adjustable tap side-fixed tap side. 2. Consolidate parallel LTC transformers into a single, equivalent parallel LTC transformer.
	WSCC1	1. Encode as adjustable tap side-fixed tap side. 2. Consolidate parallel LTC transformers into a single, equivalent parallel LTC transformer. 3. Convert taps into steps (STEPS = TAPS - 1).

Table F-1 Effect of Dialects on Network Data File (Continued)

Record or Field	Dialect	Effects
D-C "LD" record	BPA	Encode as originally submitted.
	PTI, WSCC, WSCC1	Encode as rectifier side-inverter side.

The resultant output is an ASCII file. Two formats are available for the resulting output. The BPA format retains all of the extra features that are available in the BPA Powerflow program without making any modifications to the data, while the WSCC format option consolidates and restricts the features in order to be used with WSCC's IPS Powerflow program.

The `CASEID` of the power flow case data being extracted is used to create a file named `CASEID.DAT`. Any changes made to the data for WSCC (IPS) compatibility will be flagged on file `CASEID.MES`.

F.2.1 Input

The `IPFNET` program prompts with the following requests:

- File name of the Powerflow "old base" history filename.
- Select output format desired: BPA, BPA1, BPA2, WSCC (IPS), or WSCC1 (IPS1).

F.2.2 Using The Network Extraction Program

The `IPFNET` program is initiated by entering `IPFNET` at the keyboard after the computer displays the prompt.

From this point on the operation is interactive. You should respond to the questions as they are asked.

F.2.3 Sample Run

Type `IPFNET` at the system prompt and press the `<RETURN>` key. Answer the questions appropriately. An example is given below.

```
$ ipfnet
> Enter OLD_BASE file name (or Q to quit): ../dat/43bus.bse
> Enter name of network file (default is "../dat/43bus.net"): new.net
> Enter dialect (BPA, WSCC, WSCC1 or PTI): WSCC
> Enter record size (80 or 120): 80
> Nominal rating replacement code
    T = Thermal  E = Emergency  B = Bottleneck
```

```
   T: Transformers = T, Lines = T
   E: Transformers = E, Lines = T
   B: Transformers = B, Lines = B
   ET: Transformers = E, Lines = T
   EB: Transformers = E, Lines = B
   M: Transformers = min(TEB), Lines = min(TB)
> Enter rating replacement code: T
* Options selected - dialect = WSCC
                     size  = 80
                    rating = T
> Are above options correct (Y or N)? Y
```

Note that the codes for dialect and rating must be upper case. IPFNET formats commands which are sent to IPFSRV. Some input checking is done, but invalid values may cause unexpected results.

APPENDIX G

IPS - IPF DIFFERENCES

G.1 IPS - IPF Differences

1. Powerflow Command Differences:

   All IPF commands are different from those in IPS. When you are using the GUI, you will not have to worry about any of these, but there are some things you will need to do to your input data deck, such as deleting all the IPS control records and COPE commands (`HDG,BAS,TITLE,ATTACH,$DONE,END`, etc.).

2. Terminology:

   The IPF Base Case (.bse) file is a binary file equivalent to the IPS History (.HIS) file. However, the Base Case file does not contain any mapping data, and *only one case per file* is permitted.

   The IPF Network (.net) file is an ASCII file equivalent to the IPS base case or base data file (.IPS). However, this file must *not* contain any modification records ('M' or 'D' in column 3). Changes go in a different file, which must be loaded separately.

   All mapping data is saved (in PostScript format) in a Coordinate file (.cor). Only buses which have a match in the currently loaded system data will be displayed.

3. Case Title:

   IPF builds the first line of a three-line IPS style title from the 10 character Caseid and the 20 character case description fields, and the other two lines from the two HEADER records. All of these are printed on standard BPA output listings, saved on the base case (history) file, and printed on hardcopy maps.

4. Structure:

   The IPF Changes file (.chg) contains new and modification records you want to apply in bulk to your base case (e.g. your own local system representation). You will use the GUI to make individual touch-up or particular study changes.

   The system slack bus must be specified as a 'BS' bus in the Network file; there is no GUI provision for selecting a slack bus (other than by changing the type of some bus to BS).

5. Data Differences:

   IPF system data is very similar to that for IPS, but is *not* identical. If you try to read in a WSCC base case deck as an IPF network file, you can expect numerous data errors and no solution. If you charge ahead, fixing fatal errors as you stumble over them, you will still probably not get the answers to match, because of modeling differences. The data conversion program handles most of these.

There are two categories of differences between BPA and WSCC power flow models:

a) Modeling differences (including BPA extensions).

b) Input data differences.

Modeling Differences

	WSCC's IPS	**BPA's IPF**
1	The d-c line current rating is used only as a base by IPS. Both line current and bridge current ratings are passed to the Stability program; they are not used as limits in the powerflow solution.	The minimum of the bridge current rating and the line current rating is used as a limit by the d-c system solution.
2	Type RM phase shifters (controlling P_{km} between P_{min} and P_{max}) will bias the phase shift angle towards the original phase shift angle.	Type RM phase shifters (controlling P_{km} between P_{min} and P_{max}) will bias the phase shift angle to zero degrees to minimize circulating real power flow. WSCC bias is available as a solution option on the GUI.
3	A type BG generator may control only bus type BC.	A type BG generator may control bus types BC, B , BQ, BV, and BT.
4	An LTC may control only bus type BT.	An LTC may control bus types BC, B , BQ, BV, and BT.
5	Only one voltage control strategy per bus.	A generator and an LTC may simultaneously control a common bus. If a degree of freedom exists, the LTC will control Q_{km} directly to minimize transformer var flow between terminal buses.
6	Type BX buses will bias the solution towards the original $X_{shunt.}$	Type BX buses bias the solution to $V_{max.}$ WSCC bias is available as a solution option on the GUI.
7	Infinite default limits are assigned to type BG buses	Default global voltage limits are assigned to all buses, including type BG buses, by base voltage level.
8	The bus shunt reactive on type BQ buses is fixed.	The bus shunt reactive on type BQ buses is continuously adjustable (0 to 100%). To make that quantity fixed, it must be entered on an accompanying +A continuation bus record. The conversion program automates this.
9	Inductance (G-jB) is applied to only one end of a transformer branch.	One half of G-jB is applied to each end of both transformers and balanced pi lines.

	WSCC's IPS	BPA's IPF
10	Model RF phase shifter takes several iterations to get from an initial angle to its final (fixed) phase shift angle.	No such model. Problems in solving phase shifters are handled internally.
11	Phase shifter must have same base kV at both terminals.	Step up phase shifter. Tap2 field is off-nominal tap2.
12	Phase shifter cannot be a section.	Phase shifting transformer can be a section.
13	Bus ties (zero impedance lines) receive special handling in solution and reporting.	No special bus tie model. A 'bus tie' is defined as a very low impedance line (0.0 + j0.00001).
14	Not available.	"+" continuation bus records. Except for constant current load models, these records are used mainly for accounting purposes to differentiate generation, load, and shunt with unique ownerships.
15	Not available.	"I" area intertie records. These records compute net area export on accompanying "A" records.
16	Not available.	"A" area record may be accompanied with "A1", "A2", "A3", and "A4" continuation records to accept a maximum of 50 zones per area.
17	Not available.	Branch records accept extended line current ratings: For types "L" and "E" records, thermal and bottleneck ratings. For types "T" and "TP" records, thermal, bottleneck and emergency ratings.
18	Not available.	Types "BM" and "LM" multi-terminal d-c data.
19	Not available.	Type "RZ" RANI devices.

Input Data Differences

	WSCC's IPS	BPA's IPF
1 *	Base kv field interpreted as A4 for identification purposes. SAMPLE 20.0 and SAMPLE 20 are different buses.	Base kV field interpreted as F4.0. SAMPLE 20.0 and SAMPLE 20 are the same bus.
2 *	The number of steps on R records are interpreted as steps, where STEPS = TAPS - 1	The number of steps on R records are interpreted as number of taps, where TAPS = STEPS + 1.
3 *	A parallel branch consisting of sections will accept section numbers in the set [0-9]. (Blank is interpreted as a zero.)	A parallel branch consisting of sections will accept section numbers in the set [1-9]. Zero or blank can be used as a section number only in a single section line (i.e. there are no 'sections' in the line at all.) Zero or blank can also be used on delete, to remove *all* sections of one circuit.
4 *	Remotely controlled bus for a BX bus is specified on the X record.	Remotely controlled bus for a BX bus is specified on the BX record.
5 *	Voltage limits for a bus remotely controlled by a BX bus are specified on the BC record.	Voltage limits for any bus, no matter how it is controlled, are specified on the controlled bus record.
6	Voltage limits (for reporting over and under voltage buses) are specified on A records	Default voltage limits (for all purposes) are specified by a default array which establishes limits using base KV and zones. These can be altered (but not from the GUI).
7 *	Branches entered with both R and X equal to zero receive special handling as 'bus ties'.	Zero impedance is not allowed – no bus tie simulation.
8 *	The system slack bus can be designated as a BS type bus, but very often is specified in the SOLVE options instead.	System slack bus *must* be specified as a BS bus.
9 *	IPS accepts various types of comment records ('CB', 'CL', 'CR') which annotate the data file, and are printed in the (batch) input listing.	IPF uses a "." (period) in column 1 to designate a comment. These annotate only the data file; they are never printed.

* The conversion program will handle this item.

G.2 IPS2IPF Program

The IPS2IPF conversion program is designed to ease the burden of converting an IPS data deck into one which can be input to the IPF program with the expectation of getting the same solution results, within normal engineering tolerances. However, the conversion is not 100% automatic. See the IPF-IPS Data Differences section for more detail on the data input and internal modeling differences between the two programs.

Before running IPS2IPF on an IPS data file, you should remove from the file all COPE commands (`TITLE,NEW,ATTACH`, etc.) The program will handle the standard 'control cards' HDG, BAS, and ZZ. Title records may be retained by putting an HDG in front of them, or by putting a period (.) in column 1 of each. An unlimited number of (.) comments are is allowed, but these only annotate the data; they are not printed anywhere in the output.

IPS2IPF performs the following tasks:

6. Renames duplicate buses.

   IPS uses a 12-character bus name, which includes the base KV. IPF uses only 8 characters, plus the real value of the base KV. To IPS, `SAMPLE 230.` and `SAMPLE   230` are two different buses; to IPF they are the same bus.

   IPS2IPF identifies duplicate names and generates a different name for one of them. It reports any changed names; if you don't like the name it generated, you can change it after the fact.

7. Makes the system swing bus a `BS` bus, if given its name.
8. Transfers non-zero shunt vars from `BE` and `BQ` records to `+A` records.

   In IPS, the shunt vars value entered for a bus which has variable var output is considered to be a fixed component of the total vars. In order to retain this philosophy in IPF, it is necessary to put the shunt on a `+A` (continuation bus) record. Shunt vars entered on the `BE` or `BQ` record are considered by IPF to be continuously variable.

9. Converts non-zero 'steps' on `R` records to 'taps' (by adding one).

   IPS uses the number of steps available between TCUL taps; IPF uses the number of actual taps. If you run the conversion on an already converted file, another one will be added, which is probably not desireable.

10. Converts IPS comments (`C` in column 1) to IPF comments (. in column 1).

    Unlike IPS, which prints the comments in the input data listing, IPF does not print them at all. But they can remain in the data file itself for information as long as they have a period in column 1 instead of a '`C`'.

11. Copies the controlled bus name from each `X` record to the corresponding `BX` record, to ensure that the proper bus is being controlled.
12. Copies the voltage limits from a `BX` record controlling a remote bus, to the remote bus record.
13. Corrects blank section id's in multi-section lines.

    Blank is acceptable to IPF as a section identification only on single-section lines. IPS2IPF identifies multi-section lines, and changes blank to '1', '1' to '2', etc. If there are actually 10 sections (IPS limit), then sections '8' and '9' will be combined and labeled '9'.

14. Gives bus ties a small impedance.

    IPF does not allow bus ties (0.0 impedance produces a fatal error.) IPS2IPF changes this to (0.0 + j0.00001), the same impedance IPF gives you when you sectionalize a bus and create a "bus tie" between the new bus and the old one. However, you should note that this may cause difficulties in getting a solution. (There are no zero impedance lines in standard WSCC study cases.)

15. IPF has no RF model. Any RF records in your deck will be removed.

Items which are not handled by IPS2IPF, which you need to look out for, are the following:

16. In IPS, line and bridge current ratings on DC are not processed, but only passed on to the Stability program. IPF actually uses them. You may find that the bridge current rating on the Intermountain DC line is too low. Change it to 1840.

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