Data Formats Reference Manual
PSS®E 34.8.2

February 2021

SIEMENS

Siemens Industry, Inc.
Siemens Power Technologies International
400 State Street
Schenectady, NY 12301-1058 USA
+1 518-395-5000
www.siemens.com/power-technologies

Table of Contents

List of Figures

List of Tables

Chapter 1
Power Flow Data Contents

1.1. Overview

The input stream to activity READ consists of 23 groups of records, with each group containing a particular type of data required in power flow work (refer to Figure 1-1). The end of each category of data, except the Case Identification Data, is indicated by a record specifying a value of zero; the end of the system-wide, FACTS device, DC line, and GNE device data categories may alternatively be indicated with a record specifying a NAME value with blanks. The optimal power flow problem typically consists of several components: one or more objectives, a set of available system controls and any number of system constraints. The purpose of this chapter is to present the available controls and constraints for the optimal power flow problem statement.

The sections within this chapter are presented in the order in which the data categories must appear within the OPF Raw Data File. The format of the OPF Raw Data File itself is outlined in Figure 3-1. Each section of this chapter fully describes the data elements associated with each data model. Specific information on the use of the data input facilities can be found in Section 14.8 Data Input and Storage.

1.2. Extended Bus Names

On its Bus Data record, each bus is assigned a bus number and a 12 character alphanumeric name. When the bus *names* input option of activity READ is enabled, data fields designating buses on load, fixed shunt, generator, non-transformer branch, transformer, area, two-terminal dc line, VSC dc line, multi-terminal dc line, multi-section line, FACTS device, switched shunt, GNE device, and induction machine, data records may be specified as either extended bus names enclosed in single quotes or as bus numbers.

The requirements for specifying an extended bus name are:

- The extended name of a bus is a concatenation of its 12 character alphanumeric name and its Breaker and Switch base voltage.
- It must be enclosed in single quotes.
- The 12 character bus name, *including any trailing blanks*, must be the first 12 characters of the extended bus name.
- The bus base voltage in kV follows the 12 character bus name. Up to 6 characters may be used.
- For those data fields for which a sign is used to indicate a modeling attribute, a minus sign may be specified between the leading single quote and the first character of the 12 character bus name.

Thus, valid forms of an extended bus name include '*aaaaaaaaaaaavvvvvv*' and '*aaaaaaaaaaaavvv*'. For those data fields cited in (4) above, '-*aaaaaaaaaaaavvvvvv*' and '- *aaaaaaaaaaaavvv*' are also valid forms of extended bus names.

As an example, consider a 345 kV bus with the name ERIE BLVD. The following are all valid forms of Its extended bus name:

```
'ERIE BLVD 345.0' 'ERIE BLVD 345' 'ERIE BLVD 345'
```

The following is not a valid form of its extended bus name because the three tailing blanks of its bus name are not all included before the base voltage:

```
'ERIE BLVD 345'
```

1.3. Default Values

All data is read in free format with data items separated by a comma or one or more blanks; *[Tab]* delimited data items are not recommended.

Because there are default values for many of the data items specified in the Power Flow Raw Data File, you can include only the specific information you need. For example, if bus 99 is a 345 kV Type 1 bus assigned to zone 3, the Bus Data record in the file could be:

```
99,,345,,,3
```

This is equivalent to specifying the data record:

```
99,' ',345.0,1,1,3,1,1.0,0.0
```

If, in addition, you name the bus ERIE BLVD, the minimum data line would be:

```
99,'ERIE BLVD',345,,,3
```

1.4. Q Record

Generally, specifying a data record with a Q in column one is used to indicate that no more data records are to be supplied to activity READ. This end of data input indicator is permitted anywhere in the Power Flow Raw Data File *except* where activity READ is expecting one of the following:

- one of the three Case Identification Data records
- the second or subsequent records of the four-record block defining a two-winding transformer
- the second or subsequent records of the five-record block defining a three-winding transformer
- the second or third record of the three-record block defining a two-terminal dc transmission line
- the second or third record of the three-record block defining a VSC dc transmission line
- the second or subsequent records of the series of data records defining a multi-terminal dc transmission line
- the second or subsequent records of the series of data records defining a GNE device

Case Identification Data	
System-Wide Data	
Bus Data	
Load Data	

Fixed Bus Shunt Data	
Generator Data	
Non-Transformer Branch Data	
System Switching Device Data	
Transformer Data	
Area Interchange Data	
Two-Terminal DC Transmission Line Data	
Voltage Source Converter (VSC) DC Transmission Line Data	
Transformer Impedance Correction Tables	
Multi-Terminal DC Transmission Line Data	
Multi-Section Line Grouping Data	
Zone Data	
Interarea Transfer Data	
Owner Data	
FACTS Device Data	
Switched Shunt Data	
GNE Device Data	
Induction Machine Data	
Substation Data	
Q Record	

Power Flow Raw Data Input Structure

Each substation block data consists of following records.

Substation Data Record	
Node Data	
Station Switching Device Data	
Equipment Terminal Data	

1.5. Case Identification Data

Case identification data consists of three data records. The first record contains six items of data as follows:

```
IC, SBASE, REV, XFRRAT, NXFRAT, BASFRQ
```

IC	New case flag: 0 for base case input (i.e., clear the working case before adding data to it) 1 to add data to the working case IC = 0 by default
SBASE	System MVA base SBASE = 100.0 by default
REV	PSSE revision number REV = current revision by default
XFRRAT	Units of transformer ratings (refer to Transformer Data). The transformer percent loading units program option setting (refer to Saved Case Specific Option Settings) is set according to thisdata value. XFRRAT <= 0 for MVA XFRRAT > 0 for current expressed as MVA XFRRAT = present transformer percent loading program option setting by default (refer to activity OPTN).
NXFRAT	Units of ratings of non-transformer branches (refer to Non-Transformer Branch Data). The non-transformer branch percent loading units program option setting (refer to Saved Case Specific Option Settings) is set according to this data value NXFRAT <= 0 for MVA NXFRAT > 0 for current expressed as MVA NXFRAT = present non-transformer branch percent loading program option setting by default (refer to activity OPTN).
BASFRQ	System base frequency in Hertz. The base frequency program option setting (refer to Saved Case Specific Option Settings) is set to this data value. BASFRQ = present base frequency program option setting value by default (refer to activity OPTN).

When current ratings are being specified, ratings are entered as:

$MVA_{rated} = \sqrt{3} \times E_{base} \times I_{rated} \times 10^{-6}$

where:

E_{base}	Is the branch or transformer winding voltage base in volts.
I_{rated}	Is the rated phase current in amps

The next two records each contain a line of text to be associated with the case as its case title. Each line may contain up to 60 characters, which are entered in columns 1 through 60.

1.6. System-Wide Data

Through the system-wide data category, data that pertains to the case as a whole (rather than to individual equipment items) may be included in the Power Flow Raw Data File to allow convenient transfer of it with the case. Records may be included that define:

- power flow solution parameters
- descriptions of rating sets
- information on the most recent power flow solution attempt

Generally, each record specified in the System-Wide Data category begins with a NAME that defines the type of data specified on the record. The formats of the various records are described in the following paragraphs.

1.6.1. GENERAL Record

The GENRAL record begins with the name GENERAL and contains solution parameters used by all of the power flow solution methods. Using keyword input, any or all of the following solution parameters may be specified:

- THRSHZ (the zero impedance line threshold tolerance)
- PQBRAK (the constant power load characteristic voltage breakpoint)
- BLOWUP (the largest voltage change threshold)

Those solution parameters that are specified may be entered in any order. The following is an example of the GENERAL record:

```
GENERAL, THRSHZ=0.0001, PQBRAK=0.7, BLOWUP=5.0
```

1.6.2. GAUSS Record

The GAUSS record begins with the name GAUSS and contains solution parameters used by the Gauss-Seidel power flow solution methods (SOLV and MSLV). Using keyword input, any or all of the following solution parameters may be specified:

- ITMX (the maximum number of iterations)
- ACCP (real component voltage change acceleration factor)

- ACCQ (imaginary component voltage change acceleration factor)
- ACCM (type 1 bus complex voltage change acceleration factor in MSLV)
- TOL (voltage magnitude change convergence tolerance)

Those solution parameters that are specified may be entered in any order. The following is an example of the GAUSS record:

```
GAUSS, ITMX=100, ACCP=1.6, ACCQ=1.6, ACCM=1.0, TOL=0.0001
```

1.6.3. NEWTON Record

The NEWTON record begins with the name NEWTON and contains solution parameters used by the Newton-Raphson power flow solution methods (FDNS, FNSL and NSOL). Using keyword input, any or all of the following solution parameters may be specified:

- ITMXN (the maximum number of iterations)
- ACCN (voltage magnitude setpoint change acceleration factor at voltage controlled buses)
- TOLN (mismatch convergence tolerance)
- VCTOLQ (controlled bus reactive power mismatch convergence tolerance)
- VCTOLV (controlled bus voltage error convergence tolerance)
- DVLIM (maximum votlage magnitude change that may be applied on any iteration)
- NDVFCT (non-divergent solution improvement factor)

Those solution parameters that are specified may be entered in any order. The following is an example of the NEWTON record:

```
NEWTON, ITMXN=20, ACCN=1.0, TOLN=0.1, VCTOLQ=0.1, VCTOLV=0.00001, DVLIM=0.99,
NDVFCT=0.99
```

1.6.4. ADJUST Record

The ADJUST record begins with the name ADJUST and contains solution parameters used by the automatic adjustment functions of the Gauss-Seidel and Newton-Raphson power flow solution methods. Using keyword input, any or all of the following solution parameters may be specified:

- ADJTHR (automatic adjustment threshold tolerance)
- ACCTAP (tap movement deceleration factor)
- TAPLIM (maximum tap ratio change on any iteration)
- SWVBND (percent of voltage band switched shunts with voltage violations that are adjusted on any iteration)
- MXTPSS (maximum number of tap and/or switched shunt adjustment cycles)

- MXSWIM (maximum number of induction machine state switchings)

Those solution parameters that are specified may be entered in any order. The following is an example of the ADJUST record:

```
ADJUST, ADJTHR=0.005, ACCTAP=1.0, TAPLIM=0.05, SWVBND=100.0, MXTPSS=99,
MXSWIM=10
```

1.6.5. TYSL Record

The TYSL record begins with the name TYSL and contains solution parameters used by the balanced switching network solution (TYSL). Using keyword input, any or all of the following solution parameters may be specified:

- ITMXTY (the maximum number of iterations)
- ACCTY (voltage change acceleration factor)
- TOLTY (voltage magnitude change convergence tolerance)

Those solution parameters that are specified may be entered in any order. The following is an example of the TYSL record:

```
TYSL, ITMXTY=20, ACCTY=1.0, TOLTY=0.00001
```

1.6.6. SOLVER Record

The SOLVER record begins with the name SOLVER and identifies the power flow solution method and solution options used in the last power flow solution attempt.

Following the name SOLVER is the name of the solution method (either FDNS, FNSL, NSOL, SOLV or MSLV). Then, using keyword input, any or all of the following solution option selections may be specified:

- ACTAPS (the ac tap adjustment code)
- AREAIN (the area interchange adjustment code)
- PHSHFT (the phase shift adjustment code)
- DCTAPS (the dc tap adjustment code)
- SWSHNT (the switched shunt adjustment code)
- FLATST (the flat start code)
- VARLIM (the reactive power limit application code)
- NONDIV (the non-divergent solution code)

Those solution options that are specified may be entered in any order. The following is an example of the SOLVER record:

```
SOLVER, FNSL, ACTAPS=1, AREAIN=0, PHSHFT=0, DCTAPS=1, SWSHNT=1, FLATST=0, VAR-
LIM=0, NONDIV=0
```

1.6.7. RATING Record

The RATING record begins with the name RATING and specifies a six-character name and a 32-character description associated with a specified rating set.

Following the name RATING are the following data items:

- the number of the rating set (1 through 12),
- a quoted string that contains the rating's name (this is used as a column heading in several reports), and
- a quoted string that contains the rating's description.

If no RATING record is specified for rating set "n", its name is set to "RATEn" and its description is set to "RATING SET n".

The following is an example of the RATING record:

```
RATING, 3, "STEMER", "Short term summer emergency"
```

System wide data input is terminated with a record specifying a value of zero.

1.7. Bus Data

Each network bus to be represented in PSSE is introduced by reading a bus data record. Each bus data record has the following format:

```
I, 'NAME', BASKV, IDE, AREA, ZONE, OWNER, VM, VA, NVHI, NVLO, EVHI, EVLO
```

I	Bus number (1 through 999997). No default allowed.
NAME	Alphanumeric identifier assigned to bus I. NAME may be up to twelve characters and may contain any combination of blanks, uppercase letters, numbers and special characters, but the first character *must not* be a minus sign. NAME *must* be enclosed in single or double quotes if it contains any blanks or special characters. NAME = twelve blanks by default
BASKV	Bus base voltage; entered in kV BASKV = 0.0 by default
IDE	Bus type code: • 1 - for a load bus or passive node (no generator boundarycondition) • 2 - for a generator or plant bus (either voltage regulating or fixed Mvar) • 3 - for a swing bus • 4 - for a disconnected (isolated) bus IDE = 1 by default
AREA	Area number (1 through 9999). AREA = 1 by default

ZONE	Zone number (1 through 9999). ZONE = 1 by default
OWNER	Owner number (1 through 9999). OWNER = 1 by default
VM	Bus voltage magnitude; entered in pu. VM = 1.0 by default
VA	Bus voltage phase angle; entered in degrees. VA = 0.0 by default
NVHI	Normal voltage magnitude high limit; entered in pu. NVHI = 1.1 by default
NVLO	Normal voltage magnitude low limit, entered in pu. NVLO = 0.9 by default
EVHI	Emergency voltage magnitude high limit; entered in pu. EVHI = 1.1 by default
EVLO	Emergency voltage magnitude low limit; entered in pu. EVLO = 0.9 by default

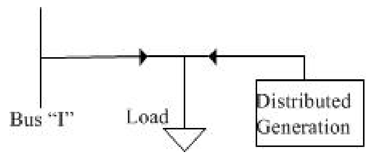
Bus data input is terminated with a record specifying a bus number of zero.

1.7.1. Bus Data Notes

VM and VA need to be set to their actual solved case values only when the network, as entered into the working case via activity READ, is to be considered solved as read in. Otherwise, unless some better estimate of the solved voltage and/or phase angle is available, VM and VA may be omitted (and therefore set to their default values; see Default Values).

1.8. Load Data

Each network bus at which load is to be represented must be specified in at least one load data record. Multiple loads may be represented at a bus by specifying more than one load data record for the bus, each with a different load identifier.



Each load at a bus can be a mixture of loads with three different characteristics: the Constant Power Load Characteristic, the Constant Current Load Characteristic, and the constant admittance load characteristic. For additional information on load characteristic modeling, refer to Load, activities CONL and RCNL, Modeling Load Characteristics and Basic Load Characteristics.

Each load data record has the following format:

```
I,ID,STATUS,AREA,ZONE,PL,QL,IP,IQ,YP,YQ,OWNER,SCALE,INTRPT,DGENP,DGENQ,DGENM
```

I	Bus number, or extended bus name enclosed in single quotes (refer to Extended Bus Names). No default allowed.
ID	One or two-character uppercase non-blank alphanumeric load identifier used to distinguish among multiple loads at bus I. It is recommended that, at buses for which a single load is present, the load be designated as having the load identifier '1'. ID = '1' by default
STATUS	Load status of one for in-service and zero for out-of-service. STATUS = 1 by default
AREA	Area to which the load is assigned (1 through 9999). By default, AREA is the area to which bus I is assigned (refer to Bus Data).
ZONE	Zone to which the load is assigned (1 through 9999). By default, ZONE is the zone to which bus I is assigned (refer to Bus Data).
PL	Active power component of constant MVA load; entered in MW. PL = 0.0 by default
QL	Reactive power component of constant MVA load; entered in Mvar. QL = 0.0 by default
IP	Active power component of constant current load; entered in MW at one per unit voltage. IP = 0.0 by default
IQ	Reactive power component of constant current load; entered in Mvar at one per unit voltage. IQ = 0.0 by default
YP	Active power component of constant admittance load; entered in MW at one per unit voltage. YP = 0.0 by default
YQ	Reactive power component of constant admittance load; entered in Mvar at one per unit voltage. YQ is a negative quantity for an inductive load and positive for a capacitive load. YQ = 0.0 by default
OWNER	Owner to which the load is assigned (1 through 9999). By default, OWNER is the owner to which bus I is assigned (refer to Bus Data).
SCALE	Load scaling flag of one for a scalable load and zero for a fixed load (refer to SCAL). SCALE = 1 by default
INTRPT	Interruptible load flag of one for an interruptible load for zero for a non interruptible load. INTRPT = 0 by default

DGENP	Distributed Generation active power component; entered in units of MW. DGENP = 0.0 by default
DGENQ	Distributed Generation reactive power component; entered in units of MVAR. DGENQ = 0.0 by default
DGENM	Distributed Generation operation mode; 0 = distributed generation on feeder is OFF, 1 = distributed generation on feeder is ON. DGENM = 0 by default

Load data input is terminated with a record specifying a bus number of zero.

1.8.1. Load Data Notes

The area, zone, and owner assignments of loads are used for area, zone, and owner totaling purposes (e.g., in activities AREA, OWNR, and ZONE) and for load scaling and conversion purposes. They may differ from those of the bus to which they are connected. The area and zone assignments of loads may optionally be used during area and zone interchange calculations (refer to Area Interchange Control and activities AREA, ZONE, TIES, TIEZ, INTA, and INTZ).

1.8.2. Constant Power Load Characteristic

The constant power characteristic holds the load power values, and also, the distributed generation power values, constant as long as the bus voltage exceeds a value specified by the solution parameter PQBRAK. The constant power characteristic assumes an elliptical current-voltage characteristic of the corresponding load current for voltages below this threshold. Figure 1-2 depicts this characteristic for PQBRAK values of 0.6, 0.7, and 0.8 pu. The user may modify the value of PQBRAK using the *[Solution Parameters]* GUI (refer to *PSSE GUI Users Guide*, Section 11.1.1, Boundary Conditions).

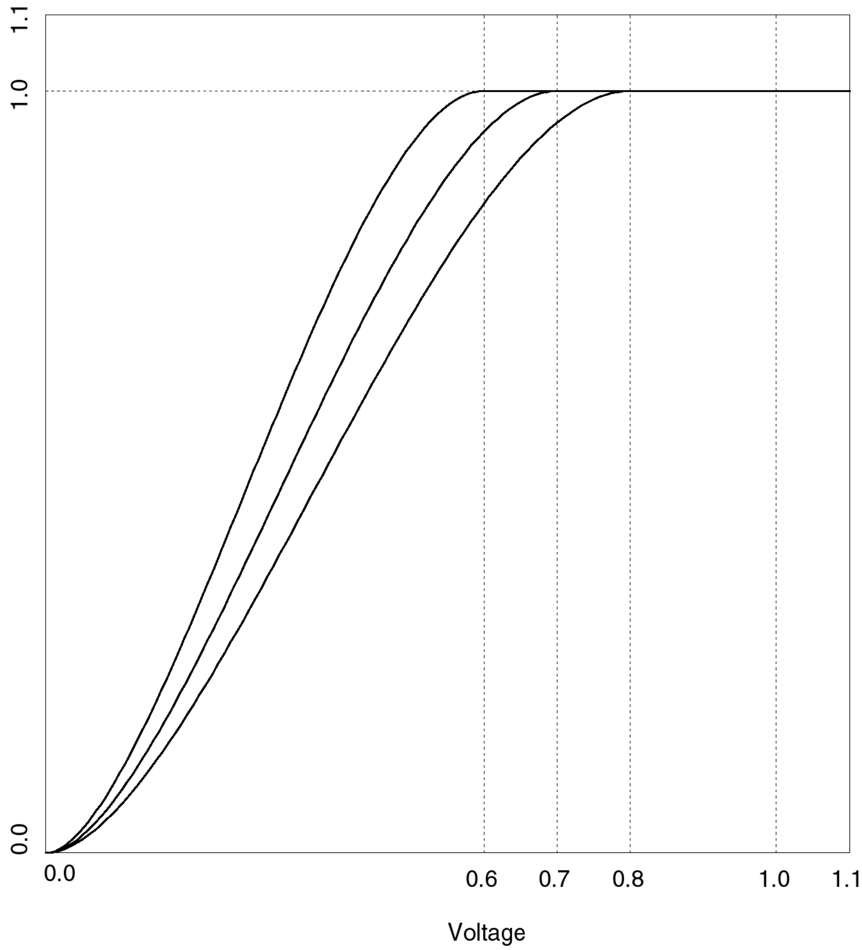


Figure 1.1. Constant Power Load Characteristics

1.8.3. Constant Current Load Characteristic

The constant current characteristic holds the load current constant as long as the bus voltage exceeds 0.5 pu, and assumes an elliptical current-voltage characteristic as shown in Figure 1-3 for voltages below 0.5 pu.

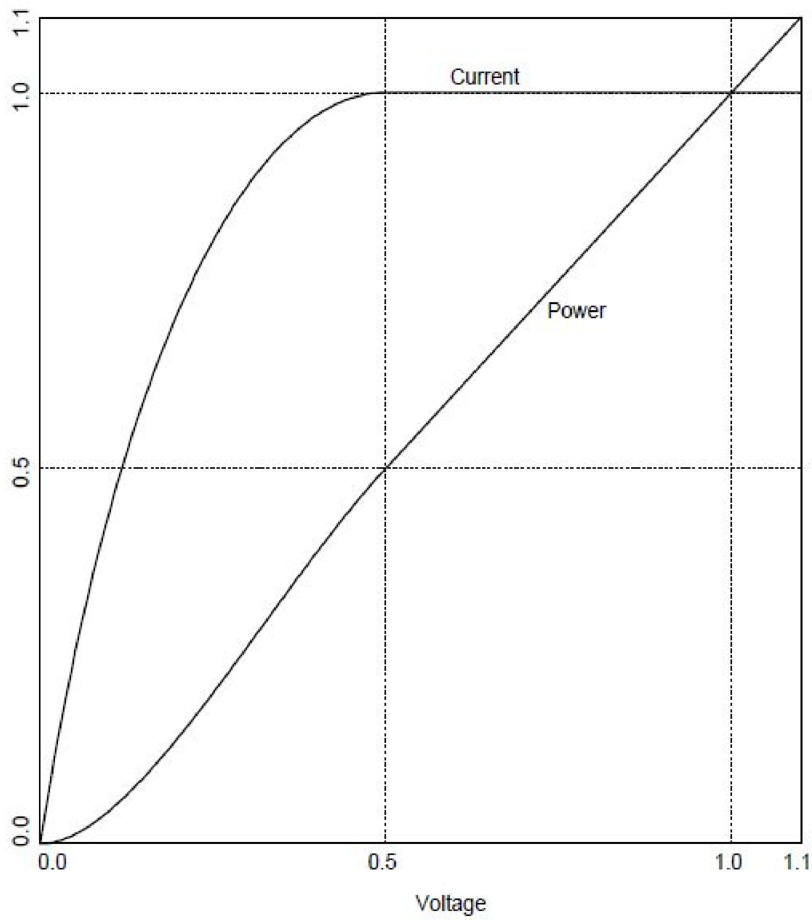
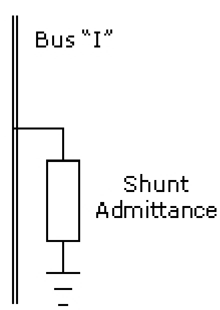


Figure 1.2. Constant Current Load Characteristics

1.9. Fixed Bus Shunt Data

Each network bus at which fixed bus shunt is to be represented must be specified in at least one fixed bus shunt data record. Multiple fixed bus shunts may be represented at a bus by specifying more than one fixed bus shunt data record for the bus, each with a different shunt identifier.



Each fixed bus shunt data record has the following format:

```
I, ID, STATUS, GL, BL
```

I	Bus number, or extended bus name enclosed in single quotes (refer to Extended Bus Names). No default allowed
ID	One- or two-character uppercase non-blank alphanumeric shunt identifier used to distinguish among multiple shunts at bus I. It is recommended that, at buses for which a single shunt is present, the shunt be designated as having the shunt identifier '1'. ID = '1' by default
STATUS	Shunt status of one for in-service and zero for out-of-service. STATUS = 1 by default
GL	Activecomponent of shunt admittance to ground; entered in MW at one per unit voltage. GL should not include any resistive impedance load, which is entered as part of load data. GL = 0.0 by default
BL	Reactive component of shunt admittance to ground; entered in Mvar at one per unit voltage. BL should not include any reactive impedance load, which is entered as part of load data; line charging and line connected shunts, which are entered as part of non-transformer branch data; transformer magnetizing admittance, which is entered as part of transformer data; or switched shunt admittance, which is entered as part of switched shunt data. BL is positive for a capacitor, and negative for a reactor or an inductive load. BL = 0.0 by default

Fixed bus shunt data input is terminated with a record specifying a bus number of zero.

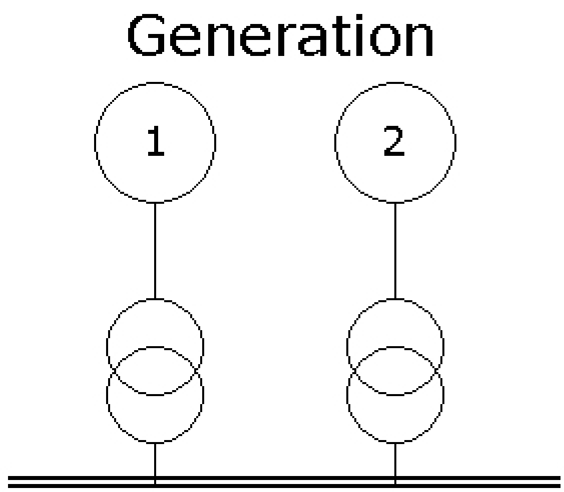
1.9.1. Fixed Shunt Data Notes

The area, zone, and owner assignments of the bus to which the shunt is connected are used for area, zone, and owner totaling purposes (e.g., in activities AREA, OWNR, and ZONE); refer to Section 12.7, “Summarizing Area Totals” through Section 12.12, “Summarizing Zone-to-Zone Interchange”) and for shunt scaling purposes (refer to SCAL).

The admittance specified in the data record can represent a shunt capacitor or a shunt reactor (both with or without a real component) or a shunt resistor. It *must not* represent line connected admittance, switched shunts, loads, line charging or transformer magnetizing impedance, all of which are entered in other data categories.

1.10. Generator Data

Each network bus to be represented as a generator or plant bus in PSSE must be specified in a generator data record. In particular, each bus specified in the bus data input with a Type code of 2 or 3 must have a generator data record entered for it.



Each generator has a single line data record with the following format:

```
I,ID,PG,QG,QT,QB,VS,IREG,MBASE,ZR,ZX,RT,XT,GTAP,STAT,RMPCT,PT,PB,
```

I	Bus number, or extended bus name enclosed in single quotes (refer to Extended Bus Names). No default allowed
ID	One- or two-character uppercase non-blank alphanumeric machine identifier used to distinguish among multiple machines at bus I. It is recommended that, at buses for which a single machine is present, the machine be designated as having the machine identifier '1'. ID = '1' by default
PG	Generator active power output; entered in MW. PG = 0.0 by default
QG	Generator reactive power output; entered in Mvar. QG needs to be entered only if the case, as read in, is to be treated as a solved case. QG = 0.0 by default
QT	Maximum generator reactive power output; entered in Mvar. For fixed output generators (i.e., nonregulating), QT must be equal to the fixed Mvar output. For infeed machines (WMOD=4), QT is not used in powerflow calculations. The reactive power output of infeed machines is held constant at QG. QT = 9999.0 by default
QB	Minimum generator reactive power output; entered in Mvar. For fixed output generators, QB must be equal to the fixed Mvar output. For infeed machines (WMOD=4), QB is not used in powerflow calculations. The reactive power output infeed machines is held constant at QB = -9999.0 by default.
VS	Regulated voltage setpoint; entered in pu.

	VS = 1.0 by default
IREG	Bus number, or extended bus name enclosed in single quotes, of the bus for which voltage is to be regulated by this plant to the value specified by VS. If IREG specifies a remote bus (i.e., a bus other than bus I), bus IREG must be a Type 1 or 2 bus (if it is other than a Type 1 or 2 bus, bus I regulates its own voltage to the value specified by VS). IREG may be entered as zero if the plant is to regulate its own voltage. If bus I is a Type 3 (swing) bus, IREG must *not* specify a remote bus. IREG = 0 by default
MBASE	Total MVA base of the units represented by this machine; entered in MVA. This quantity is not needed in normal power flow and equivalent construction work, but is required for switching studies, fault analysis, and dynamic simulation. MBASE = system base MVA by default
ZR,ZX	Complex machine impedance, ZSORCE; entered in pu on MBASE base. This data is not needed in normal power flow and equivalent construction work, but is required for switching studies, fault analysis, and dynamic simulation. For dynamic simulation, this impedance must be set equal to the unsaturated subtransient impedance for those generators to be modeled by subtransient level machine models, and to unsaturated transient impedance for those to be modeled by classical or transient level models. For short-circuit studies, the saturated subtransient or transient impedance should be used. ZR = 0.0 and ZX = 1.0 by default
RT,XT	Step-up transformer impedance, XTRAN; entered in pu on MBASE base. XTRAN should be entered as zero if the step-up transformer is explicitly modeled as a network branch and bus I is the terminal bus. RT + jXT = 0.0 by default
GTAP	Step-up transformer off-nominal turns ratio; entered in pu on a system base. GTAP is used only if XTRAN is non-zero. GTAP = 1.0 by default
STAT	Machine status of one for in-service and zero for out-of-service; STAT = 1 by default
RMPCT	Percent of the total Mvar required to hold the voltage at the bus controlled by bus I that are to be contributed by the generation at bus I; RMPCT must be positive. RMPCT is needed only if there is more than one local or remote setpoint mode voltage controlling device (plant, switched shunt, FACTS device shunt element, or VSC dc line converter) controlling the voltage at bus IREG. RMPCT = 100.0 by default
PT	Maximum generator active power output; entered in MW. PT = 9999.0 by default
PB	Minimum generator active power output; entered in MW. PB = -9999.0 by default

Oi	Owner number (1 through 9999). Each machine may have up to four owners. By default, O1 is the owner to which bus I is assigned (refer to Bus Data) and O2, O3, and O4 are zero.
Fi	Fraction of total ownership assigned to owner Oi; each Fi must be positive. The Fi values are normalized such that they sum to 1.0 before they are placed in the working case. By default, each Fi is 1.0.
WMOD	Machine control mode; WMOD is used to indicate whether a machine is a conventional or a non-conventional machine (e.g. renewables, infeed) machine, and, if it is, the type of reactive power limits to be imposed. Non-conventional machines are renewables (e.g., wind, PV etc.) and infeed machines (for definition of infeed machines, see description below of WNMOD=4) 0 - a conventional machine (e.g. synchronous machines). 1 - renewable type machine for which reactive power limits are specified by QT and QB. 2 - renewable type machine for which reactive power limits are determined from the machine's active power output and WPF; limits are of equal magnitude and opposite sign 3 - renewable type machine with a fixed reactive power setting determined from the machine's active power output and WPF; when WPF is positive, the machine's reactive power has the same sign as its active power; when WPF is negative, the machine's reactive power has the opposite sign of its active power. 4 - infeed type machine. An infeed type machine is one for which the machine reactive power (QG) is held constant. The QT and QB limits values are not used and are for information only. QG value has to be between QT and QB. WMOD = 0 by default
WPF	Power factor used in calculating reactive power limits or output when WMOD is 2 or 3. WPF = 1.0 by default
NREG	A node number of bus IREG. The bus section of bus IREG to which node NREG is connected is the bus section for which voltage is to be regulated by this plant to the value specified by VS. If bus IREG is not in a substation, NREG must be specified as 0. NREG = 0 by default

Generator data input is terminated with a record specifying a bus number of zero.

1.10.1. Reactive Power Limits

In specifying reactive power limits for voltage controlling plants (i.e., those with unequal reactive power limits), the use of very narrow var limit bands is discouraged. The Newton-Raphson based power flow solutions require that the difference between the controlling equipment's high and low reactive power limits be greater than 0.002 pu for all setpoint mode voltage controlling equipment (0.2 Mvar on a 100 MVA system base). It is recommended that voltage controlling plants have Mvar ranges substantially wider than this minimum permissible range.

For additional information on generator modeling in power flow solutions, refer to refer to Section 6.3.12, "Generation" and Section 6.3.18, "AC Voltage Control".

1.10.2. Modeling of Generator Step-Up Transformers (GSU)

Before setting-up the generator data, it is important to understand the two methods by which a generator and its associated GSU are represented.

The Implicit Method

- The transformer data is included on the generator data record.
- The transformer is not explicitly represented as a transformer branch.
- The generator terminal bus is not explicitly represented.

Figure 1-4 shows that bus K is the Type 2 bus. This is the bus at which the generator will regulate/control voltage unless the user specifies a remote bus.

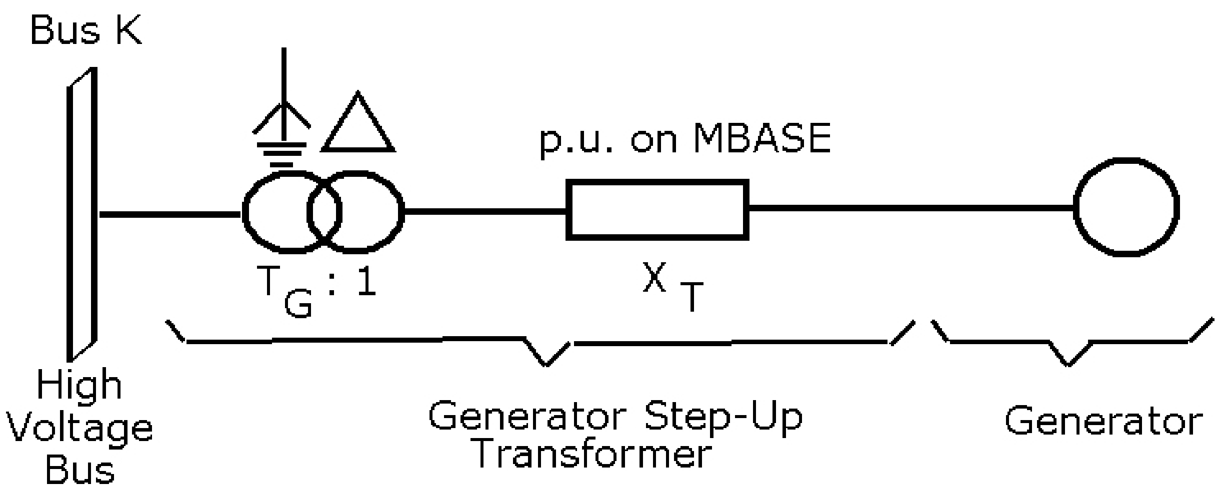


Figure 1.3. Implicit GSU Configuration – Specified as Part of the Generator

The Explicit Method

In this method, the transformer data is not specified with the generator data. It is entered separately (see Transformer Data) in a transformer branch data block.

In Figure 1-5, there is an additional bus to represent the generator terminal. This is the Type 2 bus where the generator will regulate/control voltage unless the user specifies a remote bus.

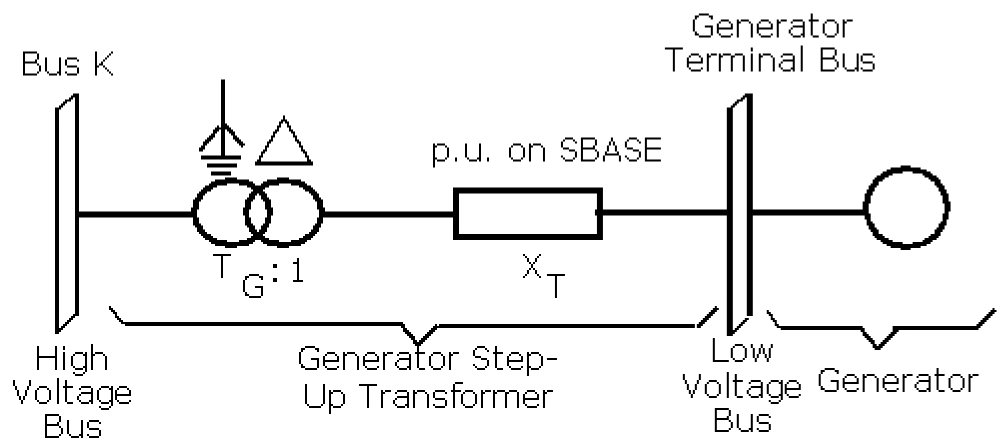


Figure 1.4. Explicit GSU Configuration– Specified Separately from the Generator

1.10.3. Multiple Machine Plants

If a generating plant has several units, they can be represented separately even if they are connected to the same Type 2 bus. When two or more machines are to be separately modeled at a plant, their data may be introduced into the working case using one of two approaches.

A generator data record may be entered in activities READ, TRSQ, or RDCH for each of the machines to be represented, with machine powers, power limits, impedance data, and step-up transformer data for each machine specified on separate generator data records. The plant power output and power limits are taken as the sum of the corresponding quantities of the in-service machines at the plant. The values specified for VS, IREG, and RMPCT, which are treated as plant quantities rather than individual machine quantities, *must be identical* on each of these generator data records.

Alternatively, a single generator record may be specified in activities READ, TREA, or RDCH with the plant total power output, power limits, voltage setpoint, remotely regulated bus, and percent of contributed Mvar entered. Impedance and step-up transformer data may be omitted. The PSSE power flow activities may be used and then, any time prior to beginning switching study, fault analysis, or dynamic simulation work, activity MCRE may be used to introduce the individual machine impedance and step-up transformer data; activity MCRE also apportions the total plant loading among the individual machines.

As an example, Figure 1-6 shows three Type 2 buses, each having two connected units. For generators 1 through 4, the GSU is explicitly represented while for generators 5 and 6 the GSU is implicitly represented. Figure 1-7 shows the generator data records corresponding to Figure 1-6.

The separate transformer data records for the explicitly represented transformers from buses 1238 and 1239 to bus 1237 are not included in Figure 1-7.

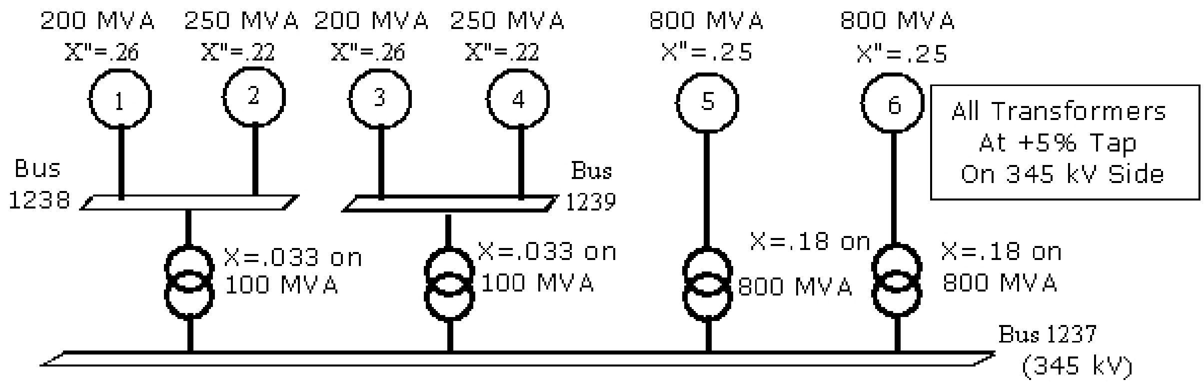
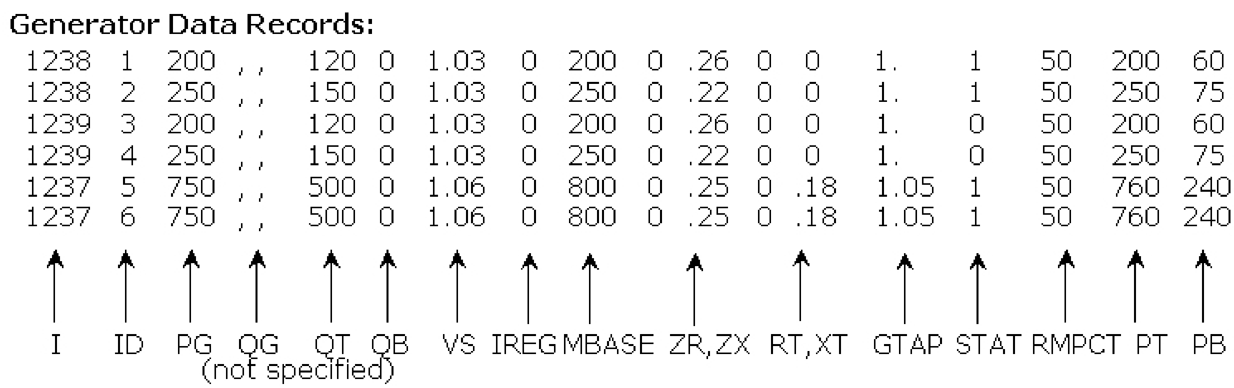


Figure 1.5. Multiple Generators at a Single Plant



Generator Data Records:

I	ID	PG	QG	QT	QB	VS	IREG	MBASE	ZR,ZX		RT,XT		GTAP	STAT	RMPCT	PT	PB
1238	1	200	, ,	120	0	1.03	0	200	0	.26	0	0	1.	1	50	200	60
1238	2	250	, ,	150	0	1.03	0	250	0	.22	0	0	1.	1	50	250	75
1239	3	200	, ,	120	0	1.03	0	200	0	.26	0	0	1.	0	50	200	60
1239	4	250	, ,	150	0	1.03	0	250	0	.22	0	0	1.	0	50	250	75
1237	5	750	, ,	500	0	1.06	0	800	0	.25	0	.18	1.05	1	50	760	240
1237	6	750	, ,	500	0	1.06	0	800	0	.25	0	.18	1.05	1	50	760	240

(not specified)

Figure 1.6. Data Set for the Multiple Generators in Figure 1-6

1.11. Non-Transformer Branch Data

Each ac network branch to be represented in PSSE as a non-transformer branch is introduced by reading a non-transformer branch data record.

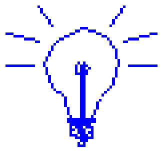
Branches to be modeled as transformers are not specified in this data category; rather, they are specified in Transformer Data.

When specifying a non-transformer branch between buses I and J with circuit identifier CKT, if a two-winding transformer between buses I and J with a circuit identifier of CKT is already present in the working case, it is replaced (i.e., the transformer is deleted from the working case and the newly specified branch is then added to the working case).

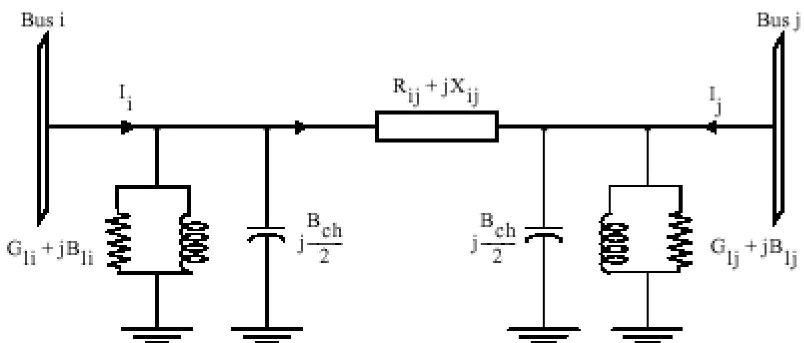
In PSSE, the basic transmission line model is an Equivalent Pi connected between network buses. Figure 1-8 shows the required parameter data where the equivalent Pi is comprised of:

- A series impedance (R + jX).
- Two admittance branches ($jB_{ch}/2$) representing the line's capacitive admittance (line charging).

- Two admittance branches (G + jB) for shunt equipment units (e.g., reactors) that are connected to and switched with the line.



To represent shunts connected to buses, that shunt data should be entered in fixed shunt and/or switched shunt data records.



Transmission Line Equivalent Pi Model

Each non-transformer branch data record has the following format:

```
I,J,CKT,R,X,B,'NAME',RATE1...RATE12,GI,BI,GJ,BJ,ST,MET,LEN,O1,F1,...,O4,F4
```

I	Branch from bus number, or extended bus name enclosed in single quotes (refer to Extended Bus Names). No default allowed
J	Branch to bus number, or extended bus name enclosed in single quotes.
CKT	One- or two-character uppercase non-blank alphanumeric branch circuit identifier; the first character of CKT *must* not be an ampersand ( ); refer to Multi-Section Line Grouping Data. If the first character of CKT is greater than sign (>), the branch buses I and J belong to the same substation in GIC data (see GIC Bus Substation). Unless it is a breaker, switch, or branch in GIC data substation, it is recommended that single circuit branches be designated as having the circuit identifier '1'. CKT = '1' by default
R	Branch resistance; entered in pu. A value of R must be entered for each branch.
X	Branch reactance; entered in pu. A non-zero value of X must be entered for each branch. Refer to Zero Impedance Lines for details on the treatment of branches as zero impedance lines.
B	Total branch charging susceptance; entered in pu. B = 0.0 by default

NAME	Alphanumeric identifier assigned to the branch. NAME may be up to forty characters and may contain any combination of blanks, uppercase letters, numbers and special characters. NAME must be enclosed in single or double quotes if it contains any blanks or special characters. NAME *must* be unique within all non-transformer and transformer branches. NAME is blank by default
RATEn	nth rating; entered in either MVA or current expressed as MVA, according to the value specified for NXFRAT specified on the first data record (refer to Case Identification). Each RATEn = 0.0 (bypass check for this branch; this branch will not be included in any examination of circuit loading) by default. Refer to activity RATE. When specified in units of current expressed as MVA, ratings are entered as: $MVA_{rated} = \sqrt{3} \times E_{base} \times I_{rated} \times 10^{-6}$ where: E_{base} is the base line-to-line voltage in volts of the buses to which the terminal of the branch is connected I_{rated} is the branch rated phase current in amperes.
GI,BI	Complex admittance of the line shunt at the bus I end of the branch; entered in pu. BI is negative for a line connected reactor and positive for line connected capacitor. GI + jBI = 0.0 by default
GJ,BJ	Complex admittance of the line shunt at the bus J end of the branch; entered in pu. BJ is negative for a line connected reactor nd positive for line connected capacitor. GJ + jBJ = 0.0 by default
ST	Branch status of one for in-service and zero for out-of-service; ST = 1 by default
MET	Metered end flag; • <= 1 to designate bus I as the metered end • >= 2 to designate bus J as the metered end MET = 1 by default. PSSE assigns losses to non-metered end of the branch.
LEN	Line length; entered in user-selected units. LEN = 0.0 by default.
Oi	Owner number (1 through 9999). Each branch may have up to four owners. By default, O1 is the owner to which bus I is assigned (refer to Bus Data) and O2, O3, and O4 are zero.

Fi	Fraction of total ownership assigned to owner Oi; each Fi must be positive. The Fi values are normalized such that they sum to 1.0 before they are placed in the working case. Each Fi is 1.0 by default

Non-transformer branch data input is terminated with a record specifying a from bus number of zero.

The branch is treated as series compensated line when its R=0 and X is < 0.

1.11.1. Zero Impedance Lines

PSSE provides for the treatment of bus ties, jumpers, breakers, switches, and other low impedance branches as zero impedance lines. For a branch to be treated as a zero impedance line, it must have the following characteristics:

- Its resistance must be zero.
- Its magnitude of reactance must be less than or equal to the zero impedance line threshold tolerance, THRSHZ.
- It must be a non-transformer branch.

During network solutions, buses connected by such lines are treated as the same bus, thus having identical bus voltages. At the completion of each solution, the loadings on zero impedance lines are determined.

When obtaining power flow solutions, zero impedance line flows, as calculated at the end of the solution, are preserved with the working case and are available to the power flow solution reporting activities. Similarly, in activity SCMU, the positive, negative, and zero sequence branch currents on zero impedance lines are determined and preserved, and are subsequently available to activity SCOP. In the ACCC, as well as activity ASCC and in the linearized network analysis activities, zero impedance line results are calculated and reported as needed.

The remainder of this section contains points to be noted, and restrictions to be observed, in using zero impedance lines.

Branch impedances may not be specified as identically zero; a non-zero reactance must be specified for all branches, and those meeting the criteria above are treated as zero impedance lines.

The zero impedance line threshold tolerance, THRSHZ, may be changed using the category of solution parameter data via activity CHNG or the *[Solution Parameters]* dialog. Setting THRSHZ to zero disables zero impedance line modeling, and all branches are represented with their specified impedances.

A zero impedance line may not have a transformer in parallel with it. Although not required, it is recommended that *no* other in-service lines exist in parallel with a zero impedance line.

A zero impedance line may have non-zero values of line charging and/or line connected shunts. This allows, for example, a low impedance cable to be modeled as a zero impedance line.

When more than two buses are connected together by zero impedance lines in a loop arrangement, there is no unique solution to the flows on the individual zero impedance lines that form the loop. In this case, the reactances specified for these branches is used in determining the zero impedance line flows.

It is important to note that buses connected together by zero impedance lines are treated as a single bus by the power flow solution activities. Hence, equipment controlling the voltages of multiple buses in a zero impedance connected group of buses must have coordinated voltage schedules (i.e., the same voltage setpoint should be specified for each of the voltage controlling devices). Activity CNTB recognizes this condition in scanning for conflicting voltage objectives, and activity REGB may be used to generate a regulated bus report.

Similarly, if multiple voltage controlling devices are present in a group of buses connected together by zero impedance lines, the power flow solution activities handle the boundary condition as if they are all connected to the same bus (refer to Setpoint Voltage Control).

In fault analysis activities, a branch treated as a zero impedance line in the positive sequence is treated in the same manner in the zero sequence, regardless of its zero sequence branch impedance. Zero sequence mutual couplings involving a zero impedance line are ignored in the fault analysis solution activities.

1.12. System Switching Device Data

Breakers and switches can be represented by system switching devices in PSSE. System switching devices are set to represent breakers or switches by setting the STYPE data element described below.

Most activities do not honor the system switching devices. System switching devices are treated as zero impedance lines if they have characteristics of zero impedance lines; otherwise, they are treated as regular non-transformer branches.

System switching devices are recognized in Substation Reliability Assessment (refer to Section 6.16, Calculating Substation Reliability) and activity DFAX. Substation Reliability Assessment simulates operations of breakers to isolate faults in a substation and manual switching to restore the service to supply loads. Distribution Factor File setup activity can process automatic commands to operate and monitor breakers and switches in Contingency Description Data File and Monitored Element Data File respectively.

As mentioned in the section Zero Impedance Lines, PSSE is able to handle a loop arrangement consisting of zero impedance lines so that users can build a fully detailed bus/breaker model for any bus configuration, such as a ring bus configuration. When adding a system switching device into a network model, connectivity nodes where the terminals of a transmission line connect to the terminals of the system switching device must be added as well. This will change a bus branch configuration which is widely used in planning studies to a detailed bus breaker configuration and lead to a tremendous increase in number of buses. In such cases as this, the use of the the use of the extensive substation modeling capabilities introduced in PSSE 34 is recommended.

```
I,J,CKT,X,RATE1...RATE12,STATUS,NSTATUS,METERED,STYPE,NAME
```

I	From bus number. No default allowed
J	To bus number. No default allowed
CKT	Two-character uppercase non-blank alphanumeric switching device identifier. CKT = '1' by default
X	Branch reactance; entered in pu, must be less than ZTHRES

RATEn	nth rating; entered in either MVA or current expressed as MVA, according to the value specified for NXFRAT specified on the first data record (refer to Case Identification Data). Each RATEn = 0.0 (bypass check for this branch; this branch will not be included in any examination of circuit loading) by default. Refer to activity RATE.
STATUS	System switching device status: 1 for closed (in service) and 0 for opened (out of service). STATUS=1 by default
NSTATUS	Normal service status: 1 for normally closed (in service) and 0 for normally opened (out of service). NSTATUS=1 by default
METERD	Metered end
STYPE	Switching device type 1 - Generic connector 2 - Circuit breaker 3 - Disconnect switch
NAME	System switching device name

System Switching Device data input is terminated with a record specifying a from bus number of zero.

1.13. Transformer Data

Each ac transformer to be represented in PSSE is introduced through transformer data record blocks that specify all the data required to model transformers in power flow calculations, with one exception. That exception is an optional set of ancillary data, transformer impedance correction tables, which define the manner in which transformer impedance changes as off-nominal turns ratio or phase shift angle is adjusted. Those data records are described in Transformer Impedance Cor.

Both two-winding and three-winding transformers are specified in transformer data record blocks. Two-winding transformers require a block of four data records. Three-winding transformers require five data records.

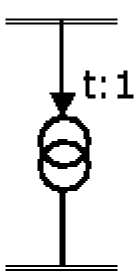
Transformer 	t_1: t_2:	$t = t_1 / t_2$; transformer turns ratio winding 1 turns ratio in kV or pu on bus voltage base or winding voltage base winding 2 turns ratio in kV or pu on bus voltage base or winding voltage base

Figure 1-9 shows the transformer winding configurations.

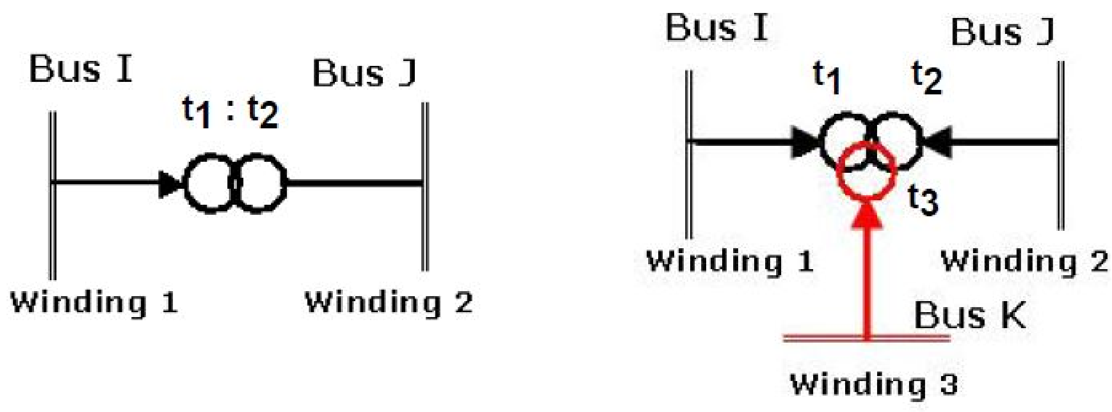


Figure 1.7. Two and Three-winding Transformer Configurations Related to Data Records

The five record transformer data block for three-winding transformers has the following format:

```
I,J,K,CKT,CW,CZ,CM,MAG1,MAG2,NMETR,'NAME',STAT,O1,F1,...,O4,F4,VECGRP,ZCOD
R1-2,X1-2,SBASE1-2,R2-3,X2-3,SBASE2-3,R3-1,X3-1,SBASE3-1,VMSTAR,ANSTAR
WINDV1,NOMV1,ANG1,RATE11...RATE121,COD1,CONT1,RMA1,RMI1,VMA1,VMI1,
WINDV2,NOMV2,ANG2,RATE12...RATE122,COD2,CONT2,RMA2,RMI2,VMA2,VMI2,
WINDV3,NOMV3,ANG3,RATE13...RATE123,COD3,CONT3,RMA3,RMI3,VMA3,VMI3,
```

The four-record transformer data block for two-winding transformers is a subset of the data required for three-winding transformers and has the following format:

```
I,J,K,CKT,CW,CZ,CM,MAG1,MAG2,NMETR,'NAME',STAT,O1,F1,...,O4,F4,VECGRP
R1-2,X1-2,SBASE1-2
WINDV1,NOMV1,ANG1,RATE11...RATE121,COD1,CONT1,RMA1,RMI1,VMA1,VMI1,
WINDV2,NOMV2
```

Control parameters for the automatic adjustment of transformers and phase shifters are specified on the third record of the two-winding transformer data block, and on the third through fifth records of the three-winding transformer data block. All transformers are adjustable and the control parameters may be specified either at the time of raw data input or subsequently via activity CHNG or the transformer *[Spreadsheets]*. Any two-winding transformer and any three-winding transformer winding for which no control data is provided has default data assigned to it; the default data is such that the two-winding transformer or three-winding transformer winding is treated as locked.

Refer to Transformer Sequence Numbers and Three-Winding Transformer Notes for additional details on the three-winding transformer model used in PSSE.

When specifying a two-winding transformer between buses I and J with circuit identifier CKT, if a nontransformer branch between buses I and J with a circuit identifier of CKT is already present in the working case, it is replaced (i.e., the nontransformer branch is deleted from the working case and the newly specified two-winding transformer is then added to the working case).

All data items on the first record are specified for both two- and three-winding transformers except for ZCOD, which is specified only for three-winding transformers.

I	The bus number, or extended bus name enclosed in single quotes (refer to Extended Bus Names), of the bus to which Winding 1 is connected. The transformer's magnetizing admittance is modeled on Winding 1. Winding 1 is the only winding of a two-winding transformer for which tap ratio or phase shift angle may be adjusted by the power flow solution activities; any winding(s) of a three-winding transformer may be adjusted. No default is allowed
J	The bus number, or extended bus name enclosed in single quotes, of the bus to which Winding 2 is connected. No default is allowed
K	The bus number, or extended bus name enclosed in single quotes, of the bus to which Winding 3 is connected. Zero is used to indicate that no third winding is present (i.e., that a two-winding rather than a three-winding transformer is being specified). K = 0 by default.
CKT	One- or two-character uppercase non-blank alphanumeric transformer circuit identifier; the first character of CKT *must not* be an ampersand ( ), at sign (@), or asterisk (*); refer to Multi-Section Line Grouping Data and Section 6.15.2, Outage Statistics Data File Contents. CKT = '1' by default.
CW	The winding data I/O code defines the units in which the turns ratios WINDV1, WINDV2 and WINDV3 are specified (the units of RMAn and RMIn are also governed by CW when |CODn| is 1 or 2): • 1 for off-nominal turns ratio in pu of winding bus base voltage • 2 for winding voltage in kV • 3 for off-nominal turns ratio in pu of nominal winding voltage, NOMV1, NOMV2 and NOMV3 CW = 1 by default.
CZ	The impedance data I/O code defines the units in which the winding impedances R1-2, X1-2, R2-3, X2-3, R3-1 and X3-1 are specified: • 1 for resistance and reactance in pu on system MVA base and winding voltage base • 2 for resistance and reactance in pu on a specified MVA base and winding voltage base • 3 for transformer load loss in watts and impedance magnitude in pu on a specified MVA base and winding voltage base

	In specifying transformer leakage impedances, the base voltage values are always the nominal winding voltages that are specified on the third, fourth and fifth records of the transformer data block (NOMV1, NOMV2 and NOMV3). If the default NOMVn is not specified, it is assumed to be identical to the winding n bus base voltage. CZ = 1 by default.
CM	The magnetizing admittance I/O code defines the units in which MAG1 and MAG2 are specified: • 1 for complex admittance in pu on system MVA base and Winding 1 bus voltage base • 2 for no load loss in watts and exciting current in pu on Winding 1 to two MVA base (SBASE1-2) and nominal Winding 1 voltage, NOMV1. CM = 1 by default.
MAG1, MAG2	The transformer magnetizing admittance connected to ground at bus I. When CM is 1, MAG1 and MAG2 are the magnetizing conductance and susceptance, respectively, in pu on system MVA base and Winding 1 bus voltage base. When a non-zero MAG2 is specified, it should be entered as a negative quantity. When CM is 2, MAG1 is the no load loss in watts and MAG2 is the exciting current in pu on Winding 1 to two MVA base (SBASE1-2) and nominal Winding 1 voltage (NOMV1). For three-phase transformers or three-phase banks of single phase transformers, MAG1 should specify the three-phase no-load loss. When a non-zero MAG2 is specified, it should be entered as a positive quantity. MAG1 = 0.0 and MAG2 = 0.0 by default.
NMETR	The nonmetered end code of either 1 (for the Winding 1 bus) or 2 (for the Winding 2 bus). In addition, for a three-winding transformer, 3 (for the Winding 3 bus) is a valid specification of NMETR. NMETR = 2 by default
NAME	Alphanumeric identifier assigned to the transformer. NAME may be up to forty characters and may contain any combination of blanks, uppercase letters, numbers and special characters. NAME *must* be enclosed in single or double quotes if it contains any blanks or special characters. NAME *must* be unique within all non-transformer and transformer branches. NAME is blank by default
STAT	Transformer status of one for in-service and zero for out-of-service. In addition, for a three-winding transformer, the following values of STAT provide for one winding out-of-service with the remaining windings in-service: • 2 for only Winding 2 out-of-service • 3 for only Winding 3 out-of-service • 4 for only Winding 1 out-of-service

	STAT = 1 by default
Oi	An owner number (1 through 9999). Each transformer may have up to four owners. By default, O1 is the owner to which bus I is assigned and O2, O3, and O4 are zero.
Fi	The fraction of total ownership assigned to owner Oi; each Fi must be positive. The Fi values are normalized such that they sum to 1.0 before they are placed in the working case. Each Fi is 1.0 by default
VECGRP	Alphanumeric identifier specifying vector group based on transformer winding connections and phase angles. VECGRP value is used for information purpose only. VECGRP is 12 blanks by default
ZCOD	Method to be used in deriving actual transformer impedances in applying transformer impedance adjustment tables: • 0 apply impedance adjustment factors to winding impedances • 1 apply impedance adjustment factors to bus-to-bus impedances ZCOD = 0 by default ZCOD value is used only for three winding transformers. It is not used for two winding transformers. For three winding transformers, winding impedances are the equivalent T-model impedances Z1, Z2 and Z3; and the bus-to-bus impedances are impedances Z12, Z23 and Z31. For three winding transformers and bus-to-bus impedance correction factors, only one of the three windings must be adjustable (only one of COD1, COD2 and COD3 can be non-zero).

The first three data items on the second record are read for both two- and three-winding transformers; the remaining data items are used *only* for three-winding transformers:

R1-2, X1-2	The measured impedance of the transformer between the buses to which its first and second windings are connected. When CZ is 1, they are the resistance and reactance, respectively, in pu on system MVA base and winding voltage base. When CZ is 2, they are the resistance and reactance, respectively, in pu on Winding 1 to 2 MVA base (SBASE1-2) and winding voltage base. When CZ is 3, R1-2 is the load loss in watts, and X1-2 is the impedance magnitude in pu on Winding 1 to 2 MVA base (SBASE1-2) and winding voltage base. For three-phase transformers or three-phase banks of single phase transformers, R1-2 should specify the three-phase load loss. R1-2 = 0.0 by default, but no default is allowed for X1-2.
SBASE1-2	The Winding 1 to 2 three-phase base MVA of the transformer. SBASE1-2 = SBASE (the system base MVA) by default.

R2-3, X2-3	The measured impedance of a three-winding transformer between the buses to which its second and third windings are connected; ignored for a two-winding transformer. When CZ is 1, they are the resistance and reactance, respectively, in pu on system MVA base and winding voltage base. When CZ is 2, they are the resistance and reactance, respectively, in pu on Winding 2 to 3 MVA base (SBASE2-3) and winding voltage base. When CZ is 3, R2-3 is the load loss in watts, and X2-3 is the impedance magnitude in pu on Winding 2 to 3 MVA base (SBASE2-3) and winding voltage base. For three-phase transformers or three-phase banks of single phase transformers, R2-3 should specify the three-phase load loss. R2-3 = 0.0 by default, but no default is allowed for X2-3.
SBASE2-3	The Winding 2 to 3 three-phase base MVA of a three-winding transformer; ignored for a two-winding transformer. SBASE2-3 = SBASE (the system base MVA) by default.
R3-1, X3-1	The measured impedance of a three-winding transformer between the buses to which its third and first windings are connected; ignored for a two-winding transformer. When CZ is 1, they are the resistance and reactance, respectively, in pu on system MVA base and winding voltage base. When CZ is 2, they are the resistance and reactance, respectively, in pu on Winding 3 to 1 MVA base (SBASE3-1) and winding voltage base. When CZ is 3, R3-1 is the load loss in watts, and X3-1 is the impedance magnitude in pu on Winding 3 to 1 MVA base (SBASE3-1) and winding voltage base. For three-phase transformers or three-phase banks of single phase transformers, R3-1 should specify the three-phase load loss. R3-1 = 0.0 by default, but no default is allowed for X3-1.
SBASE3-1	The Winding 3 to 1 three-phase base MVA of a three-winding transformer; ignored for a two-winding transformer. SBASE3-1 = SBASE (the system base MVA) by default.
VMSTAR	The voltage magnitude at the hidden star point bus; entered in pu. VMSTAR = 1.0 by default.
ANSTAR	The bus voltage phase angle at the hidden star point bus; entered in degrees. ANSTAR = 0.0 by default

All data items on the third record are read for both two- and three-winding transformers:

WINDV1	When CW is 1, WINDV1 is the Winding 1 off-nominal turns ratio in pu of Winding 1 bus base voltage; WINDV1 = 1.0 by default. When CW is 2, WINDV1 is the actual Winding 1 voltage in kV; WINDV1 is equal to the base voltage of bus I by default.

	When CW is 3, WINDV1 is the Winding 1 off-nominal turns ratio in pu of nominal Winding 1 voltage, NOMV1; WINDV1 = 1.0 by default.
NOMV1	The nominal (rated) Winding 1 voltage base in kV, or zero to indicate that nominal Winding 1 voltage is assumed to be identical to the base voltage of bus I. NOMV1 is used in converting magnetizing data between physical units and per unit admittance values when CM is 2. NOMV1 is used in converting tap ratio data between values in per unit of nominal Winding 1 voltage and values in per unit of Winding 1 bus base voltage when CW is 3. NOMV1 = 0.0 by default
ANG1	The winding one phase shift angle in degrees. For a two-winding transformer, ANG1 is positive when the winding one bus voltage leads the winding two bus voltage; for a three-winding transformer, ANG1 is positive when the winding one bus voltage leads the T (or star) point bus voltage. ANG1 must be greater than -180.0° and less than or equal to +180.0°. ANG1 = 0.0 by default.
RATEn1	Winding 1's twelve three-phase ratings, entered in either MVA or current expressed as MVA, according to the value specified for XFRRAT specified on the first data record (refer to Case Identification Data). Each RATEn1 = 0.0 (bypass loading limit check for this transformer winding) by default.
COD1	The transformer control mode for automatic adjustments of the Winding 1 tap or phase shift angle during power flow solutions: • 0 - for fixed tap and fixed phase shift • ±1 - for voltage control • ±2 - for reactive power flow control • ±3 - for active power flow control • ±4 - for control of a dc line quantity (valid only for two-winding transformers) • ±5 - for asymmetric active power flow control If the control mode is entered as a positive number, automatic adjustment of this transformer winding is enabled when the corresponding adjustment is activated during power flow solutions; a negative control mode suppresses the automatic adjustment of this transformer winding. COD1 = 0 by default.
CONT1	The bus number, or extended bus name enclosed in single quotes (refer to Extended Bus Names), of the bus for which voltage is to be controlled by the transformer turns ratio adjustment option of the power flow solution activities when COD1 is 1. CONT1 should be non-zero only for voltage controlling transformer windings. CONT1 may specify a bus other than I, J, or K; in this case, the sign of CONT1 defines the location of the controlled bus relative to the transformer winding. If CONT1 is entered as a positive number, or a quoted extended bus name, the ratio is adjusted as if bus CONT1 is on the Winding 2 or Winding 3 side of the transformer; if CONT1 is entered as a negative number, or a quoted extended bus name with a minus sign

	preceding the first character, the ratio is adjusted as if bus |CONT1| is on the Winding 1 side of the transformer. CONT1 = 0 by default.
RMA1, RMI1	When |COD1| is 1, 2, 3, or 5, the upper and lower limits, respectively, of one of the following: • Off-nominal turns ratio in pu of Winding 1 bus base voltage when |COD1| is 1 or 2 and CW is 1; RMA1 = 1.1 and RMI1 = 0.9 by default. • Actual Winding 1 voltage in kV when |COD1| is 1 or 2 and CW is 2. No default is allowed. • Off-nominal turns ratio in pu of nominal Winding 1 voltage (NOMV1) when |COD1| is 1 or 2 and CW is 3; RMA1 = 1.1 and RMI1 = 0.9 by default. • Phase shift angle in degrees when |COD1| is 3 or 5. No default is allowed. Not used when |COD1| is 0 or 4; RMA1 = 1.1 and RMI1 = 0.9 by default.
VMA1, VMI1	When |COD1| is 1, 2, 3, or 5, the upper and lower limits, respectively, of one of the following: • Voltage at the controlled bus (bus |CONT1|) in pu when |COD1| is 1. VMA1 = 1.1 and VMI1 = 0.9 by default. • Reactive power flow into the transformer at the Winding 1 bus end in Mvar when |COD1| is 2. No default is allowed. • Active power flow into the transformer at the Winding 1 bus end in MW when |COD1| is 3 or 5. No default is allowed. Not used when |COD1| is 0 or 4. VMA1 = 1.1 and VMI1 = 0.9 by default.
NTP1	The number of tap positions available; used when COD1 is 1 or 2. NTP1 must be between 2 and 9999. NTP1 = 33 by default.
TAB1	The number of a transformer impedance correction table if this transformer winding's impedance is to be a function of either off-nominal turns ratio or phase shift angle (refer to Transformer Impedance Correction Tables), or 0 if no transformer impedance correction is to be applied to this transformer winding. TAB1 = 0 by default. For three winding transformers, these impedance correction factors are applied to the equivalent T-model impedance Z1 when ZCOD=0 and to the bus-to-bus impedance Z12 when ZCOD=1.
CR1, CX1	The load drop compensation impedance for voltage controlling transformers entered in pu on system base quantities; used when COD1 is 1. CR1 + j CX1 = 0.0 by default

CNXA1	Winding connection angle in degrees; used when COD1 is 5. There are no restrictions on the value specified for CNXA1; if it is outside of the range from -90.0 to +90.0, CNXA1 is normalized to within this range. CNXA1 = 0.0 by default.
NODE1	A node number of bus CONT1. The bus section of bus CONT1 to which node NODE1 is connected is the bus section for which voltage is to be controlled by the transformer turns ratio adjustment option of the power flow solution activities when COD1 is 1. NODE1 should be non-zero only for voltage controlling transformer windings. If bus CONT1 is not in a substation, NODE1 must be specified as 0. NODE1 = 0 by default.

The first two data items on the fourth record are read for both two- and three-winding transformers; the remaining data items are used *only* for three-winding transformers:

WINDV2	When CW is 1, WINDV2 is the Winding 2 off-nominal turns ratio in pu of Winding 2 bus base voltage; WINDV2 = 1.0 by default. When CW is 2, WINDV2 is the actual Winding 2 voltage in kV; WINDV2 is equal to the base voltage of bus J by default. When CW is 3, WINDV2 is the Winding 2 off-nominal turns ratio in pu of nominal Winding 2 voltage, NOMV2; WINDV2 = 1.0 by default.
NOMV2	The nominal (rated) Winding 2 voltage base in kV, or zero to indicate that nominal Winding 2 voltage is assumed to be identical to the base voltage of bus J. NOMV2 is used in converting tap ratio data between values in per unit of nominal Winding 2 voltage and values in per unit of Winding 2 bus base voltage when CW is 3. NOMV2 = 0.0 by default.
ANG2	The winding two phase shift angle in degrees. ANG2 is ignored for a two-winding transformer. For a three-winding transformer, ANG2 is positive when the winding two bus voltage leads the T (or star) point bus voltage. ANG2 must be greater than -180.0° and less than or equal to +180.0°. ANG2 = 0.0 by default.
RATEn2	Winding 2's twelve three-phase ratings, entered in either MVA or current expressed as MVA, according to the value specified for XFRRAT specified on the first data record (refer to Case Identification Data). Each RATEn2 = 0.0 (bypass loading limit check for this transformer winding) by default.
COD2	The transformer control mode for automatic adjustments of the Winding 2 tap or phase shift angle during power flow solutions: • 0 - for fixed tap and fixed phase shift • ±1 - for voltage control • ±2 - for reactive power flow control • ±3 - for active power flow control • ±5 - for asymmetric active power flow control

	If the control mode is entered as a positive number, automatic adjustment of this transformer winding is enabled when the corresponding adjustment is activated during power flow solutions; a negative control mode suppresses the automatic adjustment of this transformer winding. COD2 = 0 by default.
CONT2	The bus number, or extended bus name enclosed in single quotes (refer to Extended Bus Names), of the bus for which voltage is to be controlled by the transformer turns ratio adjustment option of the power flow solution activities when COD2 is 1. CONT2 should be non-zero only for voltage controlling transformer windings. CONT2 may specify a bus other than I, J, or K; in this case, the sign of CONT2 defines the location of the controlled bus relative to the transformer winding. If CONT2 is entered as a positive number, or a quoted extended bus name, the ratio is adjusted as if bus CONT2 is on the Winding 1 or Winding 3 side of the transformer; if CONT2 is entered as a negative number, or a quoted extended bus name with a minus sign preceding the first character, the ratio is adjusted as if bus |CONT2| is on the Winding 2 side of the transformer. CONT2 = 0 by default.
RMA2, RMI2	When |COD2| is 1, 2, 3, or 5, the upper and lower limits, respectively, of one of the following: • Off-nominal turns ratio in pu of Winding 2 bus base voltage when |COD2| is 1 or 2 and CW is 1; RMA2 = 1.1 and RMI2 = 0.9 by default. • Actual Winding 2 voltage in kV when |COD2| is 1 or 2 and CW is 2. No default is allowed. • Off-nominal turns ratio in pu of nominal Winding 2 voltage (NOMV2) when |COD2| is 1 or 2 and CW is 3; RMA2 = 1.1 and RMI2 = 0.9 by default. • Phase shift angle in degrees when |COD2| is 3 or 5. No default is allowed. Not used when |COD2| is 0. RMA2 = 1.1 and RMI2 = 0.9 by default.
VMA2, VMI2	When |COD2| is 1, 2, 3, or 5, the upper and lower limits, respectively, of one of the following: • Voltage at the controlled bus (bus |CONT2|) in pu when |COD2| is 1. VMA2 = 1.1 and VMI2 = 0.9 by default. • Reactive power flow into the transformer at the Winding 2 bus end in Mvar when |COD2| is 2. No default is allowed. • Active power flow into the transformer at the Winding 2 bus end in MW when |COD2| is 3 or 5. No default is allowed. Not used when |COD2| is 0. VMA2 = 1.1 and VMI2 = 0.9 by default

NTP2	The number of tap positions available; used when COD2 is 1 or 2. NTP2 must be between 2 and 9999. NTP2 = 33 by default
TAB2	The number of a transformer impedance correction table if this transformer winding's impedance is to be a function of either off-nominal turns ratio or phase shift angle (refer to Transformer Impedance Correction Tables), or 0 if no transformer impedance correction is to be applied to this transformer winding. TAB2 = 0 by default. For three winding transformers, these impedance correction factors are applied to the equivalent T-model impedance Z2 when ZCOD=0 and to the bus-to-bus impedance Z23 when ZCOD=1.
CR2, CX2	The load drop compensation impedance for voltage controlling transformers entered in pu on system base quantities; used when COD2 is 1. CR2 + j CX2 = 0.0 by default.
CNXA2	Winding connection angle in degrees; used when COD2 is 5. There are no restrictions on the value specified for CNXA2; if it is outside of the range from -90.0 to +90.0, CNXA2 is normalized to within this range. CNXA2 = 0.0 by default.
NODE2	A node number of bus CONT2. The bus section of bus CONT2 to which node NODE2 is connected is the bus section for which voltage is to be controlled by the transformer turns ratio adjustment option of the power flow solution activities when COD2 is 1. NODE2 should be non-zero only for voltage controlling transformer windings. If bus CONT2 is not in a substation, NODE2 must be specified as 0. NODE2 = 0 by default.

The fifth data record is specified only for three-winding transformers:

WINDV3	When CW is 1, WINDV3 is the Winding 3 off-nominal turns ratio in pu of Winding 3 bus base voltage; WINDV3 = 1.0 by default. When CW is 2, WINDV3 is the actual Winding 3 voltage in kV; WINDV3 is equal to the base voltage of bus K by default. When CW is 3, WINDV3 is the Winding 3 off-nominal turns ratio in pu of nominal Winding 3 voltage, NOMV3; WINDV3 = 1.0 by default.
NOMV3	The nominal (rated) Winding 3 voltage base in kV, or zero to indicate that nominal Winding 3 voltage is assumed to be identical to the base voltage of bus K. NOMV3 is used in converting tap ratio data between values in per unit of nominal Winding 3 voltage and values in per unit of Winding 3 bus base voltage when CW is 3. NOMV3 = 0.0 by default
ANG3	The winding three phase shift angle in degrees. ANG3 is positive when the winding three bus voltage leads the T (or star) point bus voltage. ANG3 must be greater than -180.0° and less than or equal to +180.0°.

	ANG3 = 0.0 by default
RATEn3	Winding 3's twelve three-phase ratings, entered in either MVA or current expressed as MVA, according to the value specified for XFRRAT specified on the first data record (refer to Case Identification Data). Each RATEn3 = 0.0 (bypass loading limit check for this transformer winding) by default.
COD3	The transformer control mode for automatic adjustments of the Winding 3 tap or phase shift angle during power flow solutions: • 0 - for fixed tap and fixed phase shift • ±1 - for voltage control • ±2 - for reactive power flow control • ±3 - for active power flow control • ±5 - for asymmetric active power flow control If the control mode is entered as a positive number, automatic adjustment of this transformer winding is enabled when the corresponding adjustment is activated during power flow solutions; a negative control mode suppresses the automatic adjustment of this transformer winding. COD3 = 0 by default
CONT3	The bus number, or extended bus name enclosed in single quotes (refer to Extended Bus Names), of the bus for which voltage is to be controlled by the transformer turns ratio adjustment option of the power flow solution activities when COD3 is 1. CONT3 should be non-zero only for voltage controlling transformer windings. CONT3 may specify a bus other than I, J, or K; in this case, the sign of CONT3 defines the location of the controlled bus relative to the transformer winding. If CONT3 is entered as a positive number, or a quoted extended bus name, the ratio is adjusted as if bus CONT3 is on the Winding 1 or Winding 2 side of the transformer; if CONT3 is entered as a negative number, or a quoted extended bus name with a minus sign preceding the first character, the ratio is adjusted as if bus |CONT3| is on the Winding 3 side of the transformer. CONT3 = 0 by default
RMA3, RMI3	When |COD3| is 1, 2, 3, or 5, the upper and lower limits, respectively, of one of the following: • Off-nominal turns ratio in pu of Winding 3 bus base voltage when |COD3| is 1 or 2 and CW is 1; RMA3 = 1.1 and RMI3 = 0.9 by default. • Actual Winding 3 voltage in kV when |COD3| is 1 or 2 and CW is 2. No default is allowed. • Off-nominal turns ratio in pu of nominal Winding 3 voltage (NOMV3) when |COD3| is 1 or 2 and CW is 3; RMA3 = 1.1 and RMI3 = 0.9 by default. • Phase shift angle in degrees when |COD3| is 3 or 5. No default is allowed.

	Not used when |COD3| is 0. RMA3 = 1.1 and RMI3 = 0.9 by default
VMA3, VMI3	When |COD3| is 1, 2, 3, or 5, the upper and lower limits, respectively, of one of the following: • Voltage at the controlled bus (bus |CONT3|) in pu when |COD3| is 1. VMA3 = 1.1 and VMI3 = 0.9 by default. • Reactive power flow into the transformer at the Winding 3 bus end in Mvar when |COD3| is 2. No default is allowed. • Active power flow into the transformer at the Winding 3 bus end in MW when |COD3| is 3 or 5. No default is allowed. Not used when |COD3| is 0. VMA3 = 1.1 and VMI3 = 0.9 by default
NTP3	The number of tap positions available; used when COD3 is 1 or 2. NTP3 must be between 2 and 9999. NTP3 = 33 by default
TAB3	The number of a transformer impedance correction table if this transformer winding's impedance is to be a function of either off-nominal turns ratio or phase shift angle (refer to Transformer Impedance Correction Tables), or 0 if no transformer impedance correction is to be applied to this transformer winding. TAB3 = 0 by default For three winding transformers, these impedance correction factors are applied to the equivalent T-model impedance Z3 when ZCOD=0 and to the bus-to-bus impedance Z31 when ZCOD=1.
CR3, CX3	The load drop compensation impedance for voltage controlling transformers entered in pu on system base quantities; used when COD3 is 1. CR3 + j CX3 = 0.0 by default
CNXA3	Winding connection angle in degrees; used when COD3 is 5. There are no restrictions on the value specified for CNXA3; if it is outside of the range from -90.0 to +90.0, CNXA3 is normalized to within this range. CNXA3 = 0.0 by default
NODE3	A node number of bus CONT3. The bus section of bus CONT3 to which node NODE3 is connected is the bus section for which voltage is to be controlled by the transformer turns ratio adjustment option of the power flow solution activities when COD3 is 1. NODE3 should be non-zero only for voltage controlling transformer windings. If bus CONT3 is not in a substation, NODE3 must be specified as 0. NODE3 = 0 by default.

Transformer data input is terminated with a record specifying a Winding 1 bus number of zero.

1.13.1. Three-Winding Transformer Notes

The transformer data record blocks described in Transformer Data provide for the specification of both two-winding transformers and three-winding transformers. A three-winding transformer is modeled in PSSE as a grouping of three two-winding transformers, where each of these two-winding transformers models one of the windings. While most of the three-winding transformer data is stored in the two-winding transformer data arrays, it is accessible for reporting and modification only as three-winding transformer data.

In deriving winding impedances from the measured impedance data input values, one winding with a small impedance, in many cases negative, often results. In the extreme case, it is possible to specify a set of measured impedances that themselves do not individually appear to challenge the precision limits of typical power system calculations, but which result in one winding impedance of nearly (or identically) 0.0. Such data could result in precision difficulties, and hence inaccurate results, when processing the system matrices in power flow and short circuit calculations.

Whenever a set of measured impedance results in a winding reactance that is identically 0.0, a warning message is printed by the three-winding transformer data input or data changing function, and the winding's reactance is set to the zero impedance line threshold tolerance (or to 0.0001 if the zero impedance line threshold tolerance itself is 0.0). Whenever a set of measured impedances results in a winding impedance for which magnitude is less than 0.00001, a warning message is printed. As with all warning and error messages produced during data input and data modification phases of PSSE, the user should resolve the cause of the message (e.g., was correct input data specified?) and use engineering judgement to resolve modeling issues (e.g., is this the best way to model this transformer or would some other modeling be more appropriate?).

Activity BRCH may be used to detect the presence of branch reactance magnitudes less than a user-specified threshold tolerance; its use is always recommended whenever the user begins power system analysis work using a new or modified system model.

1.13.2. Example Two-Winding Transformer Data Records

Figure1-10 shows the data records for a 50 MVA, 138/34.5 kV two-winding transformer connected to system buses with nominal voltages of 134 kV and 34.5 kV, and sample data on 100 MVA system base and winding voltage bases of 134 kV and 34.5 kV.

Example of 2-Winding Transformer:

Data Formats

```
I,J,K,CKT,CW,CZ,CM,MAG1,MAG2,NMETR,'NAME',STAT,O1,F1,...,O4,F4,VECGRP

R1-2,X1-2,SBASE1-2

WINDV1,NOMV1,ANG1,RATE11...RATE121,COD1,CONT1,RMA1,RMI1,VMA1,VMI1,

WINDV2,NOMV2
```

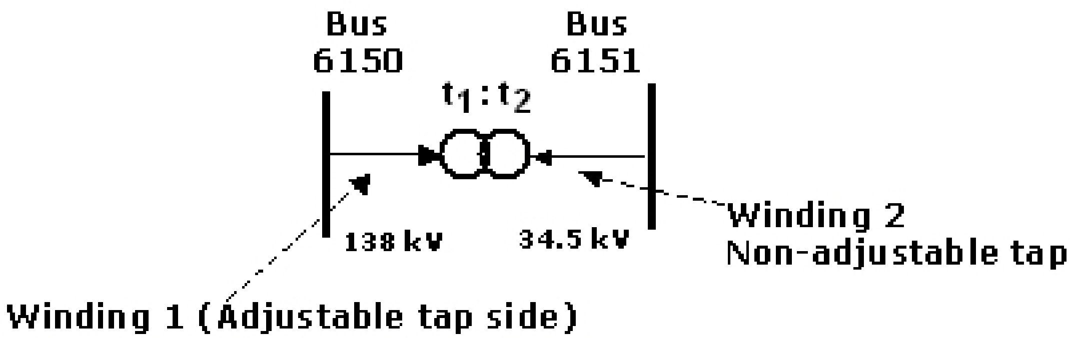
Data

6150, 6151, 0, '1', 1, 1, 1, 0.0, 0.0, 2, 'TWO-WINDINGS', 1, 5, 1.0

0.0, 0.30, 100.0

1.0299, 0.0, 0.0, 50.0, 60.0, 75.0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 6151, 1.1, 0.9, 1.025, 1.0, 33, 0, 0.0, 0.0

1.0, 0.0



Sample Data for Two-Winding Transformer

1.13.3. Example Three-Winding Transformer Data Records

Figure 1-11 shows the data records for a 300 MVA, 345/138/13.8 kV three-winding transformer connected to system buses with nominal voltages of 345 kV, 138 kV and 13.8 kV, respectively, and sample data on 100 MVA system base and winding base voltages of 345 kV, 138 kV and 13.8 kV.

Example of 3-Winding Transformer:

Data Formats

```
I,J,K,CKT,CW,CZ,CM,MAG1,MAG2,NMETR,'NAME',STAT,O1,F1,...,O4,F4,VECGRP,ZCOD

R1-2,X1-2,SBASE1-2,R2-3,X2-3,SBASE2-3,R3-1,X3-1,SBASE3-1,VMSTAR,ANSTAR

WINDV1,NOMV1,ANG1,RATE11...RATE121,COD1,CONT1,RMA1,RMI1,VMA1,VMI1,

WINDV2,NOMV2,ANG2,RATE12...RATE122,COD2,CONT2,RMA2,RMI2,VMA2,VMI2,

WINDV3,NOMV3,ANG3,RATE13...RATE123,COD3,CONT3,RMA3,RMI3,VMA3,VMI3,
```

Data

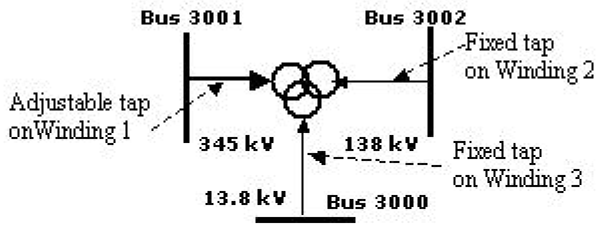
3001, 3002, 3000, '1', 1, 1, 1, 0.0, 0.0, 2, 'THREEWINDING', 1, 5, 1.0

0.003, 0.03, 100.0, 0.001, 0.03, 100.0, 0.001, 0.035, 100.0, 1.025, 0.0

1.00, 0.0, 0.0, 300, 400, 600, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 3001, 1.1, 0.9, 1.04, 1.0, 33, 0, 0.0, 0.0, 0.0

1.02, 0.0, 0.0, 300, 400, 600

1.00, 0.0, 0.0, 50, 60, 75



Sample Data for Three-Winding Transformer

1.13.4. Two Winding Transformer Vector Groups

Table 1-1, Examples of Two Winding Transformer Vector Groups shows examples of two winding transformer vector groups, corresponding phase angles and connection codes. A different winding clock position can be used by appropriately specifying the phase angle ANG1.

Table 1.1. Examples of Two Winding Transformer Vector Groups

Vector Group	PSSE Phase Angle (ANG1)	Transformer Type	Connection Code (CC)	Transformer Type	Connection Code (CC)
YNyn0	0	shell	11	core	20
YNyn6	180	shell	11	core	20
YNd1	30	shell	12		
YNd11	-30	shell	12		
YNd5	150	shell	12		
YNd7	-150	shell	12		
ZNd0	0	shell	12	core	17
ZNd1	30	shell	12	core	17
ZNd6	180	shell	12	core	17
ZNd7	-150	shell	12	core	17
ZNyn1	30	shell	12	core	17
ZNyn11	-30	shell	12	core	17
ZNyn5	150	shell	12	core	17
ZNyn7	-150	shell	12	core	17
ZNy1	30	shell	12	core	17
ZNy11	-30	shell	12	core	17
ZNy5	150	shell	12	core	17
ZNy7	-150	shell	12	core	17
Dyn1	30	shell	13		
Dyn11	-30	shell	13		
Dyn5	150	shell	13		
Dyn7	-150	shell	13		

Dzn0	0	shell	13	core	16
Dzn1	30	shell	13	core	16
Dzn6	180	shell	13	core	16
Dzn7	-150	shell	13	core	16
YNzn1	30	shell	13	core	16
YNzn11	-30	shell	13	core	16
YNzn5	150	shell	13	core	16
YNzn7	-150	shell	13	core	16
Yzn1	30	shell	13	core	16
Yzn11	-30	shell	13	core	16
Yzn5	150	shell	13	core	16
Yzn7	-150	shell	13	core	16
Dd0	0	shell	14		
Dd6	180	shell	14		
Dy1	30	shell	14		
Dy11	-30	shell	14		
Dy5	150	shell	14		
Dy7	-150	shell	14		
Yd1	30	shell	14		
Yd11	-30	shell	14		
Yd5	150	shell	14		
Yd7	-150	shell	14		
YNy0	0	shell	14	core	12
YNy6	180	shell	14	core	12
Yyn0	0	shell	14	core	13
Yyn6	180	shell	14	core	13
Yy0	0	shell	14		
Yy6	180	shell	14		
YNa0	0	core	18 or 19	shell	21
Ya0	0	core	22	shell	14

1.13.5. Three Winding Transformer Vector Groups

Table 5-1, Branch Parameter Data Check Options shows examples of three winding transformer vector groups, corresponding phase angles and connection codes. A different winding clock position can be used by appropriately specifying the phase angles ANG1, ANG2 and ANG3.

Vector groups are specified forming combinations of allowed winding connections and clock positions for various transformer connection codes.

1.13.6. Clock Positions and Phase Angles specified in Transformer Power Flow Data

Clock Position	Phase Angles (ANG1/ANG2/ANG3)

0	0
6	180
1	-30
5	-150
7	150
11	30

1.13.7. CC=11

	Allowed Winding Configurations	Allowed Clock Positions
Winding 1	YN	0, 6
Winding 2	yn	0, 6
Winding 3	yn	0, 6
Examples	YN0yn6yn0, ANG1=0, ANG2=180, ANG3=0 YN0yn0yn0, ANG1=0, ANG2=0, ANG3=0	

1.13.8. CC=12

	Allowed Winding Configurations	Allowed Clock Positions
Winding 1	YN	0, 6
Winding 2	yn	0, 6
Winding 3	y	0, 6
	d	1, 5, 7, 11
Examples	YN0yn6d5, ANG1=0, ANG2=180, ANG3=-150 YN6yn0y0 ANG1=180, ANG2=0, ANG3=0	

1.13.9. CC=13

	Allowed Winding Configurations	Allowed Clock Positions
Winding 1	D	1, 5, 7, 11
Winding 2	yn	0, 6
Winding 3	d	1, 5, 7, 11
Examples	D1YN0d1, ANG1=-30, ANG2=0, ANG3=0 D5YN0d5, ANG1=-150, ANG2=0, ANG3=-150	

1.13.10. CC=14

	Allowed Winding Configurations	Allowed Clock Positions
Winding 1	Y	0, 6
	D	1, 5, 7, 11
Winding 2	y	0, 6

	Allowed Winding Configurations	Allowed Clock Positions
	d	1, 5, 7, 11
Winding 3	y	0, 6
	d	1, 5, 7, 11
Examples	Y6d11d7, ANG1=180, ANG2=30, ANG3=150 D1d1y6, ANG1=-30, ANG2=-30, ANG3=180	

1.13.11. CC=15

	Allowed Winding Configurations	Allowed Clock Positions
Winding 1*	D	1, 5, 7, 11
Winding 2	yn	0, 6
Winding 3*	d	1, 5, 7, 11
Examples	D1yn0d1, ANG1=-30, ANG2=0, ANG3=-30 D1yn6d11, ANG1= -30, ANG2=180, ANG3=30	

* Note: Windings 1 and 3 form auto-transformer. So their clock positions are always identical.

1.13.12. CC=16

	Allowed Winding Configurations	Allowed Clock Positions
Winding 1	YN	0, 6
Winding 2	yn	0, 6
Winding 3	yn	0, 6
Examples	YN0yn0yn0, ANG1=0, ANG2=0, ANG3=0 YN6yn0yn6, ANG1=180, ANG2=0, ANG3=180	

1.13.13. CC=17

	Allowed Winding Configurations	Allowed Clock Positions
Winding 1	YNa	0
Winding 2		
Winding 3	d	1, 5, 7, 11
Examples	YNa0d1, ANG1=0, ANG2=0, ANG3=-30 YNa0d7, ANG1=0, ANG2=0, ANG3=150	

1.13.14. CC=18

	Allowed Winding Configurations	Allowed Clock Positions
Winding 1	Ya	0

	Allowed Winding Configurations	Allowed Clock Positions
Winding 2		
Winding 3	d	1, 5, 7, 11
Examples	Ya0d5, ANG1=0, ANG2=0, ANG3=-150 Ya0d11, ANG1=0, ANG2=0, ANG3=30	

1.14. Areas, Zones and Owners

In the analysis of large scale power systems for both planning and operations purposes, it is often convenient to be able to restrict the processing or reporting of PSSE functions to one or more subsets of the complete power system model. PSSE provides three groupings of network elements which may be used for these purposes: areas, zones, and owners.

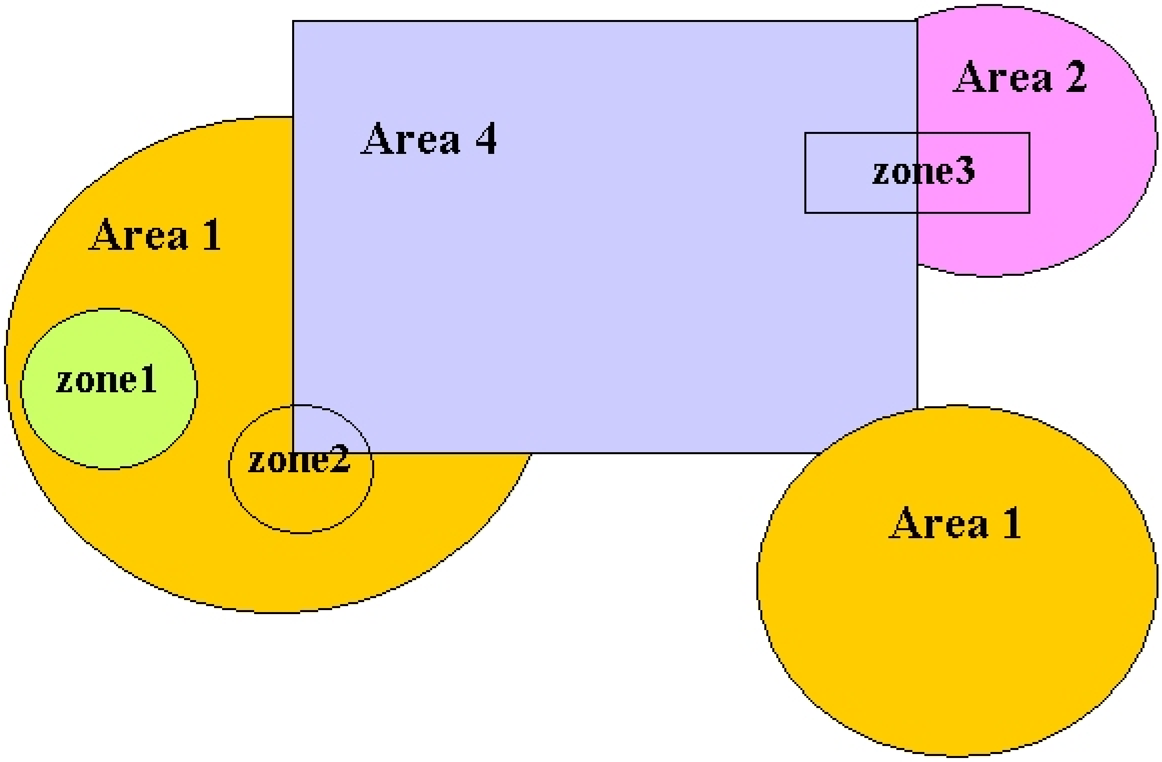
Areas are commonly used to designate sections of the network that represent control areas between which there are scheduled flows. PSSE provides for the identification of areas and their schedules. Alternatively, the network can be subdivided between utility companies or any other subdivisions useful for specific analyses. Each ac bus, load, and induction machine, as well as each dc bus of each multi-terminal dc line, is assigned to an area.

Assigning buses to specific zones allows an additional subdivision of the network to facilitate analyses and documentation. While PSSE provides documentation of zone interchange, it provides no analytical facility to schedule interchange between zones. Each ac bus, load, and induction machine as well as each dc bus of each multi-terminal dc line, is assigned to a zone.

Although areas cannot overlap other areas and zones cannot overlap other zones, areas and zones can overlap each other.

Figure 1-12 shows a system subdivided into three areas and three zones, each with a unique name. Notice the following:

- An area does not have to be contiguous. Area #1 covers two separate parts of the network.
- Zone #1 lies entirely in Area #1.
- Zone #2 lies partly in Area #1 and partly in Area #4.
- Zone #3 lies partly in Area 4 and Area 2.



Overlapping Areas and Zones

Assigning ownership attributes to buses and other equipment allows an additional subdivision of the network for analysis and documentation purposes. PSSE provides neither analytical facility to schedule interchange between owners, nor documentation of owner interchange. Each of the following power system elements is assigned to a single owner:

- ac bus
- load
- induction machine
- dc bus of a multi-terminal dc line
- FACTS device
- GNE device

Each of the following elements may have up to four owners:

- synchronous machine
- non-transformer branch

- two-winding and three-winding transformer
- VSC dc line

Area, zone and owner assignments are established at the time the network element is introduced into the working case, either as specified by the user or to a documented default value. Assignments may be modified either through the standard power flow data modification functions (refer to Section 5.9, Changing Service Status and Power Flow Parametric Data) or via activities ARNM, OWNM and ZONM.

Additional Information
See also: Section 4.8, Subsystem Selection Section 4.9, Subsystem Reporting Adjusting Net Interchange Area Interchange Control Area Interchange Data Interarea Transfer Data Owner Data Zone Data Bus Data Load Data Generator Data Non-Transformer Branch Data Transformer Data Voltage Source Converter (VSC) DC Transmission Line Data Multi-Terminal DC Transmission Line Data Induction Machine Data FACTS Device Data

1.15. Area Interchange Data

Area identifiers and interchange control parameters are specified in area interchange data records. Data for each interchange area may be specified either at the time of raw data input or subsequently via activity CHNG or the area *[Spreadsheet]*. Each area interchange data record has the following format:

```
I, ISW, PDES, PTOL, 'ARNAME'
```

I	Area number (1 through 9999). No default allowed.
ISW	Bus number, or extended bus name enclosed in single quotes (refer to Extended Bus Names), of the area slack bus for area interchange control. The bus *must* be a generator (Type 2) bus in the specified area. Any area containing a system swing bus (Type 3) *must have* either that swing bus or a bus number of zero specified for its area slack bus number. Any area with an area slack bus number of zero is considered a floating area by the area interchange control option of the power flow solution activities. ISW = 0 by default.
PDES	Desired net interchange leaving the area (export); entered in MW. PDES must be specified such that is consistent with the area interchange definition implied by the area interchange control code (tie lines only, or tie lines and loads) to be specified during power flow solutions (refer to Section 6.3.20, Automatic Adjustments and Area Interchange Control). PDES = 0.0 by default.
PTOL	Interchange tolerance bandwidth; entered in MW. PTOL = 10.0 by default
ARNAME	Alphanumeric identifier assigned to area I. ARNAME may be up to twelve characters and may contain any combination of blanks, uppercase letters, numbers and special

	characters. ARNAME *must* be enclosed in single or double quotes if it contains any blanks or special characters. ARNAME is twelve blanks by default

Area interchange data input is terminated with a record specifying an area number of zero.

1.15.1. Area Interchange Data Notes

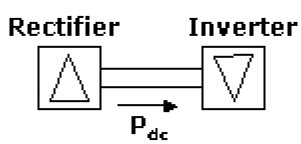
All buses (ac and dc), loads and induction machines can be assigned to an area. The area number is entered as part of the data records for the buses, loads, and induction machines (see Areas, Zones and Owners, Bus Data, Load Data and Multi-Terminal DC Transmission Line Data).

Area interchange is a required net export of power from, or net import of power to, a specific area. This does not imply that the power is destined to be transferred to or from any other specific area. To specify transfers between specific pairs of areas, see Interarea Transfer Data.

Each bus in the PSSE working case may be designated as residing in an interchange area, for purposes of both interchange control and selective output and other processing. When the interchange control option is enabled during a power flow solution, each interchange area for which an area slack bus is specified has the active power output of its area slack bus modified such that the desired net interchange for the area falls within a desired band. Refer to Area Interchange Control for further discussion on this option of the power flow solution activities.

1.16. Two-Terminal DC Transmission Line Data

The two-terminal dc transmission line model is used to simulate either a point-to-point system with rectifier and inverter separated by a bipolar or mono-polar transmission system or a back-to-back system where the rectifier and inverter are physically located at the same site and separated only by a short bus-bar.



The data requirements fall into three groups:

- Control parameters and set-points
- Converter transformers
- The dc line characteristics

Each two-terminal dc transmission line to be represented in PSSE is introduced by reading three consecutive data records. Each set of dc line data records has the following format:

```
'NAME',MDC,RDC,SETVL,VSCHD,VCMOD,RCOMP,DELTI,METER,DCVMIN,CCCITMX,CCCACC

IPR,NBR,ANMXR,ANMNR,RCR,XCR,EBASR,TRR,TAPR,TMXR,TMNR,STPR,ICR,

IPI,NBI,ANMXI,ANMNI,RCI,XCI,EBASI,TRI,TAPI,TMXI,TMNI,STPI,ICI,
```

The first of the three dc line data records defines the following line quantities and control parameters:

NAME	The non-blank alphanumeric identifier assigned to this dc line. Each two-terminal dc line *must* have a unique NAME. NAME may be up to twelve characters and may contain any combination of blanks, uppercase letters, numbers and special characters. NAME *must* be enclosed in single or double quotes if it contains any blanks or special characters. No default allowed
MDC	Control mode: 0 for blocked, 1 for power, 2 for current. MDC = 0 by default
RDC	The dc line resistance; entered in ohms. No default allowed
SETVL	Current (amps) or power (MW) demand. When MDC is one, a positive value of SETVL specifies desired power at the rectifier and a negative value specifies desired inverter power. No default allowed
VSCHD	Scheduled compounded dc voltage; entered in kV. No default allowed
VCMOD	Mode switch dc voltage; entered in kV. When the inverter dc voltage falls below this value and the line is in power control mode (i.e., MDC = 1), the line switches to current control mode with a desired current corresponding to the desired power at scheduled dc voltage. VCMOD = 0.0 by default
RCOMP	Compounding resistance; entered in ohms. Gamma and/or TAPI is used to attempt to hold the compounded voltage (VDCI + DCCUR*RCOMP) at VSCHD. To control the inverter end dc voltage VDCI, set RCOMP to zero; to control the rectifier end dc voltage VDCR, set RCOMP to the dc line resistance, RDC; otherwise, set RCOMP to the appropriate fraction of RDC. RCOMP = 0.0 by default
DELTI	Margin entered in per unit of desired dc power or current. This is the fraction by which the order is reduced when ALPHA is at its minimum and the inverter is controlling the line current. DELTI = 0.0 by default
METER	Metered end code of either R (for rectifier) or I (for inverter). METER = I by default
DCVMIN	Minimum compounded dc voltage; entered in kV. Only used in constant gamma operation (i.e., when ANMXI = ANMNI) when TAPI is held constant and an ac transformer tap is adjusted to control dc voltage (i.e., when IFI, ITI, and IDI specify a two-winding transformer). DCVMIN = 0.0 by default

CCCITMX	Iteration limit for capacitor commutated two-terminal dc line Newton solution procedure. CCCITMX = 20 by default
CCCACC	Acceleration factor for capacitor commutated two-terminal dc line Newton solution procedure. CCCACC = 1.0 by default

The second of the three dc line data records defines rectifier end data quantities and control parameters:

IPR	Rectifier converter bus number, or extended bus name enclosed in single quotes (refer to Extended Bus Names). No default allowed
NBR	Number of bridges in series (rectifier). No default allowed
ANMXR	Nominal maximum rectifier firing angle; entered in degrees. No default allowed
ANMNR	Minimum steady-state rectifier firing angle; entered in degrees. No default allowed
RCR	Rectifier commutating transformer resistance per bridge; entered in ohms. No default allowed
XCR	Rectifier commutating transformer reactance per bridge; entered in ohms. No default allowed
EBASR	Rectifier primary base ac voltage; entered in kV. No default allowed
TRR	Rectifier transformer ratio. TRR = 1.0 by default
TAPR	Rectifier tap setting. TAPR = 1.0 by default. If no two-winding transformer is specified by IFR, ITR, and IDR, TAPR is adjusted to keep alpha within limits; otherwise, TAPR is held fixed and this transformer's tap ratio is adjusted. The adjustment logic assumes that the rectifier converter bus is on the Winding 2 side of the transformer. The limits TMXR and TMNR specified here are used; except for the transformer control mode flag (COD1 of Transformer Data), the ac tap adjustment data is ignored.
TMXR	Maximum rectifier tap setting. TMXR = 1.5 by default
TMNR	Minimum rectifier tap setting. TMNR = 0.51 by default

STPR	Rectifier tap step; must be positive. STPR = 0.00625 by default
ICR	Bus number of the rectifier commutating bus (rectifier firing angle measuring bus), or extended bus name enclosed in single quotes (refer to Extended Bus Names). The firing angle and angle limits used inside the dc model are adjusted by the difference between the phase angles at this bus and the ac/dc interface (i.e., the converter bus, IPR). ICR = 0 by default
IFR	Winding 1 side from bus number, or extended bus name enclosed in single quotes, of a two-winding transformer. IFR = 0 by default
ITR	Winding 2 side to bus number, or extended bus name enclosed in single quotes, of a two-winding transformer. ITR = 0 by default
IDR	Circuit identifier; the branch described by IFR, ITR, and IDR *must* have been entered as a two-winding transformer; an ac transformer may control at most only one dc converter. IDR = '1' by default
XCAPR	Commutating capacitor reactance magnitude per bridge; entered in ohms. XCAPR = 0.0 by default
NDR	A node number of bus ICR. The bus section of bus ICR to which node NDR is connected is the bus section used as the rectifier commutating bus. If bus ICR is not in a substation, NDR must be specified as 0. NDR = 0 by default

Data on the third of the three dc line data records contains the inverter quantities corresponding to the rectifier quantities specified on the second record described above. The significant difference is that the control angle ALFA for the rectifier is replaced by the control angle GAMMA for the inverter.

```
IPI,NBI,ANMXI,ANMNI,RCI,XCI,EBASI,TRI,TAPI,TMXI,TMNI,STPI,ICI,
```

DC line data input is terminated with a record specifying a blank dc line name or a dc line name of '0'.

1.16.1. Two-Terminal DC Line Data Notes

The steady-state two-terminal dc line model used in power flow analysis establishes the initial steady state for dynamic analysis.

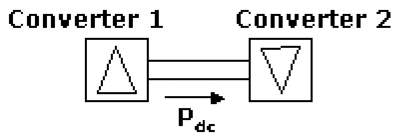
DC line converter buses, IPR and IPI, may be Type 1, 2, or 3 buses. Generators, loads, fixed and switched shunt elements, induction machines other dc line converters, FACTS device sending ends, and GNE devices are permitted at converter buses.

When either XCAPR > 0.0 or XCAPI > 0.0, the two-terminal dc line is treated as capacitor commutated. Capacitor commutated two-terminal dc lines preclude the use of a remote ac transformer as commutation transformer tap and remote commutation angle buses at either converter. Any data provided in these fields are ignored for capacitor commutated two-terminal dc lines.

For additional information on dc line modeling in power flow solutions, refer to Section 6.3.17, DC Lines.

1.17. Voltage Source Converter (VSC) DC Transmission Line Data

The voltage source converter (VSC) two-terminal dc transmission line model is used to simulate either a point-to-point system or a back-to-back system using voltage source converters.



Each voltage source converter (VSC) dc line to be represented in PSSE is introduced by reading a set of three consecutive data records. Each set of VSC dc line data records has the following format:

```
'NAME', MDC, RDC, O1, F1, ... O4, F4

IBUS,TYPE,MODE,DCSET,ACSET,ALOSS,BLOSS,MINLOSS,SMAX,IMAX,PWF,

IBUS,TYPE,MODE,DCSET,ACSET,ALOSS,BLOSS,MINLOSS,SMAX,IMAX,PWF,
```

The first of the three VSC dc line data records defines the following line quantities and control parameters:

NAME	The non-blank alphanumeric identifier assigned to this dc line. Each VSC dc line *must* have a unique NAME. NAME may be up to twelve characters and may contain any combination of blanks, uppercase letters, numbers and special characters. NAME *must* be enclosed in single or double quotes if it contains any blanks or special characters. No default allowed.
MDC	Control mode: • 0 - for out-of-service • 1 - for in-service MDC = 1 by default.
RDC	The dc line resistance; entered in ohms. RDC must be positive. No default allowed
Oi	An owner number (1 through 9999). Each VSC dc line may have up to four owners. By default, O1 is 1, and O2, O3 and O4 are zero.
Fi	The fraction of total ownership assigned to owner Oi; each Fi must be positive. The Fi values are normalized such that they sum to 1.0 before they are placed in the working case. Each Fi is 1.0 by default

The remaining two data records define the converter buses (converter 1 and converter 2), along with their data quantities and control parameters:

IBUS	Converter bus number, or extended bus name enclosed in single quotes (refer to Extended Bus Names). No default allowed
TYPE	Code for the type of converter dc control: • 0 - for converter out-of-service • 1 - for dc voltage control • 2 -for MW control When both converters are in-service, exactly one converter of each VSC dc line must be TYPE 1. No default allowed
MODE	Converter ac control mode: • 1 - for ac voltage control • 2 - for fixed ac power factor MODE = 1 by default
DCSET	Converter dc setpoint. For TYPE = 1, DCSET is the scheduled dc voltage on the dc side of the converter bus; entered in kV. For TYPE = 2, DCSET is the power demand, where a positive value specifies that the converter is feeding active power into the ac network at bus IBUS, and a negative value specifies that the converter is withdrawing active power from the ac network at bus IBUS; entered in MW. No default allowed
ACSET	Converter ac setpoint. For MODE = 1, ACSET is the regulated ac voltage setpoint; entered in pu. For MODE = 2, ACSET is the power factor setpoint. ACSET = 1.0 by default
ALOSS, BLOSS	Coefficients of the linear equation used to calculate converter losses: $KW_{conv\ loss} = ALOSS + (I_{dc} * BLOSS)$ ALOSS is entered in kW. BLOSS is entered in kW/amp. ALOSS = BLOSS = 0.0 by default
MINLOSS	Minimum converter losses; entered in kW. MINLOSS = 0.0 by default
SMAX	Converter MVA rating; entered in MVA. SMAX = 0.0 to allow unlimited converter MVA loading. SMAX = 0.0 by default

IMAX	Converter ac current rating; entered in amps. IMAX = 0.0 to allow unlimited converter current loading. If a positive IMAX is specified, the base voltage assigned to bus IBUS must be positive. IMAX = 0.0 by default
PWF	Power weighting factor fraction (0.0 <= PWF <= 1.0) used in reducing the active power order and either the reactive power order (when MODE is 2) or the reactive power limits (when MODE is 1) when the converter MVA or current rating is violated. When PWF is 0.0, only the active power is reduced; when PWF is 1.0, only the reactive power is reduced; otherwise, a weighted reduction of both active and reactive power is applied. PWF = 1.0 by default
MAXQ	Reactive power upper limit; entered in Mvar. A positive value of reactive power indicates reactive power flowing into the ac network from the converter; a negative value of reactive power indicates reactive power withdrawn from the ac network. Not used if MODE = 2. MAXQ = 9999.0 by default
MINQ	Reactive power lower limit; entered in Mvar. A positive value of reactive power indicates reactive power flowing into the ac network from the converter; a negative value of reactive power indicates reactive power withdrawn from the ac network. Not used if MODE = 2. MINQ = -9999.0 by default
VSREG	Bus number, or extended bus name enclosed in single quotes (refer to Extended Bus Names), of the bus for which voltage is to be regulated by this converter to the value specified by ACSET. If VSREG specifies a remote bus (i.e., a bus other than bus IBUS), bus VSREG must be a Type 1 or 2 bus (if it is other than a Type 1 or 2 bus, bus IBUS regulates its own voltage to the value specified by ACSET). VSREG may be entered as zero if the converter is to regulate its own voltage. Not used if MODE = 2. VSREG = 0 by default
RMPCT	Percent of the total Mvar required to hold the voltage at the bus controlled by bus IBUS that are to be contributed by this VSC converter; RMPCT must be positive. RMPCT is needed only if there is more than one local or remote setpoint mode voltage controlling device (plant, switched shunt, FACTS device shunt element, or VSC dc line converter) controlling the voltage at bus VSREG. RMPCT = 100.0 by default
NREG	A node number of bus VSREG. The bus section of bus VSREG to which node NREG is connected is the bus section for which voltage is to be regulated by this converter to the value specified by ACSET. If bus VSREG is not in a substation, NREG must be specified as 0. NREG = 0 by default

VSC dc line data input is terminated with a record specifying a blank dc line name or a dc line name of '0'.

1.17.1. VSC DC Line Data Notes

Each VSC dc line converter bus must have the following characteristics:

- It must be a Type 1 or 2 bus. Generators, loads, fixed and switched shunt elements, induction machines, other dc line converters, FACTS device sending ends, and GNE devices are permitted at converter buses.
- It must not have the terminal end of a FACTS device connected to the same bus.
- It must not be connected by a zero impedance line to another bus that violates any of the above restrictions.

In specifying reactive power limits for converters that control ac voltage (i.e., those with unequal reactive power limits where the MODE is 1), the use of very narrow var limit bands is discouraged. The Newton-Raphson based power flow solutions require that the difference between the controlling equipment's high and low reactive power limits be greater than 0.002 pu for all setpoint mode voltage controlling equipment (0.2 Mvar on a 100 MVA system base). It is recommended that voltage controlling VSC converters have Mvar ranges substantially wider than this minimum permissible range.

For interchange and loss assignment purposes, the dc voltage controlling converter is assumed to be the non-metered end of each VSC dc line. As with other network branches, losses are assigned to the subsystem of the non-metered end, and flows at the metered ends are used in interchange calculations.

For additional information on dc line modeling in power flow solutions, refer to Section 6.3.17 DC Lines.

1.18. Transformer Impedance Correction Tables

Transformer impedance correction tables are used to model a change of transformer impedance as off-nominal turns ratio or phase shift angle is adjusted. Data for each table may be specified either at the time of raw data input, or subsequently via activity CHNG or the impedance table *[Spreadsheet]*.

Each impedance correction table may have up to 99 points. The scaling factors are complex numbers; the imaginary components of these factors may be specified as 0.0. Points are specified six per line in the impedance correction table data block. As many records as are needed (with six points per record) are entered. End of data for a table is specified by specifying an additional point with the three values defining the point all specified as 0.0.

Each transformer impedance correction table data block has the following format:

```
I, T1, Re(F1), Im(F1), T2, Re(F2), Im(F2), ... T6, Re(F6), Im(F6)

T7, Re(F7), Im(F7), T8, Re(F8), Im(F8), ... T12, Re(F12), Im(F12)

.

.

Tn, Re(Fn), Im(Fn), 0.0, 0.0, 0.0
```

I	Impedance correction table number (1 through the maximum number of impedance correction tables at the current size level; refer to Table 3-1, Standard Maximum PSS®E Program Capacities). No default allowed
T_i	Either off-nominal turns ratio in pu of the controlling windings bus voltage base or phase shift angle in degrees.

	T_i = 0.0 by default
F_i	Complex scaling factor by which transformer nominal impedance is to be multiplied to obtain the actual transformer impedance for the corresponding T_i. F_i = (0.0+j0.0) by default. The impedances used in calculation of F_i should be expressed in percent or pu on on winding voltage base at specified tap position Ti and MVA base used in power flow data. This is the same base as per CZ of power flow data but winding voltage at tap Ti.

Transformer impedance correction data input is terminated with a record specifying a table number of zero.

Example: Transformer Test Data, MVA=50, Nominal Tap position=10, winding voltage=132 kV, Impedance=123.1118 ohms/phase

Tap Position	Winding kV	Z12 Data (ohms/phase)	Base Z (ohms)	PU Z
1	112.20	81.7016	251.7768	0.3245
10	132.0	123.1118	346.48	0.3532
19	151.8	178.8155	460.8648	0.3880

Corresponding Impedance Correction Table data would be as below (CZ=2).

Ti	Fi
0.85=112.2/132.0	0.9187=0.3245/0.3532
1.0=132.0/132.0	1.0=0.3532/0.3532
1.15=151.8/132.0	1.098277=0.3880/0.3532

1.18.1. Impedance Correction Table Notes

The T_i values on a transformer impedance correction table record block must all be either tap ratios or phase shift angles. They must be entered in strictly ascending order; i.e., for each i, T_{i+1}>T_i. Each F_i entered must be non-zero. For each table, at least 2 sets of values must be specified (plus the additional end-of-table point of zeros), and up to 99 may be entered. For a graphical view of a correction table for which the imaginary component of each scaling factor is 0.0, see Figure 1-13.

The T_i values for tables that are a function of tap ratio (rather than phase shift angle) in pu of the controlling winding bus voltage base.

A transformer impedance is assigned to an impedance correction table either on the third, fourth or fifth record of the transformer data record block of activities READ, TREA, RDCH (refer to Trans), or via activity CHNG or the two-winding and three-winding transformer *[Spreadsheets]*. Each table may be shared among many transformer impedances. If the first T in a table is less than 0.5 or the last T entered is greater than 1.5, T is assumed to be the phase shift angle and each transformer impedance dependent on the table is treated as a function of phase shift angle. Otherwise, the transformer impedances dependent on the table are made sensitive to off-nominal turns ratio.

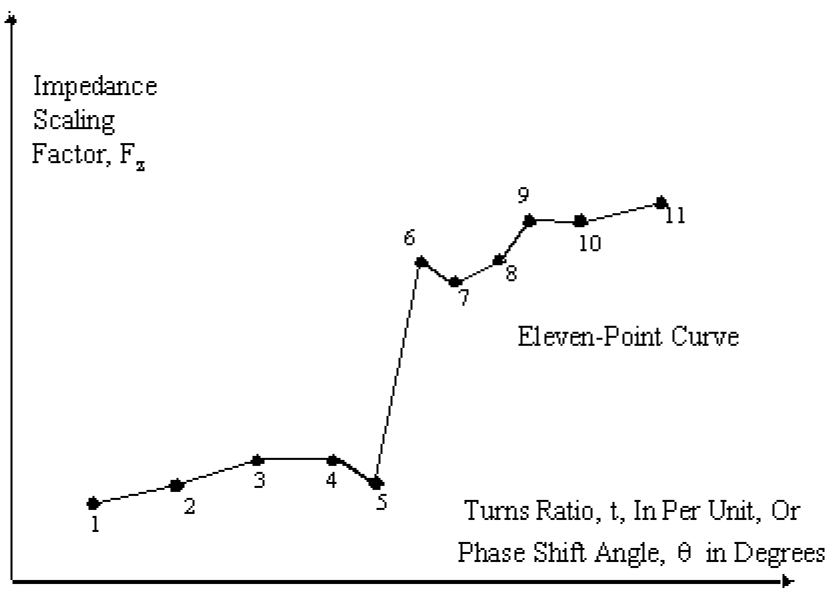
For three-winding transformers, a data item associated with the transformer (ZCOD) indicates whether impedance adjustment is to be applied to winding impedances or to the bus-to-bus impedances. If applied to winding impedances, the input to the table look-up is the winding tap ratio or phase shift angle, as appropriate, and the scaling factor is applied to the winding's nominal impedance.

When impedance adjustment is applied to the bus-to-bus impedances of a three-winding transformer, the following requirements must be met:

- exactly one winding of the transformer must be automatically adjustable.
- at least one winding must have an impedance correction table assigned to it.
- the impedance correction table(s) must be sensitive to the quantity that is automatically adjustable (tap ratio or phase shift angle, as appropriate).

In this case, the input to each of the tables is the appropriate quantity (tap ratio or phase shift angle) of the adjustable winding. If an impedance correction table is specified for winding 1, impedance adjustment is applied to Z1-2; if an impedance correction table is specified for winding 2, impedance adjustment is applied to Z2-3; and if an impedance correction table is specified for winding 3, impedance adjustment is applied to Z3-1.

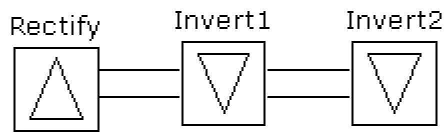
The power flow case stores both a nominal and actual impedance for each transformer winding impedance. The value of transformer impedance entered in activities READ, TREA, RDCH, CHNG, or the transformer *[Spreadsheets]* is taken as the nominal value of impedance. Each time the complex tap setting of a transformer is changed, either automatically by the power flow solution activities or manually by the user, and the modified quantity is an input to the table look-up function of any impedance correction table associated with the transformer, actual transformer impedances are redetermined if appropriate. First, the scaling factor is established from the appropriate table by linear interpolation; then nominal impedance is multiplied by the scaling factor to determine actual impedance. An appropriate message is printed any time the actual impedance is modified.



Typical Impedance Correction Factor Curve

1.19. Multi-Terminal DC Transmission Line Data

PSSE allows the representation of up to 12 converter stations on one multi-terminal dc line. The dc network of each multi-terminal dc line may consist of up to 20 dc network buses connected together by up to 20 dc links.



Each multi-terminal dc transmission line to be represented in PSSE is introduced by reading a series of data records. Each set of multi-terminal dc line data records begins with a record that defines the number of converters, number of dc buses and number of dc links as well as related bus numbers and the control mode. Following this first record there are subsequent records for each converter, each dc bus, and each dc link.

Each set of multi-terminal dc line data records begins with a record of system definition data in the following format:

```
'NAME', NCONV, NDCBS, NDCLN, MDC, VCONV, VCMOD,VCONVN
```

NAME	The non-blank alphanumeric identifier assigned to this dc line. Each multi-terminal dc line *must* have a unique NAME. NAME may be up to twelve characters and may contain any combination of blanks, uppercase letters, numbers and special characters. NAME *must* be enclosed in single or double quotes if it contains any blanks or special characters. No default allowed
NCONV	Number of ac converter station buses in multi-terminal dc line I. No default allowed
NDCBS	Number of dc buses in multi-terminal dc line I (NCONV NDCBS). No default allowed
NDCLN	Number of dc links in multi-terminal dc line I. No default allowed
MDC	Control mode: • 0 - for blocked • 1 - for power control • 2 - for current control MDC = 0 by default
VCONV	Bus number, or extended bus name enclosed in single quotes (refer to Extended Bus Names), of the ac converter station bus that controls dc voltage on the positive pole of multi-terminal dc line I. Bus VCONV *must* be a positive pole inverter. No default allowed
VCMOD	Mode switch dc voltage; entered in kV. When any inverter dc voltage magnitude falls below this value and the line is in power control mode (i.e., MDC = 1), the line switches to current control mode with converter current setpoints corresponding to their desired powers at scheduled dc voltage. VCMOD = 0.0 by default

VCONVN	Bus number, or extended bus name enclosed in single quotes, of the ac converter station bus that controls dc voltage on the negative pole of multi-terminal dc line I. If any negative pole converters are specified (see below), bus VCONVN must be a negative pole inverter. If the negative pole is not being modeled, VCONVN *must* be specified as zero. VCONVN = 0 by default

This data record is followed by NCONV converter records of the following format:

```
IB,N,ANGMX,ANGMN,RC,XC,EBAS,TR,TAP,TPMX,TPMN,TSTP,SETVL,DCPF,MARG,CNVCOD
```

IB	ac converter bus number, or extended bus name enclosed in single quotes (refer to Extended Bus Names). No default allowed
N	Number of bridges in series. No default allowed.
ANGMX	Nominal maximum ALPHA or GAMMA angle; entered in degrees. No default allowed
ANGMN	Minimum steady-state ALPHA or GAMMA angle; entered in degrees. No default allowed
RC	Commutating resistance per bridge; entered in ohms. No default allowed
XC	Commutating reactance per bridge; entered in ohms. No default allowed
EBAS	Primary base ac voltage; entered in kV. No default allowed
TR	Actual transformer ratio. TR = 1.0 by default
TAP	Tap setting. TAP = 1.0 by default
TPMX	Maximum tap setting. TPMX = 1.5 by default
TPMN	Minimum tap setting. TPMN = 0.51 by default
TSTP	Tap step; must be a positive number. TSTP = 0.00625 by default
SETVL	Converter setpoint. When IB is equal to VCONV or VCONVN, SETVL specifies the scheduled dc voltage magnitude, entered in kV, across the converter. SETVL is positive for

	positive pole inverter and negative for negative pole inverter. For other converter buses, SETVL contains the converter current (amps) or power (MW) demand; a positive value of SETVL indicates that bus IB is a rectifier, and a negative value indicates an inverter. No default allowed
DCPF	Converter participation factor. When the order at any rectifier in the multi-terminal dc line is reduced, either to maximum current or margin, the orders at the remaining converters on the same pole are modified according to their DCPFs to: SETVL + (DCPF/SUM)*R where SUM is the sum of the DCPFs at the unconstrained converters on the same pole as the constrained rectifier, and R is the order reduction at the constrained rectifier. DCPF = 1. by default
MARG	Rectifier margin entered in per unit of desired dc power or current. The converter order reduced by this fraction, (1.-MARG)*SETVL, defines the minimum order for this rectifier. MARG is used only at rectifiers. MARG = 0.0 by default
CNVCOD	Converter code. A positive value or zero must be entered if the converter is on the positive pole of multi-terminal dc line I. A negative value must be entered for negative pole converters. CNVCOD = 1 by default

These data records are followed by NDCBS dc bus records of the following format:

```
IDC, IB, AREA, ZONE, 'DCNAME', IDC2, RGRND, OWNER
```

IDC	dc bus number (1 to NDCBS). The dc buses are used internally within each multi-terminal dc line and *must* be numbered 1 through NDCBS. No default allowed
IB	ac converter bus number, or extended bus name enclosed in single quotes (refer to Extended Bus Names), or zero. Each converter station bus specified in a converter record must be specified as IB in exactly one dc bus record. DC buses that are connected only to other dc buses by dc links and not to any ac converter buses must have a zero specified for IB. A dc bus specified as IDC2 on one or more other dc bus records must have a zero specified for IB on its own dc bus record. IB = 0 by default
AREA	Area number (1 through 9999). AREA = 1 by default
ZONE	Zone number (1 through 9999). ZONE = 1 by default
DCNAME	Alphanumeric identifier assigned to dc bus IDC. DCNAME may be up to twelve characters and may contain any combination of blanks, uppercase letters, numbers and

	special characters. DCNAME *must* be enclosed in single or double quotes if it contains any blanks or special characters. DCNAME is twelve blanks by default
IDC2	Second dc bus to which converter IB is connected, or zero if the converter is connected directly to ground. For voltage controlling converters, this is the dc bus with the lower dc voltage magnitude and SETVL specifies the voltage difference between buses IDC and IDC2. For rectifiers, dc buses should be specified such that power flows from bus IDC2 to bus IDC. For inverters, dc buses should be specified such that power flows from bus IDC to bus IDC2. IDC2 is ignored on those dc bus records that have IB specified as zero. IDC2 = 0 by default
RGRND	Resistance to ground at dc bus IDC; entered in ohms. During solutions RGRND is used only for those dc buses specified as IDC2 on other dc bus records. RGRND = 0.0 by default
OWNER	Owner number (1 through 9999). OWNER = 1 by default

These data records are followed by NDCLN dc link records of the following format:

```
IDC, JDC, CKT, MET, RDC, LDC
```

IDC	Branch from bus dc bus number. No default allowed
JDC	Branch to bus dc bus number. No default allowed
CKT	One-character uppercase alphanumeric branch circuit identifier. It is recommended that single circuit branches be designated as having the circuit identifier '1'. CKT = '1' by default
MET	Metered end flag: • <= 1 - to designate bus IDC as the metered end • >= 2 - to designate bus JDC as the metered end MET = 1 by default
RDC	dc link resistance, entered in ohms. No default allowed
LDC	dc link inductance, entered in mH. LDC is not used by the power flow solution activities but is available to multi-terminal dc line dynamics models. LDC = 0.0 by default

Multi-terminal dc line data input is terminated with a record specifying a dc line number of zero.

1.19.1. Multi-Terminal DC Line Notes

The following points should be noted in specifying multi-terminal dc line data:

- Conventional two-terminal (refer to Two-Terminal DC Transmission Line Data) and multi-terminal dc lines are stored separately in PSSE working memory. Therefore, there may simultaneously exist, for example, a two-terminal dc line identified as dc line ABC along with a multi-terminal line for which the name is ABC.

- Multi-terminal lines should have at least three converter terminals; conventional dc lines consisting of two terminals should be modeled as two-terminal lines (refer to Two-Terminal DC Transmission Line Data).

- AC converter buses may be Type 1, 2, or 3 buses. Generators, loads, fixed and switched shunt elements, induction machines, other dc line converters, FACTS device sending ends, and GNE devices are permitted at converter buses.

- Each multi-terminal dc line is treated as a subnetwork of dc buses and dc links connecting its ac converter buses. For each multi-terminal dc line, the dc buses must be numbered 1 through NDCBS.

- Each ac converter bus must be specified as IB on exactly one dc bus record; there may be dc buses connected only to other dc buses by dc links but not to any ac converter bus.

- AC converter bus IB may be connected to a dc bus IDC, which is connected directly to ground. IB is specified on the dc bus record for dc bus IDC; the IDC2 field is specified as zero.

- Alternatively, ac converter bus IB may be connected to two dc buses IDC and IDC2, the second of which is connected to ground through a specified resistance. IB and IDC2 are specified on the dc bus record for dc bus IDC; on the dc bus record for bus IDC2, the ac converter bus and second dc bus fields (IB and IDC2, respectively) must be specified as zero and the grounding resistance is specified as RGRND.

- The same dc bus may be specified as the second dc bus for more than one ac converter bus.

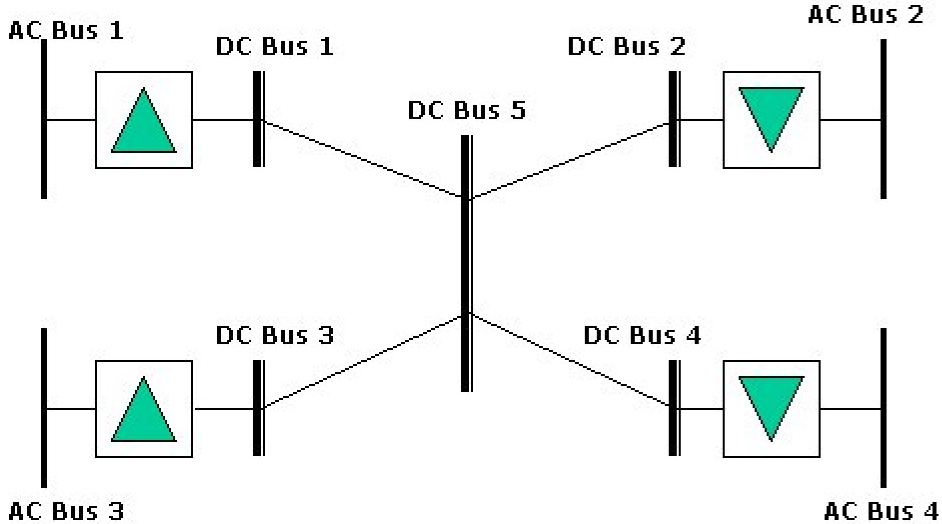
- All dc buses within a multi-terminal dc line must be reachable from any other point within the dc subnetwork.

- The area numbers assigned to dc buses and the metered end designations of dc links are used in calculating area interchangeand assigning losses in activities AREA, INTA, TIES, and SUBS as well as in the interchange control option of the power flow solution activities. Similarly, the zone assignments and metered end specifications are used in activities ZONE, INTZ, TIEZ, and SUBS.

- Section 5.7.2 Reading RDCH Data Files Created by Previous Releases of PSS®E describes the specification of NCONV, NDCBS and NDCLN when specifying changes to an existing multi-terminal dc line in activity RDCH.

For additional information on dc line modeling in power flow solutions, refer to Section 6.3.17, DC Lines.

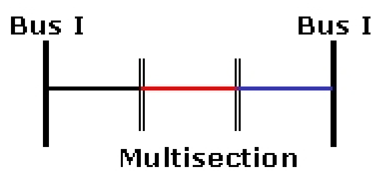
A multi-terminal layout is shown in Figure 1-14. There are 4 convertors, 5 dc buses and 4 dc links.



Multi-Terminal DC Network

1.20. Multi-Section Line Grouping Data

Transmission lines commonly have a series of sections with varying physical structures. The section might have different tower configurations, conductor types and bundles, or various combinations of these. The physical differences can result in the sections having different resistance, reactance and charging.



A transmission line with several distinct sections can be represented as one multisection line group.

Each multi-section line grouping to be represented in PSSE is introduced by reading a multi-section line grouping data record. Each multi-section line grouping data record has the following format:

```
I, J, ID, MET, DUM1, DUM2, ... DUM9
```

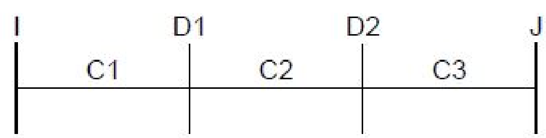
I	From bus number, or extended bus name enclosed in single quotes (refer to Extended Bus Names). No default allowed
J	To bus number, or extended bus name enclosed in single quotes. No default allowed
ID	Two-character upper case alphanumeric multi-section line grouping identifier. The first character *must* be an ampersand (' '). ID = '1' by default
MET	Metered end flag:

	• <= 1 - to designate bus I as the metered end • >= 2 - to designate bus J as the metered end MET = 1 by default
DUM_i	Bus numbers, or extended bus names enclosed in single quotes (refer to Extended Bus Names), of the dummy buses connected by the branches that comprise this multi-section line grouping. No defaults allowed

Multi-section line grouping data input is terminated with a record specifying a from bus number of zero.

1.20.1. Multi-Section Line Example

The DUM_i values on each record define the branches connecting bus I to bus J, and are entered so as to trace the path from bus I to bus J. Specifically, for a multi-section line grouping consisting of three line sections (and hence two dummy buses):



The path from I to J is defined by the following branches:

I	D1	C1
D1	D2	C2
D2	J	C3

If this multi-section line grouping is to be assigned the line identifier 1, the corresponding multi-section line grouping data record is given by:

```
I J 1 1 D1 D2
```

1.20.2. Multi-Section Line Notes

Up to 10 line sections (and hence 9 dummy buses) may be defined in each multi-section line grouping. A branch may be a line section of at most one multi-section line grouping.

Each dummy bus must have exactly two branches connected to it, both of which must be members of the same multi-section line grouping. A multi-section line dummy bus may not be a converter bus of a dc transmission line. A FACTS control device may not be connected to a multi-section line dummy bus.

The status of line sections and type codes of dummy buses are set such that the multi-section line is treated as a single entity with regards to its service status.

When the multi-section line reporting option is enabled (refer to Section 3.3.3, Program Run-Time Option Settings and activity OPTN), several power flow reporting activities such as POUT and LOUT do not tabulate conditions at multi-section line dummy buses. Accordingly, care must be taken in interpreting power flow output reports when dummy buses are other than passive nodes (e.g., if load or generation is present at a dummy bus).

1.21. Zone Data

Zone identifiers are specified in zone data records. Zone names may be specified either at the time of raw data input or subsequently via activity CHNG or the zone *[Spreadsheet]*. Each zone data record has the following format:

```
I, 'ZONAME'
```

I	Zone number (1 through 9999). No default allowed
ZONAME	Alphanumeric identifier assigned to zone I. ZONAME may be up to twelve characters and may contain any combination of blanks, uppercase letters, numbers and special characters. ZONAME *must* be enclosed in single or double quotes if it contains any blanks or special characters. ZONAME is twelve blanks by default

Zone data input is terminated with a record specifying a zone number of zero.

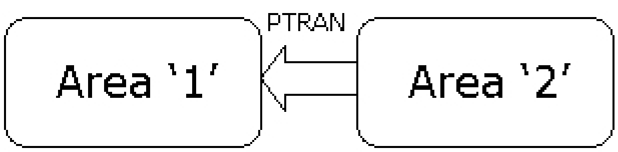
1.21.1. Zone Data Notes

All buses (ac and dc), loads, and induction machines can be assigned to a zone. The zone number is entered as part of the data records for the buses, loads, and induction machines (see Areas, Zones and Owners, Bus Data, Load Data and Multi-Terminal DC Transmission Line Data).

The use of zones enables the user to develop reports and to check results on the basis of zones and, consequently, be highly specific when reporting and interpreting analytical results.

1.22. Interarea Transfer Data

The PSSE user has the ability to assign each bus, load, and induction machine to an area (see Bus Data, Load Data, Multi-Terminal DC Transmission Line Data, Area Interchange Data and Areas, Zones and Owners). Furthermore, the user can schedule active power transfers between pairs of areas.



These active power transfers are specified in interarea transfer data records. Each interarea transfer data record has the following format:

```
ARFROM, ARTO, TRID, PTRAN
```

ARFROM	From area number (1 through 9999). No default allowed
ARTO	To area number (1 through 9999). No default allowed

TRID	Single-character (0 through 9 or A through Z) upper case interarea transfer identifier used to distinguish among multiple transfers between areas ARFROM and ARTO. TRID = '1' by default
PTRAN	MW comprising this transfer. A positive PTRAN indicates that area ARFROM is selling to area ARTO. PTRAN = 0.0 by default

Interarea transfer data input is terminated with a record specifying a from area number of zero.

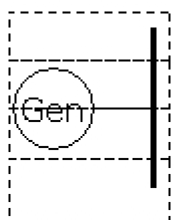
1.22.1. Interarea Transfer Data Notes

Following the completion of interarea transfer data input, activity READ generates an alarm for any area for which at least one interarea transfer is present and where the sum of transfers differs from its desired net interchange, PDES (refer to Area Interchange Data).

1.23. Owner Data

PSSE allows the user to identify which organization or utility actually owns a facility, a piece of equipment or a load. Buses (ac and dc), loads, induction machines, FACTS devices, and GNE devices have provision for an owner, while machines, ac branches, and VSC dc lines can have up to four different owners. Ownership is specified as part of the data records for these network elements (see Bus Data, Load Data, FACTS Device Data, Generator Data, Non-Transformer Branch Data, Transformer Data, Voltage Source Converter (VSC) DC Transmission Line Data, Multi-Ter, and GNE Device Data).

The use of the ownership attribute enables the user to develop reports and to check results on the basis of ownership and, consequently, be highly specific when reporting and interpreting analytical results.



Owner identifiers are specified in owner data records. Owner names may be specified either at the time of raw data input or subsequently via activity CHNG or the owner *[Spreadsheet]*. Each owner data record has the following format:

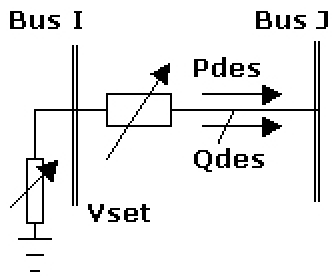
```
I, 'OWNAME'
```

I	Owner number (1 through 9999). No default allowed
OWNAME	Alphanumeric identifier assigned to owner I. OWNAME may be up to twelve characters and may contain any combination of blanks, uppercase letters, numbers and special characters. OWNAME *must* be enclosed in single or double quotes if it contains any blanks or special characters. OWNAME is twelve blanks by default

Owner data input is terminated with a record specifying an owner number of zero.

1.24. FACTS Device Data

There are a variety of Flexible AC Transmission System (FACTS) devices currently available. These include shunt devices, such as the Static Compensator (STATCOM), series devices such as the Static Synchronous Series Compensator (SSSC), combined devices such as the Unified Power Flow Controller (UPFC), and parallel series devices such as the Interline Power Flow Controller (IPFC).



PSSE accepts data for all of these devices through one generic set of data records. Each FACTS device to be represented in PSSE is specified in FACTS device data records. Each FACTS device data record has the following format:

```
'NAME',I,J,MODE,PDES,QDES,VSET,SHMX,TRMX,VTMN,VTMX,VSMX,IMX,LINX,
```

NAME	The non-blank alphanumeric identifier assigned to this FACTS device. Each FACTS device *must* have a unique NAME. NAME may be up to twelve characters and may contain any combination of blanks, uppercase letters, numbers and special characters. NAME *must* be enclosed in single or double quotes if it contains any blanks or special characters. No default allowed
I	Sending end bus number, or extended bus name enclosed in single quotes (refer to Extended Bus Names). No default allowed
J	Terminal end bus number, or extended bus name enclosed in single quotes; 0 for a STATCON. J = 0 by default
MODE	Controlmode: For a STATCON (i.e., a FACTS devices with a shunt element but no series element), J must be 0 and MODE must be either 0 or 1): • 0 - out-of-service (i.e., shunt link open) • 1 - shunt link operating For a FACTS device with a series element (i.e., J is not 0), MODE may be: • 0 - out-of-service (i.e., series and shunt links open)

	• 1 - series and shunt links operating • 2 - series link bypassed (i.e., like a zero impedance line) and shunt link operating as a STATCON • 3 - series and shunt links operating with series link at constant series impedance • 4 - series and shunt links operating with series link at constant series voltage • 5 - master device of an IPFC with P and Q setpoints specified; another FACTS device must be designated as the slave device (i.e., its MODE is 6 or 8) of this IPFC • 6 - slave device of an IPFC with P and Q setpoints specified; the FACTS device specified in MNAME must be the master device (i.e., its MODE is 5 or 7) of this IPFC. The Q setpoint is ignored as the master device dictates the active power exchanged between the two devices. • 7 - master device of an IPFC with constant series voltage setpoints specified; another FACTS device must be designated as the slave device (i.e., its MODE is 6 or 8) of this IPFC • 8 - slave device of an IPFC with constant series voltage setpoints specified; the FACTS device specified in MNAME must be the master device (i.e., its MODE is 5 or 7) of this IPFC. The complex $V_d + jV_q$ setpoint is modified during power flow solutions to reflect the active power exchange determined by the master device MODE = 1 by default
PDES	Desired active power flow arriving at the terminal end bus; entered in MW. PDES = 0.0 by default
QDES	Desired reactive power flow arriving at the terminal end bus; entered in MVAR. QDES = 0.0 by default
VSET	Voltage setpoint at the sending end bus; entered in pu. VSET = 1.0 by default
SHMX	Maximum shunt current at the sending end bus; entered in MVA at unity voltage. SHMX = 9999.0 by default
TRMX	Maximum bridge active power transfer; entered in MW. TRMX = 9999.0 by default
VTMN	Minimum voltage at the terminal end bus; entered in pu. VTMN = 0.9 by default
VTMX	Maximum voltage at the terminal end bus; entered in pu. VTMX = 1.1 by default
VSMX	Maximum series voltage; entered in pu. VSMX = 1.0 by default

IMX	Maximum series current, or zero for no series current limit; entered in MVA at unity voltage. IMX = 0.0 by default
LINX	Reactance of the dummy series element used during power flow solutions; entered in pu. LINX = 0.05 by default
RMPCT	Percent of the total Mvar required to hold the voltage at the bus controlled by the shunt element of this FACTS device that are to be contributed by the shunt element; RMPCT must be positive. RMPCT is needed only if there is more than one local or remote setpoint mode voltage controlling device (plant, switched shunt, FACTS device shunt element, or VSC dc line converter) controlling the voltage at bus FCREG. RMPCT = 100.0 by default
OWNER	Owner number (1 through 9999). OWNER = 1 by default
SET1, SET2	If MODE is 3, resistance and reactance respectively of the constant impedance, entered in pu; if MODE is 4, the magnitude (in pu) and angle (in degrees) of the constant series voltage with respect to the quantity indicated by VSREF; if MODE is 7 or 8, the real (V_d) and imaginary (V_q) components (in pu) of the constant series voltage with respect to the quantity indicated by VSREF; for other values of MODE, SET1 and SET2 are read, but not saved or used during power flow solutions. SET1 = 0.0 and SET2 = 0.0 by default
VSREF	Series voltage reference code to indicate the series voltage reference of SET1 and SET2 when MODE is 4, 7 or 8: • 0 - for sending end voltage • 1 - for series current VSREF = 0 by default
FCREG	Bus number, or extended bus name enclosed in single quotes (refer to Extended Bus Names), of the bus for which voltage is to be regulated by the shunt element of this FACTS device to the value specified by VSET. If FCREG specifies a remote bus (i.e., a bus other than bus I), bus FCREG must be a Type 1 or 2 bus (if it is other than a Type 1 or 2 bus, the shunt element regulates voltage at the sending end bus to the value specified by VSET). FCREG may be entered as zero if the shunt element is to regulate voltage at the sending end bus and *must* be zero if the sending end bus is a Type 3 (swing) bus. FCREG = 0 by default
MNAME	The name of the FACTS device that is the IPFC master device when this FACTS device is the slave device of an IPFC (i.e., its MODE is specified as 6 or 8). MNAME *must* be enclosed in single or double quotes if it contains any blanks or special characters. MNAME is blank by default
NREG	A node number of bus FCREG. The bus section of bus FCREG to which node NREG is connected is the bus section for which voltage is to be regulated by the shunt element

	to the value specified by VSET. If bus FCREG is not in a substation, NREG must be specified as 0. NREG = 0 by default

FACTS device data input is terminated with a record specifying a FACTS device number of zero.

1.24.1. FACTS Device Notes

PSSE's FACTS device model contains a shunt element that is connected between the sending end bus and ground, and a series element connected between the sending and terminal end buses.

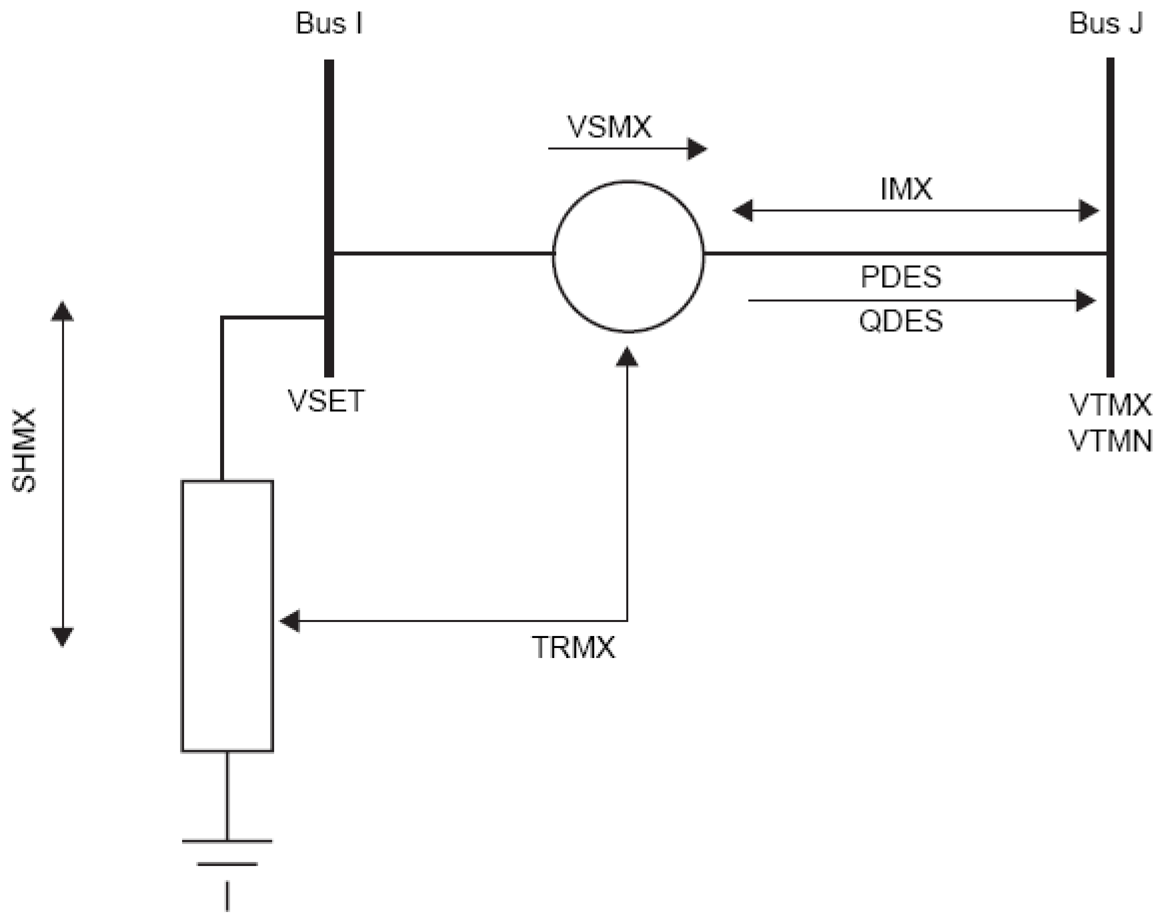
A static synchronous condenser (STATCON) or static compensator (STATCOM) is modeled by a FACTS device for which the terminal end bus is specified as zero (i.e., the series element is disabled).

A unified power flow controller (UPFC) has both the series and shunt elements active, and allows for the exchange of active power between the two elements (i.e., TRMX is positive). A static synchronous series compensator (SSSC) is modeled by setting both the maximum shunt current limit (SHMX) and the maximum bridge active power transfer limit (TRMX) to zero (i.e., the shunt element is disabled).

An Interline Power Flow Controller (IPFC) is modeled by using two series FACTS devices. One device of this pair must be assigned as the IPFC master device by setting its control mode to 5 or 7; the other must be assigned as its companion IPFC slave device by setting its control mode to 6 or 8 *and* specifying the name of the master device in its MNAME. In an IPFC, both devices have a series element but no shunt element. Therefore, both devices typically have SHMX set to zero, and VSET of both devices is ignored. Conditions at the master device define the active power exchange between the two devices. TRMX of the master device is set to the maximum active power transfer between the two devices, and TRMX of the slave device is set to zero.

Figure 1-15 shows the PSSE FACTS control device model with its various setpoints and limits.

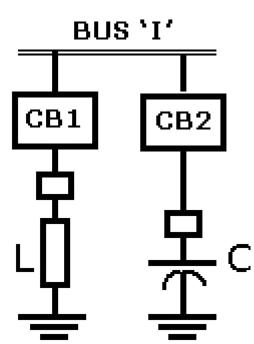
Each FACTS sending end bus must be a Type 1 or 2 bus, and each terminal end bus must be a Type 1 bus. Refer to Section 6.3.16, FACTS Devices and Section 6.3.18, AC Voltage Control for other topological restrictions and for details on the handling of FACTS devices during the power flow solution activities.



FACTS Control Device Setpoints and Limits

1.25. Switched Shunt Data

Automatically switched shunt devices may be represented on a network bus.



The switched shunt elements at a bus may consist entirely of blocks of shunt reactors (each B_i is a negative quantity), entirely of blocks of capacitor banks (each B_i is a positive quantity), or of both reactors and capacitors.

Each network bus to be represented in PSSE with switched shunt admittance devices must have a switched shunt data record specified for it. The switched shunts are represented with up to eight blocks of admittance, each one of which consists of up to nine steps of the specified block admittance. Each switched shunt data record has the following format:

```
I,MODSW,ADJM,STATUS,VSWHI,VSWLO,SWREG,RMPCT,'RMIDNT',BINIT,
```

I	Bus number, or extended bus name enclosed in single quotes (refer to Extended Bus Names). No default allowed
MODSW	Control mode: • 0 - locked • 1 - discrete adjustment, controlling voltage locally or at bus SWREG • 2 - continuous adjustment, controlling voltage locally or at bus SWREG • 3 - discrete adjustment, controlling the reactive power output of the plant at bus SWREG • 4 - discrete adjustment, controlling the reactive power output of the VSC dc line converter at bus SWREG of the VSC dc line for which the name is specified as RMIDNT • 5 - discrete adjustment, controlling the admittance setting of the switched shunt at bus SWREG • 6 - discrete adjustment, controlling the reactive power output of the shunt element of the FACTS device for which the name is specified as RMIDNT MODSW = 1 by default
ADJM	Adjustment method: • 0 - steps and blocks are switched on in input order, and off in reverse input order; this adjustment method was the only method available prior to PSSE-32.0. • 1 - steps and blocks are switched on and off such that the next highest (or lowest, as appropriate) total admittance is achieved. ADJM = 0 by default
STATUS	Initial switched shunt status of one for in-service and zero for out-of-service. STATUS = 1 by default
VSWHI	When MODSW is 1 or 2, the controlled voltage upper limit; entered in pu. When MODSW is 3, 4, 5 or 6, the controlled reactive power range upper limit; entered in pu of the total reactive power range of the controlled voltage controlling device.

	VSWHI is not used when MODSW is 0. VSWHI = 1.0 by default
VSWLO	When MODSW is 1 or 2, the controlled voltage lower limit; entered in pu. When MODSW is 3, 4, 5 or 6, the controlled reactive power range lower limit; entered in pu of the total reactive power range of the controlled voltage controlling device. VSWLO is not used when MODSW is 0. VSWLO = 1.0 by default
SWREG	Bus number, or extended bus name enclosed in single quotes (refer to Extended Bus Names), of the bus for which voltage or connected equipment reactive power output is controlled by this switched shunt. When MODSW is 1 or 2, SWREG specifies the bus for which voltage is regulated. If SWREG specifies a remote bus (i.e., a bus other than bus I), bus SWREG must be a Type 1 or 2 bus (if it is other than a Type 1 or 2 bus, the switched shunt controls its own voltage). SWREG may be entered as 0 if the switched shunt is to regulate its own voltage. When MODSW is 3, SWREG specifies the Type 2 or 3 bus where plant reactive power output is to be regulated by this switched shunt. Set SWREG to I if the switched shunt and the plant that it controls are connected to the same bus. When MODSW is 4, SWREG specifies the converter bus of a VSC dc line where converter reactive power output is to be regulated by this switched shunt. Set SWREG to I if the switched shunt and the VSC dc line converter that it controls are connected to the same bus. When MODSW is 5, SWREG specifies the remote bus to which the switched shunt for which the admittance setting is to be regulated by this switched shunt is connected. SWREG is not used when MODSW is 0 or 6. SWREG = 0 by default
RMPCT	Percent of the total Mvar required to hold the voltage at the bus controlled by bus I that are to be contributed by this switched shunt; RMPCT must be positive. RMPCT is needed only if there is more than one local or remote setpoint mode voltage controlling device (plant, switched shunt, FACTS device shunt element, or VSC dc line converter) controlling the voltage at bus SWREG. Only used if MODSW = 1 or 2. RMPCT = 100.0 by default
RMIDNT	When MODSW is 4, the name of the VSC dc line where the converter bus is specified in SWREG. When MODSW is 6, the name of the FACTS device where the shunt element's reactive output is to be controlled. RMIDNT is not used for other values of MODSW. RMIDNT is a blank name by default
BINIT	Initial switched shunt admittance; entered in Mvar at unity voltage. BINIT = 0.0 by default

N_i	Number of steps for block i (0 Ni 9). The first zero value of N_i or B_i is interpreted as the end of the switched shunt blocks for bus I. N_i = 0 by default
B_i	Admittance increment for each of N_i steps in block i; entered in Mvar at unity voltage. B_i = 0.0 by default
NREG	A node number of bus SWREG. The bus section of bus SWREG to which node NREG is connected is the bus section for which voltage or connected equipment reactive power output is controlled by this switched shunt. If bus SWREG is not in a substation, NREG must be specified as 0. NREG = 0 by default

Switched shunt data input is terminated with a record specifying a bus number of zero.

1.25.1. Switched Shunt Notes

BINIT needs to be set to its actual solved case value only when the network, as entered into the working case via activity READ, is to be considered solved as read in, or when the device is to be treated as locked (i.e., MODSW is set to zero or switched shunt adjustment is disabled during power flow solutions).

The switched shunt elements at a bus may consist entirely of reactors (each B_i is a negative quantity) or entirely of capacitor banks (each B_i is a positive quantity). In these cases, when ADJM is zero, the shunt blocks are specified in the order in which they are switched on the bus; when ADJM is one, the shunt blocks may be specified in any order.

The switched shunt devices at a bus may be comprised of a mixture of reactors and capacitors. In these cases, when ADJM is zero, the reactor blocks are specified first in the order in which they are switched on, followed by the capacitor blocks in the order in which they are switched on; when ADJM is one, the reactor blocks are specified first in any order, followed by the capacitor blocks in any order.

In specifying reactive power limits for setpoint mode voltage controlling switched shunts (i.e., those with MODSW of 1 or 2), the use of a very narrow admittance range is discouraged. The Newton-Raphson based power flow solutions require that the difference between the controlling equipment's high and low reactive power limits be greater than 0.002 pu for all setpoint mode voltage controlling equipment (0.2 Mvar on a 100 MVA system base). It is recommended that voltage controlling switched shunts have admittance ranges substantially wider than this minimum permissible range.

When MODSW is 3, 4, 5 or 6, VSWLO and VSWHI define a restricted band of the controlled device's reactive power range. They are specified in pu of the total reactive power range of the controlled device (i.e., the plant QMAX - QMIN when MODSW is 3, MAXQ - MINQ of a VSC dc line converter when MODSW is 4, SNiBi - SNjBj when MODSW is 5 where i are those switched shunt blocks for which Bi is positive and j are those for which Bi is negative, and 2.*SHMX of the shunt element of the FACTS device, reduced by the current corresponding to the bridge active power transfer when a series element is present, when MODSW is 6). VSWLO must be greater than or equal to 0.0 and less than VSWHI, and VSWHI must be less than or equal to 1.0. That is, the following relationship must be honored:

0.0 VSWLO VSWHI 1.0

The reactive power band for switched shunt control is calculated by applying VSWLO and VSWHI to the reactive power band extremes of the controlled plant or VSC converter. For example, with MINQ of -50.0 pu and MAXQ of +50.0 pu, if VSWLO is 0.2 pu and VSWHI is 0.75 pu, then the reactive power band defined by VSWLO and VSWHI is:

-50.0 + 0.2*(50.0 - (-50.0)) = -50.0 + 0.2*100.0 = -50.0 + 20.0 = -30.0 Mvar

through:

-50.0 + 0.75*(50.0 - (-50.0)) = -50.0 + 0.75*100.0 = -50.0 + 75.0 = +25.0 Mvar

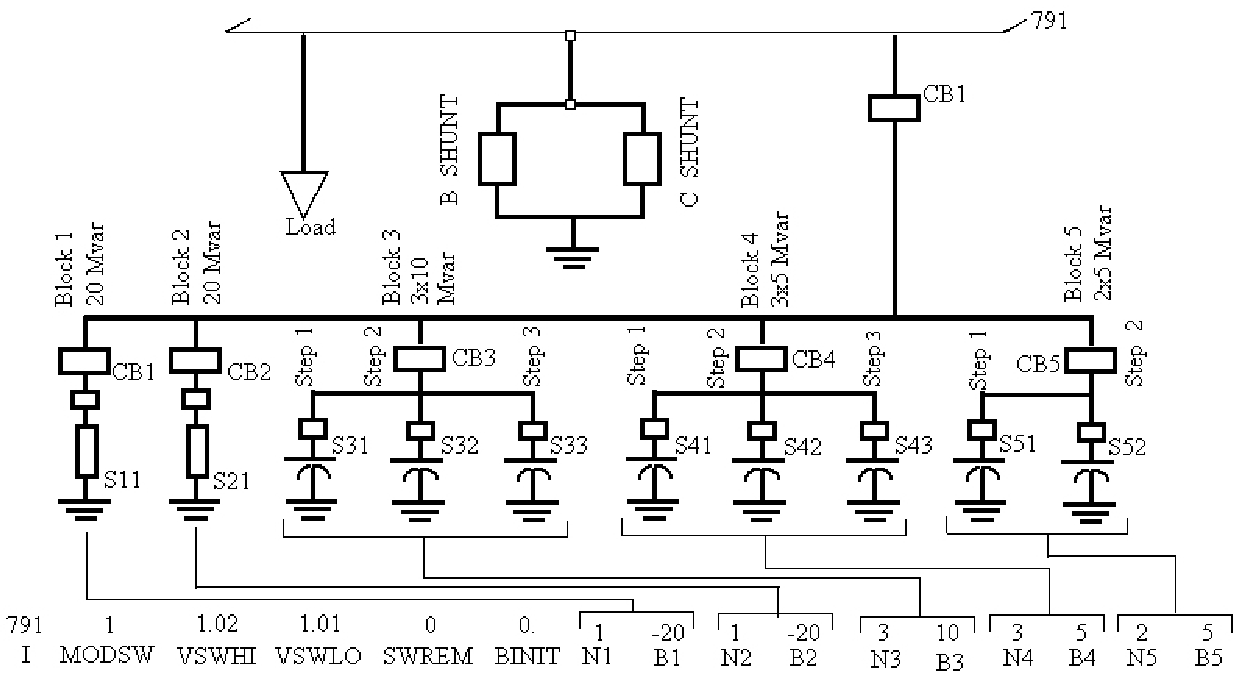
The switched shunt admittance is kept in the working case and reported in output tabulations separately from the fixed bus shunt, which is entered on the fixed bus shunt data record (refer to Fixed Bus Shunt Data).

Refer to Section 6.3.15, Switched Shunt Devices and Section 6.3.17, DC Lines and Switched Shunt Adjustment for details on the handling of switched shunts during power flow solutions.

It is recommended that data records for switched shunts for which the control mode is 5 (i.e., they control the setting of other switched shunts) be grouped together following all other switched shunt data records. This practice will eliminate any warnings of no switched shunt at the specified remote bus simply because the remote bus switched shunt record has not as yet been read.

1.25.2. Switched Shunt Example

Figure 1-16 shows the data record that may be specified to match the combination of switched elements on Bus 791. Note that the quantity shown as Load is entered as Load Data, and the fixed bus shunt indicated as B SHUNT and G SHUNT is entered as Fixed Bus Shunt Data.



Example Data Record for Combination of Switched Shunts

1.26. GNE Device Data

PSSE accepts data for Generic Network Element (GNE) devices that are modeled in BOSL ".mac" or ".xmac" files. Each instance of a GNE device to be represented in PSSE is specified in a GNE device data record block. Each GNE device data record block has the following format:

```
'NAME','MODEL',NTERM, BUS1, ...,BUSNTERM,NREAL,NINTG,NCHAR,
STATUS, OWNER,NMETR
REAL1, ..., REALmin(10,NREAL)
INTG1, ..., INTGmin(10,NINTG)
CHAR1, ..., CHARmin(10,NCHAR)
```

NAME	The non-blank alphanumeric identifier assigned to this GNE device. Each GNE device instance *must* have a unique NAME. NAME may be up to twelve characters and may contain any combination of blanks, uppercase letters, numbers and special characters. NAME *must* be enclosed in single or double quotes if it contains any blanks or special characters. No default allowed
MODEL	The name of the BOSL model. NAME is the root name of the ".mac" or ".xmac" file containing the BOSL model. No default allowed
NTERM	The number of buses to which this instance of the model is connected. NTERM may be either 1 or 2 for a variable admittance model, and must be 1 for a variable power model and a variable current model. NTERM = 1 by default
BUSi	Bus number, or extended bus name enclosed in single quotes (refer to Extended Bus Names). No default allowed
NREAL	Number of floating point data items required by model MODEL. NREAL must be identical to the number required by the ".mac" or ".xmac" file. NREAL = 0 by default
NINTG	Number of buses required in calculating the inputs required by model MODEL. NINTG must be identical to the number required by the ".mac" or .".xmac" file. NINTG = 0 by default
NCHAR	Number of two-character identifiers (e.g., machine identifiers, circuit identifiers, etc.) required in calculating the inputs required by model MODEL. NCHAR must be identical to the number required by the ".mac" or ".xmac" file. NINTG = 0 by default
STATUS	Device status of one for in-service and zero for out-of-service. STATUS = 1 by default

OWNER	Owner to which the device is assigned (1 through 9999). By default, OWNER is the owner to which BUS1 is assigned (refer to Bus Data).
NMETR	Bus number, or extended bus name enclosed in single quotes (refer to Extended Bus Names), of the non-metered end bus. NMETR is used for GNE devices with NTERM > 1. NMETR = BUSNTERM by default
$REAL_I$	NREAL floating point data items required by model MODEL. Data items are entered 10 per line, with as many lines as required to supply NREAL data items. If NREAL is 0, no record is specified. $REAL_I$ = 0.0 by default
$INTG_I$	NINTG bus numbers or extended bus names required by model MODEL. $INTG_I$ = BUS1 by default. Data items are entered 10 per line, with as many lines as required to supply NINTG data items. If NINTG is 0, no record is specified. $INTG_I$ = BUS1 by default
$CHAR_I$	NCHAR two-character identifiers required by model MODEL. Data items are entered 10 per line, with as many lines as required to supply NCHAR data items. If NCHAR is 0, no record is specified. $CHAR_I$ = '1' by default

GNE device data input is terminated with a record specifying a blank GNE device name or a GNE device name of ’0’.

GNE devices are not recognized in all forms of analysis available in PSS®E. For example, they are ignored in the fault analysis activities. Those analysis functions from which they are excluded print an appropriate message if any in-service GNE devices are present in the working case.

1.27. Induction Machine Data

Each network bus at which an induction machine is to be represented must be specified in at least one induction machine data record. Multiple induction machines may be represented at a bus by specifying more than one induction machine data record for the bus, each with a different machine identifier.

Each induction machine data record has the following format:

```
I,ID,STATUS,SCODE,DCODE,AREA,ZONE,OWNER,TCODE,BCODE,MBASE,RATEKV,PCODE,          PSET,H,A,
```

I	Bus number, or extended bus name enclosed in single quotes (refer to Extended Bus Names). No default allowed
ID	One- or two-character uppercase non-blank alphanumeric machine identifier used to distinguish among multiple induction machines at bus I. It is recommended that, at buses for which a single induction machine is present, it be designated as having the machine identifier '1'.

	ID = '1' by default
STATUS	Machine status of 1 for in-service and 0 for out-of-service. STATUS = 1 by default
SCODE	Machine standard code: • 1 - for NEMA • 2 - for IEC SCODE = 1 by default
DCODE	Machine design code. Following are allowed machine design codes: • 0 - for Custom design with equivalent circuit reactances specified • 1 - for NEMA Design A • 2 - for NEMA Design B / IEC Design N • 3 - for NEMA Design C / IEC Design H • 4 - for NEMA Design D • 5 - for NEMA Design E DCODE = 2 by default
AREA	Area to which the induction machine is assigned (1 through 9999). By default, AREA is the area to which bus I is assigned (refer to Bus Data).
ZONE	Zone to which the induction machine is assigned (1 through 9999). By default, ZONE is the zone to which bus I is assigned (refer to Bus Data).
OWNER	Owner to which the induction machine is assigned (1 through 9999). By default, OWNER is the owner to which bus I is assigned (refer to Bus Data).
TCODE	Type of mechanical load torque variation: • 1 - for the simple power law • 2 - for the WECC model TCODE = 1 by default
BCODE	Machine base power code: • 1 - for 1 for mechanical power (MW) output of the machine • 2 - for apparent electrical power (MVA) drawn by the machine BCODE = 1 by default
MBASE	Machine base power; entered in MW or MVA. This value is specified according to BCODE, and could be either the mechanical rating of the machine or the electrical input. It is necessary only that the per unit values entered for the equivalent circuit parameters match the base power.

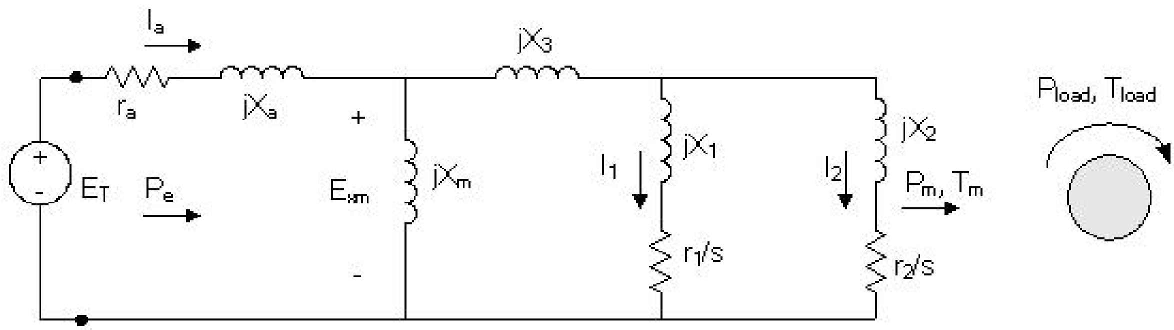
	MBASE = system base MVA by default
RATEKV	Machine rated voltage; entered in kV line-to-line, or zero to indicate that machine rated voltage is assumed to be identical to the base voltage of bus I. RATEKV = 0.0 by default
PCODE	Scheduled power code: • 1 - for mechanical power (MW) output of the machine • 2 - for electrical real power (MW) drawn by the machine PCODE = 1 by default
PSET	Scheduled active power for a terminal voltage at the machine of 1.0 pu of the machine rated voltage; entered in MW. This value is specified according to PCODE, and is either the mechanical power output of the machine or the real electrical power drawn by the machine. The sign convention used is that PSET specifies power supplied to the machine: A positive value of electrical power means that the machine is operating as a motor; similarly, a positive value of mechanical power output means that the machine is driving a mechanical load and operating as a motor. No default allowed.
H	Machine inertia; entered in per unit on MBASE base. H = 1.0 by default
A, B, D, E	Constants that describe the variation of the torque of the mechanical load with speed. If TCODE is 1 (simple power law model), only D is used; if TCODE is 2 (WECC model), all of these constants are used. A = B = D = E = 1.0 by default.
RA	Armature resistance, R_a (> 0.0); entered in per unit on the power base MBASE and voltage base RATEKV. RA = 0.0 by default
XA	Armature leakage reactance, X_a (> 0.0); entered in per unit on the power base MBASE and voltage base RATEKV. XA = 0.0 by default
XM	Unsaturated magnetizing reactance, X_m (> 0.0); entered in per unit on the power base MBASE and voltage base RATEKV. XM = 2.5 by default
R1	Resistance of the first rotor winding ("cage"), r_1 (> 0.0); entered in per unit on the power base MBASE and voltage base RATEKV. R1 = 999.0 by default
X1	Reactance of the first rotor winding ("cage"), X_1 (>0.0); entered in per unit on the power base MBASE and voltage base RATEKV.

	X1 = 999.0 by default
R2	Resistance of the second rotor winding ("cage"), r_2 (> 0.0); entered in per unit on the power base MBASE and voltage base RATEKV. R2 = 999.0 by default
X2	Reactance of the second rotor winding ("cage"), X_2 (>0.0); entered in per unit on the power base MBASE and voltage base RATEKV. X2 = 999.0 by default
X3	Third rotor reactance, X_3 (> 0.0); entered in per unit on the power base MBASE and voltage base RATEKV. X3 = 0.0 by default
E1	First terminal voltage point from the open circuit saturation curve, E_1 (> 0.0); entered in per unit on RATEKV base. E1 = 1.0 by default
SE1	Saturation factor at terminal voltage E1, $S(E_1)$. SE1 = 0.0 by default
E2	Second terminal voltage point from the open circuit saturation curve, E_2 (> 0.0); entered in per unit on RATEKV base. E2 = 1.2 by default
SE2	Saturation factor at terminal voltage E2, $S(E_2)$. SE2 = 0.0 by default
IA1,IA2	Stator currents in PU specifying saturation of the stator leakage reactance, XA. IA1 =IA2 = 0.0 by default
XAMULT	Multiplier for the saturated value. Allowed value 0 to 1.0. XAMULT = 1.0 by default

Induction machine data input is terminated with a record specifying a bus number of zero.

1.27.1. Machine Electrical Data

The positive sequence steady state equivalent circuit for the induction machine is shown in Figure 1-17.



Induction Machine Equivalent Circuit

The machine model is described by eight electrical elements: three resistive and five inductive. Values are specified in per unit on the base power, MBASE, and rated voltage, RATEKV, which are also specified on the data record.

The left side of the circuit is the machine armature: r_a is the armature resistance and X_a is the armature leakage reactance. The armature and the rotor are linked through the magnetizing reactance X_m; the unsaturated value of the mutual reactance is specified.

The rotor is described by two parallel resistance and reactance branches, r_1, X_1 and r_2, X_2, that represent the "cages" or windings in the rotor. To model a single cage machine, the resistance and reactance of the second of these parallel branches must *both* be specified as 999.0; i.e., to model a single cage machine, specify $r_2 = X_2 = 999.0$ on the data record.

The reactance X_3 is included to allow a more general model.

The mutual reactance X_m saturates. The saturation curve is for the induction machine operating with no load. Two points on the saturation curve must be specified. These are normally chosen such that E_1 is near the "knee" of the saturtion curve and E_2 is near its ceiling. Saturation is neglected if $E_1 * S(E_1) = 0.0$; therefore, to neglect saturation, specify either E1 or SE1 as 0.0.

If a non-zero machine design code (DCODE) value is specified, all data items from RA to the end of the record are ignored, and pre-programmed machine electrical and saturation data values are assigned to the machine. If you wish to modify any of these data items after they have been assigned, you may change the machine design code to 0 (custom).

1.27.2. Load Mechanical Data

Five data items (TCODE, A, B, D and E) are used to describe how the torque of the mechanical load varies with speed. When TCODE is 1, a simple power law is applied that uses the constant specified as D. The equation is

$$T_{load} = T_{load0} \frac{(1-s)^D}{(1-s_0)^D}$$

where T_{load0} is the load torque and S_0 is the slip at a terminal voltage of 1.0 pu.

The WECC model applies the following equations:

$T_{load} = T_{load0}\ [A(1\text{-}s)^2 + B(1\text{-}s) + D(1\text{-}s)^E + C_0]$ WECC Model

$C_0 = 1 - A(1-s_0)^2 - B(1-s_0) + D(1-s_0)^E$

1.28. Substation Data

Each substation to be represented in PSS®E is introduced by reading a substation data record block. Each substation block consists of:

- A substation data record
- Several node data records
- Several substation switching device data records
- Several equipment terminal data records

1.28.1. Substation Data Record

The first record in each substation block is a substation data record. Exactly one such record is specified in each substation block. Each substation data record has the following format:

```
IS, NAME, LATI, LONG, SGR
```

IS	Substation number (1 through 99999). No default allowed
NAME	Substation name, NAME may be up to forty characters and may contain any combination of blanks, uppercase letters, numbers and special characters. NAME must be enclosed in single or double quotes if it contains any blanks or special characters. NAME is forty blanks by default
LATI	Substation latitude in degrees (-90.0 to 90.0). It is positive for North and negative for South, 0.0 by default
LONG	Substation longitude in degrees. (-180.0 to 180.0). It is positive for East and negative for West, 0.0 by default
SRG	Substation grounding DC resistance in ohms. Substation grounding DC resistance in ohms 0.1 ohms by default

Substation data input is terminated with a record specifying a substation number of zero.

1.28.2. Node Data

The substation data record is followed by substation node data. Each node in the substation is specified in a node data record. Each node data record has the following format:

```
NI, NAME, I, STATUS, VM, VA
```

NI	Node number (1 through 999). No default allowed
NAME	Node name, NAME may be up to 40 characters and may contain any combination of blanks, uppercase letters, numbers and special characters. NAME must be enclosed in single or double quotes if it contains any blanks or special characters. NAME is 40 blanks by default
I	Electrical Bus number (1 through 999997) in bus branch model. The electrical bus represents this node NI and others that are connected by closed switching devices. No default allowed
STATUS	Node status. One for in-service and zero for out-of-service. STATUS = 1 by default
VM	Node voltage magnitude; entered in pu. VM = -1.0 by default
VA	Node voltage phase angle; entered in degrees. VA = 0.0 by default

Node data input for this substation is terminated with a record specifying a node number of zero.

Node Data Notes

VM and VA need to be set to their actual solved case values only under the following conditions:

- The network, as entered into the working case via activity READ, is to be considered solved as read in
- Substation bus "I" is represented in the bus branch model by multiple bus sections

The voltage of each bus representing one of the bus sections is set to the node voltage corresponding to the bus section number (e.g., if bus 154 is represented by the bus sections154-1 and 154-4, the voltage at bus 154-1 is set to the voltage specified for node 1 and the voltage at bus 154-4 is set to the voltage specified for node 4).

Otherwise, unless some better estimate of the solved voltage and/or phase angle is available, VM and VA may be omitted. In this case, the voltage at each of the bus sections is set to the voltage specified for bus "I".

1.28.3. Station Switching Device Data

The node data records are followed by substation switching device data. Each station switching device in the substation is specified in a station switching device data record. Each station switching device data record has the following format:

```
NI,NJ,CKT,NAME,TYPE,STATUS,NSTAT,X,RATE1,RATE2,RATE3
```

NI	From node number (1 through 999). The from node must be in the sub- station IS. No default allowed

NJ	To node number (1 through 999). The to node must be in the substation IS. No default allowed
CKT	Two-character uppercase non-blank alphanumeric switching device identifier. CKT = '1' by default
NAME	Switching device name, NAME may be up to 40 characters and may contain any combination of blanks, uppercase letters, numbers and special characters. NAME must be enclosed in single or double quotes if it contains any blanks or special characters. NAME is 40 blanks by default
TYPE	Switching device type 1 - Generic connector 2 - Circuit breaker 3 - Disconnect switch
STATUS	Switching device status. One for close and zero for open. STATUS = 1 by default
NSTAT	Switching device normal status. One for close and zero for open. NSTAT = 1 by default
X	Switching device reactance; entered in pu. A non-zero value of X must be entered for each switching device. X = 0.0001 by default
RATE1	First rating; entered in either MVA or current expressed as MVA.
RATE2	Second rating; entered in either MVA or current expressed as MVA.
RATE3	Third rating; entered in either MVA or current expressed as MVA.

Station switching device data input for this substation is terminated with a record specifying a from node number of zero.

1.28.4. Equipment Terminal Data

The substation switching device data records are followed by equipment terminal data. Equipment items that are connected to substation buses are specified in equipment terminal data records. The following paragraphs describe the record formats of the various types of terminal equipment that may be specified. Within the set equipment terminal data records specified for a substation, records maybe specified in any order.

Equipment terminal data input for this substation is terminated with a record specifying a bus number of zero.

Load Terminal Data

Each load terminal data record has the following format:

```
I, NI, 'L', ID
```

I	Bus number.

	No default allowed
NI	Node number (1 through 999). If the electrical bus has node breaker model, in other words it represents a set of nodes in a substation, the node must be one node in the set and indicates the connections of the load within the substation. If the electrical bus has no node breaker model, it is zero. No default allowed
L	Single character 'L' to indicate the record contains terminal information for a Load.
ID	One or two-character uppercase non-blank alphanumeric load identifier used to distinguish among multiple loads at bus I. It is recommended that, at buses for which a single load is present, the load be designated as having the load identifier '1'. ID = '1' by default

Fixed Shunt Terminal Data

Each fixed shunt terminal data record has the following format:

```
I, NI, 'F', ID
```

I	Bus number. No default allowed
NI	Node number (1 through 999). If the electrical bus has node breaker model, in other words it represents a set of nodes in a substation, the node must be one node in the set and indicates the connections of the shunt within the substation. If the electrical bus has no node breaker model, it is zero. No default allowed
F	Single character 'F' to indicate the record contains terminal information for a Fixed Shunt.
ID	One or two-character uppercase non-blank alphanumeric shunt identifier used to distinguish among multiple shunts at bus I. It is recommended that, at buses for which a single shunt is present, the shunt be designated as having the shunt identifier '1'. ID = '1' by default

Machine Terminal Data

Each machine terminal data record has the following format:

```
I, NI, 'M', ID
```

I	Bus number. No default allowed
NI	Node number (1 through 999). If the electrical bus has node breaker model, in other words it represents a set of nodes in a substation, the node must be one node in the set and indicates the connections of the machine within the substation. If the electrical bus has no node breaker model, it is zero.

	No default allowed
M	Single character 'M' to indicate the record contains terminal information for a Machine.
ID	One or two-character uppercase non-blank alphanumeric machine identifier used to distinguish among multiple machines at bus I. It is recommended that, at buses for which a single machine is present, the machine be designated as having the machine identifier '1'. ID = '1' by default

Branch and two winding Transformer Terminal Data

Each non-transformer branch and two-winding transformer terminal data record has the following format:

`I,NI,'B',J,CKT` or: `I,NI,'2',J,CKT`

I	From bus number. No default allowed
NI	From node number (1 through 999). If the electrical from bus has node breaker model, in other words it represents a set of nodes in a substation, the from node must be one node in the set and indicates the connections of branch within the substation. If the electrical from bus has no node breaker model, it is zero. No default allowed
'B' or 2	Specifies that the record contains terminal information for a non-transformer or two-winding transformer.
J	To bus number. No default allowed
CKT	One or two-character uppercase non-blank alphanumeric switching device identifier. CKT = '1' by default

Three winding Transformer Terminal Data

Each three winding transformer terminal data record has the following format:

`I, NI, '3', J, K, CKT`

I	From bus number. No default allowed
NI	From node number (1 through 999). If the electrical from bus I has node breaker model, in other words it represents a set of nodes in a substation, the from node must be one node in the set and indicates the connections of branch within the substation. If the electrical from bus has no node breaker model, it is zero. No default allowed
3	Single character '3' to indicate the record contains terminal information for a three-winding transformer.
J	To bus number.

	No default allowed
K	To bus number. No default allowed
CKT	One or two-character uppercase non-blank alphanumeric switching device identifier. CKT = '1' by default

Switched Shunt Terminal Data

Each switched shunt terminal data record has the following format:

```
I, NI, 'S'
```

I	Bus number. No default allowed
NI	Node number (1 through 999). If the electrical bus has node breaker model, in other words it represents a set of nodes in a substation, the node must be one in the set and indicates the connections of the switched shunt within the substation. If the electrical bus has no node breaker model, it is zero. No default allowed
S	Single character 'S' to indicate the record contains terminal information for a switched shunt.

Induction Machine Terminal Data

Each induction machine terminal data record has the following format:

```
I, NI, 'I', ID
```

I	Bus number. No default allowed
NI	Node number (1 through 999). Must be one of the nodes of the bus within the substation to which the induction machine is to be connected to. If the bus has no node breaker model, it is zero. No default allowed
I	Single character 'I' to indicate the record contains terminal information for an induction machine.
ID	One or two-character uppercase non-blank alphanumeric machine identifier used to distinguish among multiple machines at bus I. It is recommended that, at buses for which a single machine is present, the machine be designated as having the machine identifier '1'. ID = '1' by default

Two-terminal DC Line Terminal Data

Each two-terminal DC line terminal data record has the following format:

```
I, NI, 'D', "NAME'
```

I	Rectifier or Inverter converter bus number. No default allowed
NI	Node number (1 through 999). Must be one of the nodes of the bus within the substation to which one end of the two-terminal dc line is to be connected to. If the electrical bus has no node breaker model, it is zero. No default allowed
D	Single character 'D' to indicate that the record contains terminal information for a two-terminal dc line connection.
NAME	The non-blank alphanumeric identifier of the two-terminal dc line. No default allowed

Voltage Source Converter (VSC) DC Line Terminal Data

Each VSC DC line terminal data record has the following format:

```
I, NI, 'V', "NAME'
```

I	Converter bus number. No default allowed
NI	Node number (1 through 999). Must be one of the nodes of a converter bus within a substation to which one end of the VSC dc line is to be connected to. If the bus has no node breaker model, it is zero. No default allowed
V	Single character 'V' to indicate that the record contains terminal information for a VSC dc line connection.
NAME	The non-blank alphanumeric identifier of the VSC dc line. No default allowed

Multi-terminal DC Line Terminal Data

Each multi-terminal DC line terminal data record has the following format:

```
I, NI, 'N', "NAME'
```

I	AC converter station bus number. No default allowed
NI	Node number (1 through 999). Must be one of the nodes of the ac converter station bus within the substation to which the multi-terminal dc line is to be connected to. If the bus has no node breaker model, it is zero. No default allowed
N	Single character 'N' to indicate that the record contains terminal information for a multi-terminal dc line connection.

NAME	The non-blank alphanumeric identifier of the multi-terminal dc line. No default allowed

FACTS Device Terminal Data

Each FACTS device terminal data record has the following format:

```
I, NI, 'A', "NAME'
```

I	Sending or terminal end bus number of the FACTS device. No default allowed
NI	Node number (1 through 999). Must be one of the nodes of the ac converter station bus within the substation to which the FACTS device is to be connected to. If the bus has no node breaker model, it is zero. No default allowed
A	Single character 'A' to indicate that the record contains terminal information for a FACTS device connection.
NAME	The non-blank alphanumeric identifier of the FACTS device. No default allowed

1.29. End of Data Indicator

It is good practice to end the Power Flow Raw Data File with a Q Record. Then, if new data categories are introduced in a point release of PSS®E, no modification of the file is required.

Chapter 2
Sequence Data File

2.1. Overview

The input stream to activity RESQ is a Sequence Data File containing 11 groups of records with each group specifying a particular type of sequence data required for fault analysis work (see Figure 2-1). Any piece of equipment for which sequence data is to be entered in activity RESQ *must* be represented as power flow data in the working case. That is, activity RESQ will not accept data for a bus, generator, branch, switched shunt or fixed shunt not contained in the working case.

All data is read in free format with data items separated by a comma or one or more blanks. Each category of data except the change code is terminated by a record specifying an I value of zero. Termination of all data is indicated by a value of Q.

Change Code
System Wide Data
Generator Sequence Data
Load Sequence Data
Zero Sequence Non-Transformer Branch Data
Zero Sequence Mutual Impedance Data
Zero Sequence Transformer Data
Zero Sequence Switched Shunt Data
Zero Sequence Fixed Shunt Data
Induction Machine Sequence Data
Non-Conventional Source Fault Contribution Data
Q Record

Sequence Data Input Structure

2.2. Change Code

The first record in the Sequence Data File contains two data items as follows:

```
IC, REV
```

IC	IC = 0 indicates the initial input of sequence data for the network contained in the working case. All buses, generators, branches, switched shunts and fixed shunts for which no data record is entered in a given category of data have the default values assigned for those data items. IC = 1 indicates change case input of sequence data for the network contained in the working case. All buses, generators, branches, switched shunts and fixed shunts for which no data record is entered in a given category of data have those data items unchanged; i.e., they are not set to the default values. IC=0 by default.
REV	PSSE revision number. REV = Current revision by default.

The use of the change case mode in activity RESQ is identical to its use in activity READ: for the addition of equipment to the working case (e.g., to add a zero sequence mutual coupling to the working case). It is not valid to set IC to one for the initial execution of activity RESQ for the network in the working case; in this case, an appropriate message is printed and activity RESQ continues its execution as if IC had been specified as zero.

2.3. System Wide Data

Through the system-wide data category, data that pertains to the case as a whole (rather than to individual equipment items) may be included in the Sequence Data File to allow convenient transfer of it with the case. Records may be included that define:

- Short Circuit Output Report Format
- Metal Var Oxide (MOV) Iteration Options
- Short Circuit Model

Generally, each record specified in the System-Wide Data category begins with a NAME that defines the type of data specified on the record. The formats of the various records are described in the following paragraphs.

RPTFORMAT Record

The Short Circuit Output Report Format record begins with the name RPTFORMAT and contains unit and co-ordinates option for reporting current, voltage and Thevenin impedance. Using keyword input, any or all of the following report format parameters may be specified:

AMPOUT = 0, Current and Voltages in PU) (default)

= 1, Current in Amperes and Voltages in kV

POLROU = 0, Currents and Voltages in Rectangular co-ordinates (default)

= 1, Currents and Voltages in Polar co-ordinates

AMPOUTZ = 0, Thevenin Impedance in PU (default)

= 1, Thevenin Impedance in ohms

POLROUZ = 0, Thevenin Impedance in Rectangular co-ordinates (default)

= 1, Thevenin Impedance in Polar co-ordinates

Those RPTFORMAT parameters that are specified may be entered n any order. The following is an example of this record:

RPTFORMAT, AMPOUT=0, POLROU=0, AMPOUTZ=0, POLROUZ=0

MOV Record

The Metal Var Oxide (MOV) Iteration Options record begins with the name MOV and contains linearized MOV model iteration parameters used by short circuit calculation methods. Using keyword input, any or all of the following MOV iteration parameters may be specified:

ITERATIONS Maximum number of iterations (default=20)

TOLERANCE Tolerance (default=0.01)

MOVALPHA Acceleration factor (default=0.3)

Those parameters that are specified may be entered in any order. The following is an example of this record:

MOV, ITERATIONS=20, TOLERANCE=0.01, MOVALPHA=0.3

SCMODEL Record

The Short Circuit Model Options record begins with the name SCMODEL and contains fault analysis modeling option setting. Using keyword input, SCMODEL parameters may be specified:

SCNRML = 0, center tapped two-phase modeling

= 1, Normal three-phase modeling (default)

The following is an example of this record:

SCMODEL, SCNRML=1

2.4. Generator Sequence Data

Each network bus to be represented as a generator bus (i.e., as a current source) in the unbalanced analysis activities must have sequence generator impedances entered into the PSSE working case for all in-service machines at the bus.

Each generator sequence impedance data record has the following format:

`I, ID, ZRPOS, ZXPPDV, ZXPDV, ZXSDV, ZRNEG, ZXNEGDV, ZR0, ZX0DV, CZG, ZRG, ZXG, REFDEG`

I	Bus number; bus I must be present in the working case as a generator bus.
ID	One or two character machine identifier of the machine bus I for which the data is specified by this record. ID = '1' by default
ZRPOS	Generator positive sequence resistance; entered in pu on machine base (i.e., on bus voltage base and MBASE). ZRPOS = ZR (source resistance in raw data) by default.
ZXPPDV	Generator positive sequence saturated subtransient reactance; entered in pu on machine base (i.e., on bus voltage base and MBASE). ZXPPDV = ZX (source reactance in raw data) by default
ZXPDV	Generator positive sequence saturated transient reactance; entered in pu on machine base (i.e., on bus voltage base and MBASE). ZXPDV = ZXPPDV by default
ZXSDV	Generator positive sequence saturated synchronous reactance; entered in pu on machine base (i.e., on bus voltage base and MBASE). ZXSDV = XPPDV by default.
ZRNEG	Generator negative sequence resistance; entered in pu on machine base (i.e., on bus voltage base and MBASE). ZRNEG = ZRPOS by default
ZXNEGDV	Generator negative sequence saturated reactance; entered in pu on machine base (i.e., on bus voltage base and MBASE). ZXNEGDV = ZXPPDV by default
ZR0	Generator zero sequence resistance; entered in pu on machine base (i.e., on bus voltage base and MBASE). ZR0 = ZRPOS by default
ZX0DV	Generator zero sequence saturated reactance; entered in pu on machine base (i.e., on bus voltage base and MBASE). ZX0DV = ZXPPDV by default
CZG	Units of grounding impedance (ZRG and ZXG) values, = 1 for pu (on bus voltage base and MBASE), = 2 for Ohms
ZRG	Generator grounding resistance; entered in pu on machine base (i.e., on bus voltage base and MBASE) when CZG=1 or in ohms when CZG=2. ZRG = 0.0 by default
ZXG	Generator grounding reactance; entered in pu on machine base (i.e., on bus voltage base and MBASE) when CZG=1 or in ohms when CZG=2. ZXG = 0.0 by default

REFDEG	Generator Reference Angle; entered in degrees. This angle is used only when fault calculations with for "FLAT" voltage profile is selected. REFDEG = 0.0 by default

Throughout this Manual, the complex positive sequence generator impedance used in fault analysis will be referred to as ZPOS. The real component of ZPOS is always ZRPOS. Its imaginary component is either ZXPPDV, ZXPDV or ZXSDV, according to the selection made in selecting the fault analysis calculation activity. Similarly, the negative sequence generator impedance, ZNEG, is ZRNEG + j ZXNEGDV, and the zero sequence generator impedance, ZZERO, is ZR0 + j ZX0DV.

During the initial input of sequence data (i.e., IC = 0 on the first data record), any machine for which no data record of this category is entered has its positive sequence resistance set to ZR (the real component of ZSORCE), and all three positive sequence reactances set to ZX (the imaginary component of ZSORCE). ZSORCE is the generator impedance entered in activities READ, Section Activity, TREA, RDCH, and MCRE; it is used in switching studies and dynamic simulations (refer to Generator Data).

In subsequent executions of activity RESQ (i.e., IC = 1 on the first data record), any machine for which no data record of this category is entered has its positive sequence generator impedance values unchanged. Note that the generator positive sequence impedance values entered in activity RESQ for fault analysis purposes is not necessarily the same as the generator impedance (ZSORCE) used in dynamics, and that it does not overwrite ZSORCE. That is, the two different sets of positive sequence impedance data are specified in the working case simultaneously at different locations.

During the initial input of sequence data (i.e., IC = 0 on the first data record), any machine for which no data record of this category is entered has its negative sequence generator impedance ZNEG set equal to ZRPOS + j ZXPPDV. In subsequent executions of activity RESQ (i.e., IC = 1 on the first data record), any machine for which no data record of this category is entered has its negative sequence generator impedance unchanged.

For those machines at which the step-up transformer is represented as part of the generator data (i.e., XTRAN is non-zero), ZZERO is not used and, in the fault analysis activities, the step-up transformer is assumed to be a delta wye transformer. Refer to Modeling of Generator Step-Up Transformers (GSU).

For those machines that do not include the step-up transformer as part of the generator data (i.e., XTRAN is zero), a zero sequence impedance of zero results in the machine being treated as an open circuit in the zero sequence.

During the initial input of sequence data (i.e., IC = 0 on the first data record), any machine for which no data record of this category is entered has its zero sequence generator impedance ZZERO set equal to ZRPOS + j ZXPPDV. In subsequent executions of activity RESQ (i.e., IC = 1 on the first data record), any machine for which no data record of this category is entered has its zero sequence generator impedance unchanged.Generator sequence impedance data input is terminated with a record specifying a bus number of zero.

Figure 2-2 shows generator representation in sequence networks.

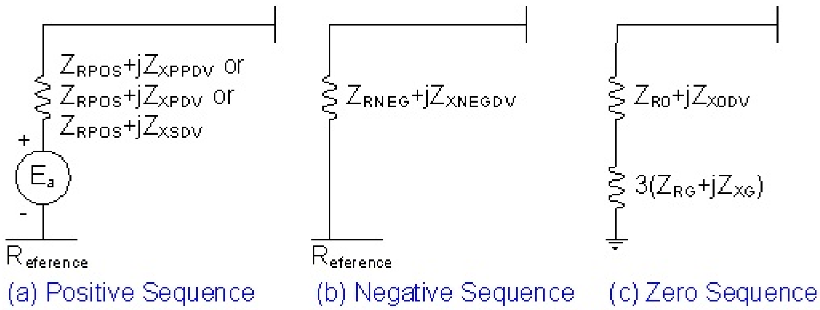


Figure - Generator Sequence Networks

PSS®E calculates pu grounding impedance from ohm as below:

$$Z_{RG} + jZ_{XG}\,\mathrm{in PU} = Z_{RG} + jZ_{XG}\,\mathrm{in\ ohm} \times \frac{\mathrm{MBASE}}{\mathrm{BASEKV}^2}$$

2.5. Load Sequence Data

Exceptional negative sequence loads (i.e., loads that, in the negative sequence, differ from the positive sequence loads) and zero sequence loads are entered into the working case in load sequence data records in the Sequence Data File. Each load negative and zero sequence data record has the following format:

```
I, ID, PNEG, QNEG, GRDFLG, PZERO, QZERO
```

I	Bus number, bus I must be present in the working case.
ID	One or two character load identifier of the load at bus I for which the data is specified by this record. ID = '1' by default
PNEG	Active component of negative sequence load; entered in MW at one per unit voltage. If PNEG=0 or is not specified, PNEG = positive sequence load MW.
QNEG	Reactive component of negative sequence load; entered in MVAR at one per unit voltage. If QNEG=0 or is not specified, QNEG = positive sequence load MVAR. QNEG is specified as negative MVAR for lagging (reactive) power factor loads.
GRDFLG	Grounding flag; 1 for grounded loads and 0 for ungrounded loads. GRDFLG=0 by default
PZERO	Active component of zero sequence load; entered in MW at 1 pu voltage. If PZERO is non-zero and GRDFLG=1, PZERO is modelled. If GRDFLG=0, PZERO is ignored. PZERO=0 by default
QZERO	Reactive component of zero sequence load; entered in MVAR at 1 pu voltage. If QZERO is non-zero and GRDFLG=1, QZERO is modelled. If GRDFLG=0, QZERO is ignored. QZERO is specified as negative MVAR for lagging (reactive) power factor loads. QZERO = 0.0 by default

For any bus where no load sequence data record is specified, or PNEG and QNEG are both specified as zero, the load elements are assumed to be equal in the positive and negative sequence networks. For any bus where no load sequence data record is specified, or PZERO and QZERO are both specified as zero, or GRDFLG is specified as zero (i.e., an ungrounded load), no load component is represented in the zero sequence.

The user is advised to exercise caution in specifying negative and zero sequence loads. In the fault analysis calculations, constant power and constant current loads are converted to constant admittance at the pre-fault voltage. Further, when positive sequence loads are changed, either directly by the user or by activities such as SCAL, it may be appropriate to change previously specified negative and zero sequence loads. It is the user's responsibility to ensure that the positive sequence loading data, as contained in the working case, is coordinated with the specified negative and zero sequence load data.

Load sequence data input is terminated with a record specifying a bus number of zero.

2.6. Zero Sequence Non-Transformer Branch Data

Zero sequence non-transformer branch parameters are entered into the working case in zero sequence non-transformer branch data records in the Sequence Data File. Each zero sequence branch data record has the following format:

```
I, J, CKT, RLINZ, XLINZ, BCHZ, GI, BI, GJ, BJ, IPR, SCTYP
```

I	Bus number of one end of the branch.
J	Bus number of the other end of the branch.
CKT	One- or two-character branch circuit identifier; a non-transformer branch with circuit identifier CKT between buses I and J must be in the working case. CKT = '1' by default
RLINZ	Zero sequence branch resistance; entered in pu on system base MVA and bus voltage base. RLINZ = 0.0 by default
XLINZ	Zero sequence branch reactance; entered in pu on system base MVA and bus voltage base. Any branch for which RLINZ and XLINZ are both 0.0 is treated as open in the zero sequence network. XLINZ must be negative for a series capacitor branch. XLINZ = 0.0 by default
BCHZ	Total zero sequence branch charging susceptance; entered in pu. BCHZ = 0.0 by default
GI,BI	Complex zero sequence admittance of the line connected shunt at the bus I end of the branch; entered in pu. GI + jBI = 0.0 by default
GJ,BJ	Complex zero sequence admittance of the line connected shunt at the bus J end of the branch; entered in pu. GJ + jBJ = 0.0 by default
IPR	MOV rated current for a series capacitor branch; entered in kA. It must be positive. IPR = 0.0 by default

SCTYP	MOV Protection Mode • 0 for normal branch (i.e., not a MOV protected branch) • 1 for MOV Protection enabled • 2 for MOV Protection disabled • 3 for Spark Gap Protection enabled (information only, not used in any calculations) SCTPY=0 by default

The zero sequence network is assumed to be a topological subset of the positive sequence network. That is, it may have a branch in every location where the positive sequence network has a branch, and may not have a branch where the positive sequence network does not have a branch. The zero sequence network does not need to have a branch in every location where the positive sequence network has a branch.

A branch treated as a zero impedance line in the positive sequence (refer to Zero Impedance Lines) is treated in the same manner in the zero sequence, regardless of its specified zero sequence impedance.

During the initial input of sequence data (i.e., IC = 0 on the first data record), any non-transformer branch for which no data record of this category is entered is treated as open in the zero sequence network (i.e., the zero sequence impedance is set to zero). In subsequent executions of activity RESQ (i.e., IC = 1 on the first data record), any branch for which no data record of this category is entered has its zero sequence branch data unchanged.

Zero sequence branch data input is terminated with a record specifying a from bus number of zero.

2.7. Zero Sequence Mutual Impedance Data

Data describing mutual couplings between branches in the zero sequence network are entered into the working case in zero sequence mutual impedance data records in the Sequence Data File. Each zero sequence mutual impedance data record has the following format:

```
I, J, CKT1, K, L, CKT2, RM, XM, BIJ1, BIJ2, BKL1, BKL2
```

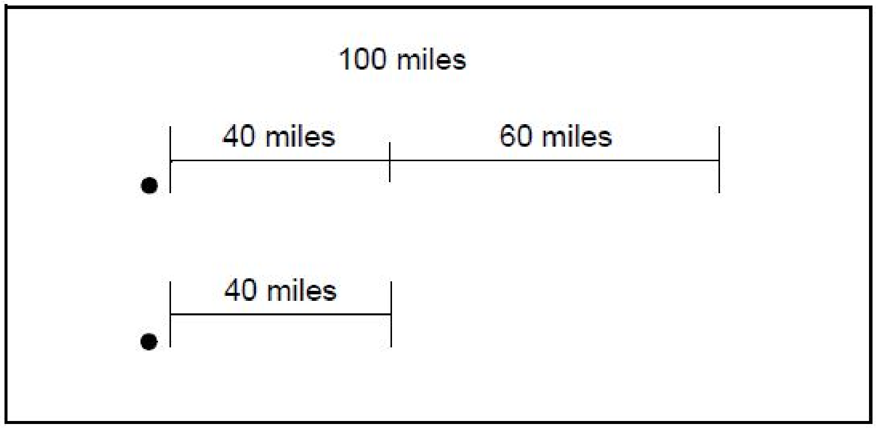
I	Bus number of one end of the first branch
J	Bus number of the other end of the first branch
CKT1	One- or two-character branch circuit identifier of the first branch; a non-transformer branch with circuit identifier ICKT1 between buses I and J must be in the working case. CKT1 = '1' by default
K	Bus number of one end of the second branch
L	Bus number of the other end of the second branch
CKT2	One- or two-character branch circuit identifier of the second branch; a non-transformer branch with circuit identifier ICKT2 between buses K and L must be in the working case. CKT2 = '1' by default
RM,XM	Branch-to-branch mutual impedance coupling circuit CKT1 from bus I to bus J with circuit CKT2 from bus K to bus L; entered in pu.

	No default is allowed
BIJ1	Starting location of the mutual coupling along circuit CKT1 from bus I to bus J relative to the bus I end of the branch; entered in per unit of total line length. BIJ1 = 0.0 by default
BIJ2	Ending location of the mutual coupling along circuit CKT1 from bus I to bus J relative to the bus I end of the branch; entered in per unit of total line length. BIJ2 = 1.0 by default
BKL1	Starting location of the mutual coupling along circuit CKT2 from bus K to bus L relative to the bus K end of the branch; entered in per unit of total line length. BKL1 = 0.0 by default
BKL2	Ending location of the mutual coupling along circuit CKT2 from bus K to bus L relative to the bus K end of the branch; entered in per unit of total line length. BKL2 = 1.0 by default

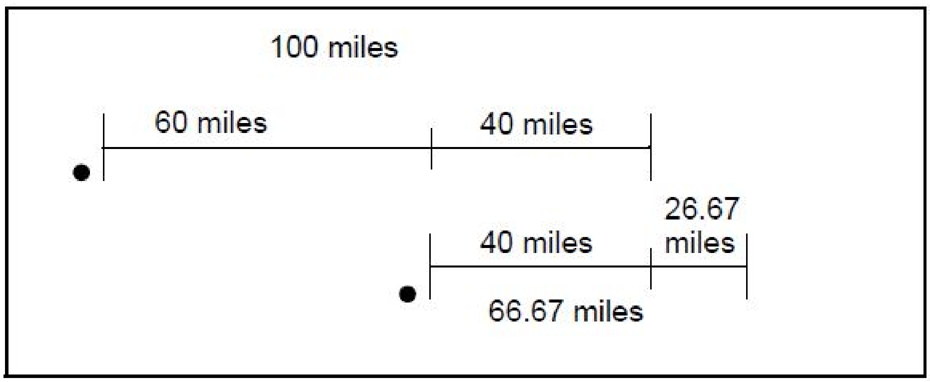
The following rules must be observed in specifying mutual impedance data:

- The maximum number of zero sequence mutual couplings that may be entered at the standard size levels of PSSE is defined in Table 3-1 Standard Maximum PSS®E Program Capacities.
- The polarity of a mutual coupling is determined by the ordering of the bus numbers (I,J,K,L) in the data record. The dot convention applies, with the from buses (I and K) specifying the two dot ends of the coupled branches.
- RM+jXM specifies the circuit-to-circuit mutual impedance, given the polarity implied by I and K.
- The geographical B factors are required only if one or both of the two mutually coupled lines is to be involved in an unbalance part way down the line, *and* only part of the length of one or both of the lines is involved in the coupling. (Note that the default values of the B factors result in the entire length of the first line coupled to the entire length of the second line.)
- The values of the B factors must be between zero and one inclusive; they define the portion of the line involved in the coupling.
- BIJ1 must be less than BIJ2, and BKL1 must be less than BKL2.
- Mutuals involving transformers or zero impedance lines are ignored by the fault analysis solution activities.

The following figure schematically illustrates a mutual coupling with BIJ1 = 0.0, BIJ2 = 0.4, BKL1 = 0.0 and BKL2 = 1.0 (the first 40% of the first line coupled with the entire second line).



As a second example, BIJ1 = 0.6, BIJ2 = 1.0, BKL1 = 0.0 and BKL2 = 0.6 (last 40% of the first line coupled with the first 60% of the second line) might be depicted as follows:



Zero sequence mutual impedance data input is terminated with a record specifying a from bus number of zero.

2.8. Zero Sequence Transformer Data

Zero sequence transformer parameters are entered into the working case in zero sequence transformer data records in the Sequence Data File. Each transformer data record has one of the following formats:

For two-winding transformers:

`I,J,K,CKT,CZ0,CZG,CC,RG1,XG1,R01,X01,RG2,XG2,R02,X02,RNUTRL,XNUTRL`

For three-winding transformers:

`I,J,K,CKT,CZ0,CZG,CC,RG1,XG1,R01,X01,RG2,XG2,R02,X02,`

`RG3,XG3,R03,X03,RNUTRL,XNUTRL`

Notations used in Zero Sequence Networks

Z01=R01+jX01 Z02=R02+jX02 Z03=R03+jX03

Zg1=RG1+jXG1 Zg2=RG2+jXG2 Zg3=RG3+jXG3

Znutrl=RNUTRL+jXNUTRL

I	Bus number of the bus to which a winding of the transformer is connected.
J	Bus number of the bus to which another winding of the transformer is connected.
K	Bus number of the bus to which another winding of the transformer is connected. Zero is used to indicate that no third winding is present (i.e., that a two-winding transformer is being specified). K = 0 by default
CKT	One- or two-character transformer circuit identifier; a transformer with circuit identifier CKT between buses I and J (and K if K is non-zero) must be in the working case. CKT = '1' by default
CZ0	The non-grounding impedance data I/O code defines the units in which the impedance values Z01, Z02 and Z03 are specified. In specifying these impedances, the winding base voltage values are always the nominal winding voltages (NOMV1, NOMV2 and NOMV3) that are specified on the third, fourth and fifth records of the Transformer Data block in the Power Flow Raw Data File; see Transformer Data for more details. If no value for NOMVn is specified, the winding "n" voltage base is assumed to be identical to the winding "n" bus base voltage. **Legacy Connection Codes** For those connection codes that existed prior to PSS®E-33, CZ0 must be specified as 1. • For two-winding transformers, these are connection codes 1 through 9; • for three-winding transformers, these are connection codes 1 through 6, as well as the three digit connection codes where each digit refers to one of the two-winding connection codes 1 through 7 that is to be applied to one of the three windings of the transformer. • For all two-winding transformers with legacy connection codes, Z01 is specified in per unit on system MVA base and winding voltage base. Only for two-winding transformers with connection code 9, Z02 is specified in per unit on system MVA base and winding 2 voltage base. • For all three-winding transformers with legacy connection codes, Z01, Z02 and Z03 are specified in per unit on system MVA base and winding "n" voltage base. **Connection Codes Introduced in PSS®E-33** For all two-digit connection codes for two- and three-winding transformers, CZ0 may be specified as one of the following values: • 1 for per unit on system MVA base and winding "n" voltage base • 2 for per unit on a specified MVA base and winding "n" voltage base

	These are the same units dictated by CZ values 1 and 2 on the transformer data record of the Power Flow Raw Data File.
CZG	The grounding impedance data I/O code defines the units in which the impedance values Zg1, Zg2, Zg3 and Znutrl are specified. In specifying these impedances, the winding base voltage values are always the nominal winding voltages (NOMV1, NOMV2 and NOMV3) that are specified on the third, fourth and fifth records of the Transformer Data block in the Power Flow Raw Data File. If no value for NOMVn is specified, the winding "n" voltage base is assumed to be identical to the winding "n" bus base voltage. **Legacy Connection Codes** For those connection codes that existed prior to PSS®E-33, CZG must be specified as 1. • For two-winding transformers, these are connection codes 1 through 9; • For three-winding transformers, these are connection codes 1 through 6, as well as the three digit connection codes. • For two-winding transformers with legacy connection codes 2, 3 and 9, Zg1 is specified in per unit on system MVA base and winding voltage base. • For two-winding transformers with connection codes 5 through 8, Zg1 is specified in per unit on system MVA base and winding voltage base. • For two-winding transformers with connection code 8, Zg2 is specified in per unit on system MVA base and winding 2 voltage base. • For three-winding transformers with legacy connection code 1, Zg1 is specified in per unit on system MVA base and winding 1 voltage base. • For three-winding transformers with legacy connection code 5, Zg2 is specified in per unit on system MVA base and winding 2 voltage base. **Connection Codes Introduced in PSS®E-33** For all two-digit connection codes for two- and three-winding transformers, CZG may be specified as one of the following values: • 1 for per unit on system MVA base and winding voltage base • 2 for per unit on a specified MVA base and winding voltage base • 3 for ohms For three winding transformers, Zg1 is on SBASE12, Zg2 on SBASE23, Zg3 on SBASE31, and Znutrl on SABSE12. For CZG values of 1 and 2, these are the same units dictated by CZ values 1 and 2 on the transformer data record of the Power Flow Raw Data File
CC	Winding connection code indicating the connections and ground paths to be used in modeling the transformer in the zero sequence network.

For a two-winding transformer, valid values are 1 through 9 and 11 through 23. They define the following zero sequence connections that are shown in Section Two Winding Transformer Zero Sequence Network Diagrams and Connection Codes.

1, 11 series path, no ground path.

2, 12 no series path, ground path on Winding 1 side.

3, 13 no series path, ground path on Winding 2 side.

4, 14 no series or ground paths.

5, 15 series path, ground path on Winding 2 side (normally only used as part of a three-winding transformer).

6, 16 no series path, ground path on Winding 1 side, earthing transformer on Winding 2 side.

7, 17 no series path, earthing transformer on Winding 1 side, ground path on Winding 2 side.

8, 18 series path, ground path on each side.

9, 19 series path on each side, ground path at the junction point of the two series paths.

20 series path on each side, ground path at the junction point of the two series paths; wye grounded - wye grounded core type transfromer

21 series path, no ground path; wye grounded - wye grounded non core type auto transfromer

22 series path, no ground path; wye - wye ungrounded core type auto transfromer

For a three-winding transformer, CC may be specified as a three digit number, each digit of which is 1 through 7; the first digit applies to Winding 1, the second to Winding 2, and the third to Winding 3, where the winding connections correspond to the first seven two-winding transformer connections defined above and shown in Section 5.5.6, Three Winding Transformer Zero Sequence Network Diagrams and Connection Codes.

Alternatively, several common zero sequence three-winding transformer connection combinations may be specified using the single digit values 1 through 6. These are defined the zero sequence transformer connections.

The following ' single digit three-winding connection codes are available, where the connection codes of the three two-winding transformers comprising the three-winding transformer are shown in parenthesis in winding number order:

1, 11 series path in all three windings, Winding 1 ground path at the star point bus (5-1-1).

	2, 12 series path in Windings 1 and 2, Winding 3 ground path at the star point bus (1-1-3). 3, 13 series path in Winding 2, ground paths from windings one and three at the star point bus (3-1-3).
	4, 14 no series paths, ground paths from all three windings at the star point bus (3-3-3). 5, 15 series path in windings one and three, ground path at the Winding 2 side bus (1-2-1). 6, 16 series path in all three windings, no ground path (1-1-1). 17 series path in Windings 1 and 2, Winding 3 ground path at the star point bus; wye grounded - wye grounded - delta auto transfromer 18 series path in Windings 1 and 2, no ground path in Winding 3;wye - wye - delta ungrounded neutral auto transfromer Section 5.5.3, Transformers in the Zero Sequence, includes examples of the proper specification of CC and the remaining transformer data items for several types of transformers. CC = 14 by default
RG1, XG1	Zero sequence grounding impedance on for an impedance grounded transformer. This data is specified in units specified by CZG. Refer zero sequence network diagrams for each connection code for specifying this value. RG1 = 0.0 and XG1 = 0.0 by default
	From two winding transformers connection codes ZG1=RG1+jXG1 is interpreted as: • ZG1 is grounding impedance of winding 1 when CC>9 • ZG1 is grounding impedance of winding 1 when CC=2 • ZG1 is grounding impedance of winding 2 when CC=3 • ZG1 is grounding impedance at winding 2 bus when CC=5,6 • ZG1 is grounding impedance at winding 1 bus when CC=7,8 • ZG1 is grounding impedance at star point of zero-sequence network T-model when CC=9
	From three winding transformers connection codes ZG1=RG1+jXG1 is interpreted as: • ZG1 is grounding impedance of winding 1 when CC are two digits, like, CC=12 • ZG1 is grounding impedance at star point of zero-sequence network T-model when CC=1 or User Code Digit=5

	• ZG1 is grounding impedance of winding 1 when CC=2 or user code digit is 2. • ZG1 is grounding impedance of winding 2 when CC=3 or user code digit is 3.
R01, X01	Refer zero sequence network diagram for each connection code for specifying this value. This value could be: • Two winding transformer: Z01 is equal to the transformer's zero sequence leakage impedance. Z01 is equal to the transformer's positive sequence impedance by default. • Three winding transformers and connection codes CC=11 and higher: Z01 is equal to the transformer's winding 1 to winding 2 zero sequence impedance. Z01 is equal to the transformer's winding 1 to winding 2 positive sequence impedance by default. • For three winding transformers and connection codes CC=1 through 9 and User Code: Z01 is equal to the transformer's winding 1 star-circuit equivalent zero sequence impedance. is equal to the transformer's winding 1 star-circuit equivalent positive sequence impedance by default. This data is specified in units specified by CZ0.
RG2, XG2	Zero sequence grounding impedance on winding 2 for an impedance grounded transformer. This data is applicable for connection codes CC=11 and higher. This data is specified in units specified by CZG. Refer zero sequence network diagram for each connection code for specifying this value. RG2 = 0.0 and XG2 = 0.0 by default

R02, X02	Refer zero sequence network diagram for each connection code for specifying this value. This value could be: • For two winding transformer: Refer zero sequence network diagram for each connection code for specifying Z02 value. R02 = 0.0 and X02 = 0.0 by default. • For three winding transformer and connection codes CC=11 and higher: Z02 is equal to the transformer's winding 2 to winding 3 zero sequence impedance. Z02 is equal to the transformer's winding 2 to winding 3 positive sequence impedance by default. • For three winding transformer and connection codes CC=1 through 9 and User Code: Z02 is equal to the transformer's winding 2 star-circuit equivalent zero sequence impedance. Z02 is equal to the transformer's winding 2 star-circuit equivalent positive sequence impedance by default. This data is specified in units specified by CZ0.

RG3, XG3	Zero sequence grounding impedance on winding 3 for an impedance grounded transformer. This data is applicable for connection codes CC=11 and higher. This data is specified in units specified by CZG. Refer zero sequence network diagram for each connection code for specifying this value. RG3 = 0.0 and XG3 = 0.0 by default.
R03, X03	Refer zero sequence network diagram for each connection code for specifyingthis value. This value could be: • For three winding transformer and connection codes CC=11 and higher: Z03 is equal to the transformer's winding 3 to winding 1 zero sequence impedance. Z03 is equal to the transformer's winding 3 to winding 1 positive sequence impedance by default. • For three winding transformer and connection codes CC=1 through 9: Z03 is equal to the transformer's winding 3 star-circuit equivalent zero sequence impedance. Z03 is equal to the transformer's winding 3 star-circuit equivalent positive sequence impedance by default. This data is specified in units specified by CZ0.
RNUTRL, XNUTRL	Zero sequence common neutral grounding impedance. This data is applicable for connection codes CC=11 and higher. This data is specified in units specified by CZG. Refer zero sequence network diagram for each connection code for specifying this value. RNUTRL = 0.0 and XNUTRL = 0.0 by default.

Refer Sections 5.5.4, 5.5.5 and 5.5.6 for transformer winding connections, zero sequence network diagrams and connection codes.

In specifying zero sequence impedances for three-winding transformers, note that *winding* impedances are required, and that the zero sequence impedances return to the default value of the positive sequence winding impedances. Recall that, in specifying positive sequence data for three-winding transformers (refer to Transformer Data), measured impedances between pairs of buses to which the transformer is connected, not winding impedances, are required. PSSE converts the measured bus-to-bus impedances to winding impedances that are subsequently used in building the network matrices. Activities LIST and EXAM tabulate both sets of positive sequence impedances.

Recall that the service status of a three-winding transformer may be specified such that two of its windings are in-service and the remaining winding is out-of-service (refer to Transformer Data). Recall also that data for the three windings of a three-winding transformer is stored in the working case as three two-winding transformers (refer to Three-Winding Transformer Notes). Ri + jXi is stored with the two-winding transformer containing winding i's data; RG + jXG is stored with the two-winding transformer containing the data of the winding at which it is applied.

Placing one winding of a three-winding transformer out-of-service may require a change to the zero sequence data of the two windings that remain in-service. As the fault analysis calculation functions construct the zero sequence admittance matrix, when a three-winding transformer with one winding out-of-service is encountered, all data pertaining to the out-of-service winding (i.e., pertaining to the two-winding transformer containing the data of the out-of-service winding) is ignored. Thus, any zero sequence series and ground paths resulting from the impedances and connection code of the out-of-service winding are excluded from the zero sequence admittance matrix. It is the user's responsibility to ensure that the zero sequence impedances and connection codes of the two in-service windings result in the appropriate zero sequence modeling of the transformer.

Specification of the transformer connection code along with the impedances entered here enables the fault analysis activities to correctly model the zero sequence transformer connections, including the ground ties and open series branch created by certain grounded transformer windings. If no connection code is entered for a transformer, all windings are assumed to be open. Section 5.5.3, Transformers in the Zero Sequence gives additional details on the treatment of transformers in the zero sequence network, including examples of specifying data for several types of transformers.

During the initial input of sequence data (i.e., IC = 0 on the first data record), any transformer for which no data record of this category is entered has it zero sequence winding impedance(s) set to the same value(s) as its positive sequence winding impedance(s). In subsequent executions of activity RESQ (i.e., IC = 1 on the first data record), any transformer for which no data record of this category is entered has its zero sequence transformer data unchanged.

Zero sequence transformer data input is terminated with a record specifying a from bus number of zero.

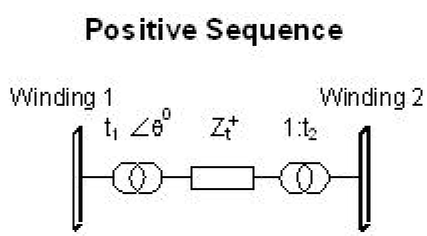


Figure 2.1. Two-Winding Transformer Positive Sequence Connections

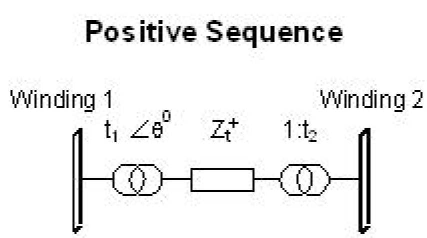


Figure 2.2. Three-Winding Transformer Positive Sequence Connections

2.9. Zero Sequence Switched Shunt Data

Zero sequence shunt admittances for switched shunts are entered into the working case in zero sequence switched shunt data records in the Sequence Data File. Each switched shunt data record has the following format:

```
I, ID, BZ1, BZ2, ... BZ8
```

I	Bus number; bus I must be present in the working case with positive sequence switched shunt data.
ID	One or two character identifier of the switched shunt at bus I for which the data is specified by this record. ID = '1' by default
BZ_i	Zero sequence admittance increment for each of the steps in block i; entered in MVAR at 1 pu unit voltage. BZ_i = 0.0 by default

Data specified on zero sequence switched shunt data records must be coordinated with the corresponding positive sequence data (refer to Switched Shunt Data). The number of blocks and the number of steps in each block are taken from the positive sequence data.

Activity RESQ generates an alarm for any block for which any of the following applies:

- The positive sequence admittance is positive and the zero sequence admittance is negative.
- The positive sequence admittance is negative and the zero sequence admittance is positive.
- The positive sequence admittance is zero and the zero sequence admittance is non-zero.

The zero sequence admittance switched on at a bus is determined from the bus positive sequence value, with the same number of blocks and steps in each block switched on.

Zero sequence switched shunt data input is terminated with a record specifying a bus number of zero.

2.10. Zero Sequence Fixed Shunt Data

Zero sequence fixed shunts are entered into the working case in zero sequence fixed shunt data records in the Sequence Data File. Each zero sequence fixed shunt data record has the following format:

```
I, ID, GSZERO, BSZERO
```

I	Bus number; bus I must be present in the working case.
ID	One or two character identifier of the fixed shunt at bus I for which the data is specified by this record. ID = '1' by default
GSZERO	Active component of zero sequence admittance to ground to represent this fixed shunt at bus I; entered in MW at 1 pu voltage.
BSZERO	Reactive component of zero sequence admittance to ground to represent this fixed shunt at bus I; entered in MVAR at 1 pu voltage.

For any fixed shunt for which either no such data record is specified or GSZERO and BSZERO are both specified as 0.0, no zero sequence ground path is modeled for this fixed shunt. The zero sequence ground tie created by a grounded transformer winding is automatically added to whatever zero sequence fixed shunt and shunt load is specified at the bus when the transformer winding connection code data for the transformer is specified (refer to Zero Sequence Transformer Data).

Zero sequence fixed shunt data input is terminated with a record specifying a bus number of zero.

2.11. Induction Machine Sequence Data

Each zero sequence induction machine data has the following format:

```
I, ID, CZG, GRDFLG, ILR2IR_SUB, R2X_SUB, ZR0, ZX0, ZRG, ZXG, ILR2IR_TRN, R2X_TRN,
ILR2IR_NEG, R2X_NEG
```

I	Bus number; bus I must be present in the working case as an induction machine bus.
ID	One or two character identifier of the induction machine at bus I for which the data is specified by this record. ID = '1' by default
CZG	Units of grounding impedance (ZRG and ZXG) values, = 1 for pu (on bus voltage base and MBASE), = 2 for Ohms
GRDFLG	1 for grounded machine, 0 for ungrounded machine (Most commonly, stator winding is either delta connected or star connected with the neutral isolated.) GRDFLG=0 by default.
ILR2IR_SUB	Ratio of positive sequence subtransient locked rotor current to rated current.
R2X_SUB	Ratio of positive sequence subtransient resistance to reactance. This is used only when positive sequence impedance is calculated using ILR2IR_SUB. R2X_SUB = 0.0 by default
ZR0	Zero sequence resistance; entered in pu on machine base (i.e., on bus voltage base and MBASE). ZR0 = 0.0 by default
ZX0	Zero sequence reactance; entered in pu on machine base (i.e., on bus voltage base and MBASE). Induction machine is isolated in zero sequence if the stator winding is either delta connected or star connected with the neutral isolated. For a star connected stator winding with an earthed neutral, zero sequence impedance is much smaller than motor starting impedance (subtransient or transient) and does not vary with time. Induction machine zero sequence impedance can be assumed equal to the stator ac resistance ZX0 = ZXPPDV by default depending on generator impedance option
ZRG	Grounding resistance; entered in pu on machine base (i.e., on bus voltage base and MBASE) when CZG=1 or in ohms when CZG=2. ZRG = 0.0 by default
ZXG	Grounding reactance; entered in pu on machine base (i.e., on bus voltage base and MBASE) when CZG=1 or in ohms when CZG=2. ZXG = 0.0 by default
ILR2IR_TRN	Ratio of positive sequence transient locked rotor current to rated current.
R2X_TRN	Ratio of positive sequence transient resistance to reactance. This is used only when positive sequence impedance is calculated using ILR2IR_TRN. R2X_TRN = 0.0 by default
ILR2IR_NEG	Ratio of negative sequence locked rotor current to rated current.

R2X_NEG	Ratio of negative sequence resistance to reactance. This is used only when negative sequence impedance is calculated using ILR2IR_NEG. R2X_NEG = 0.0 by default

Application Notes:

Positive (ZP) and negative (ZN) sequence impedances are calculated as below.

1. When locked rotor current to rated current sequence data is provided, depending on activity "reactance" option used:

$$|Z_P| = \frac{1}{\mathrm{ILR2IR_{SUB}}} \text{ OR } \frac{1}{\mathrm{ILR2IR_{TRN}}}$$

$$|Z_N| = \frac{1}{\mathrm{ILR2IR_{NEG}}}$$

2. When locked rotor current to rated current sequence data is not provided:

$$X'' = X_\alpha + \frac{X_m\left[X_3 + \frac{X_1X_2}{X_1+X_2}\right]}{X_m + X_3 + \frac{X_1X_2}{X_1+X_2}}$$

$$R_m = R_a$$

$$Z_P = Z_N = R_m + jX''$$

3. When ILR2IR_NEG and R2X_NEG are not provided, ZN=ZP.

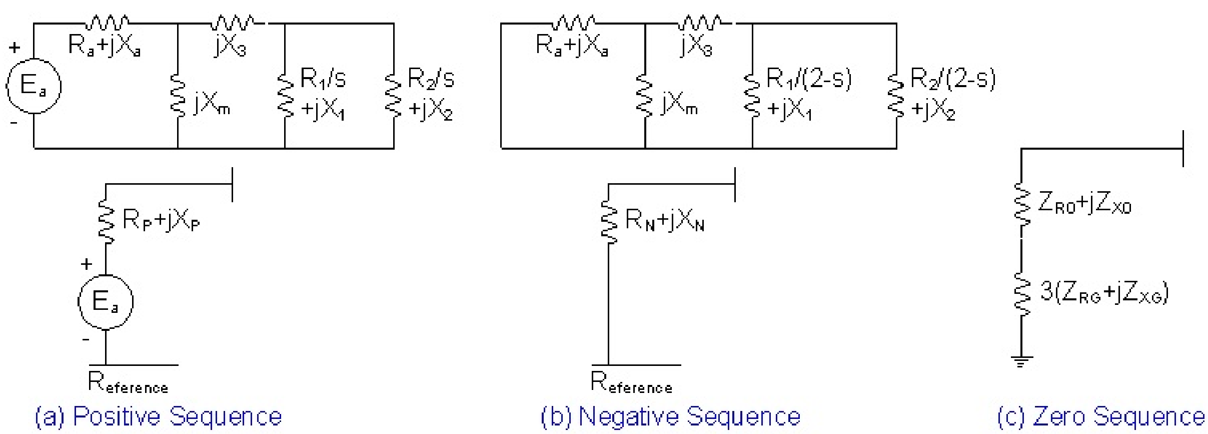


Figure 2.3. Induction machine sequence networks

2.12. Non-Conventional Source Fault Contribution Data

When a source in the network is not a conventional synchronous machine, but a non-conventional source which is typically connected to the grid through voltage source converters, viz., Type 4 WTG or PV, then the fault contribution from such a source is specified using this data record. For these sources the fault response is controlled by its converter control characteristics.

When a generator has non-conventional source data specified, its "generator sequnce data" record even if present is ignored.

The fault current contribution and its sequece network is modeled as shown in Figure 2.4, “Non-conventional Source Sequence Network”

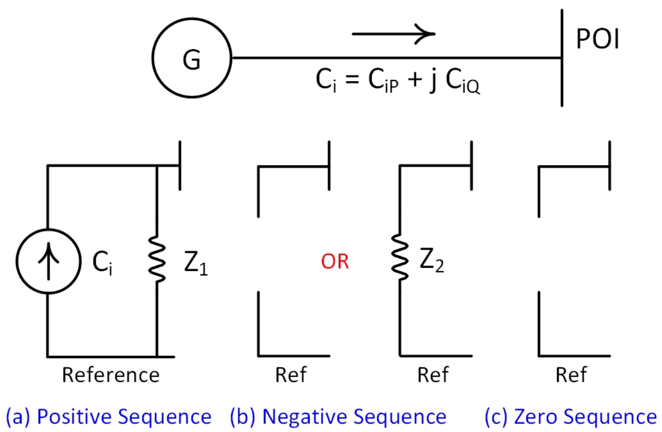


Figure 2.4. Non-conventional Source Sequence Network

The fault current contribution characteristics is modeled as shown in Figure 2.5, “Non-conventional Source Fault Contribution Characteristics”

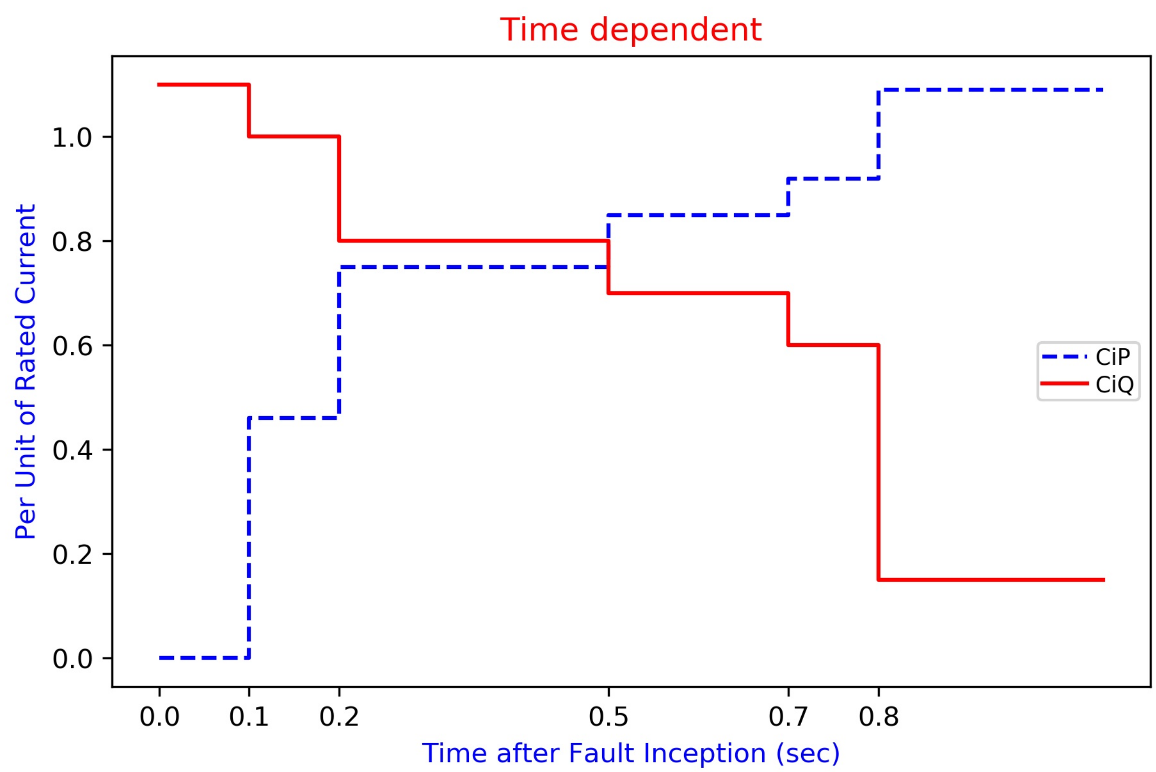


Figure 2.5. Non-conventional Source Fault Contribution Characteristics

In order to accommodate large number of possibilities and still provide flexibility, the fault contribution data is provided as a time dependent capability curve. Each data record has following format:

```
I, ID, T1, C1P, C1Q, T2, C2P, C2Q, T3, C3P, C3Q, T4, C4P, C4Q, T5, C5P, C5Q,
T6, C6P, C6Q
```

I	Bus number; bus I must be present in the working case as a generator bus. No default is allowed
ID	One or two character machine identifier of the generator bus I for which the data is specified by this record. ID = '1' by default
Ti	Time in seconds
CiP	The active component of the fault current contribution in pu on rated (nominal) current and rated voltage base (1.0 pu) at time Ti
CiQ	The reactive component of fault current contribution in pu on rated (nominal) current and rated voltage base (1-0 pu) at time Ti. When supplying reactive power, specify CiQ as positive.

Application Note - Refer Program Application Guide for technical details.

2.13. Application Notes - Transformers in the Zero Sequence

The fault analysis activities of PSS®E handle the zero sequence representation of two- and three-winding transformers automatically. Other nonstandard transformer types must be reduced to combinations of two-winding transformers, three-winding transformers, and/or branches by the use of dummy buses and equivalent circuits. Note again that the introduction of buses and branches needed for the modeling of nonstandard transformers is accomplished by their addition to the positive sequence network via activities READ, TREA, or RDCH, or the *[Spreadsheet]*.

Transformer zero sequence data is entered into the working case by means of zero sequence transformer data records in the Sequence Data File. Transformers are represented in the zero sequence as per their connection codes. The establishment of the connections and ground paths is handled automatically on the basis of the impedances and connection code entered and the winding turns ratios.

Zero sequence transformer default data is such that the transformer appears as an open circuit in the zero sequence network. Therefore, zero sequence data must be entered for all grounded transformers.

Connection codes *do not* indicate the inherent phase shift due to the relative connection of delta and wye windings. If this phase shift is to be represented, it must be specified in the positive sequence power flow data.

Virtually any impedance grounded two-winding transformer may be modeled automatically by specifying its winding and grounding impedances along with the appropriate connection code. Many three-winding transformer configurations may be handled in a similar manner; others require the addition of $3Z_g$ or other impedances to one or more of the winding impedances.

The winding numbers specified in zero sequence network diagrams are not directly associated with the nominal voltage levels of those windings. They are associated with corresponding winding connection only.

2.13.1. Auto Transformer Equivalent Circuit

The equivalent circuit impedance of an auto transformer can be determined from a short circuit test performed as shown in Figure 2.6, “Auto-transformer Equivalent Circuit”.

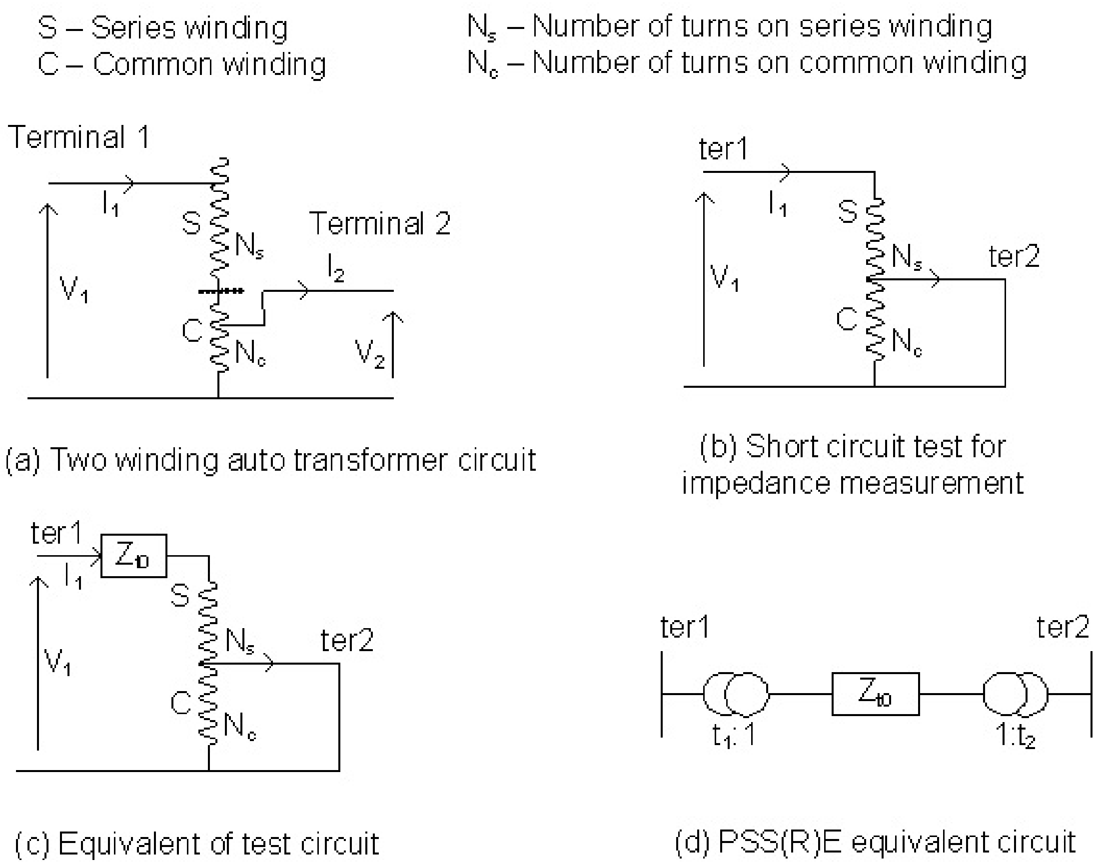


Figure 2.6. Auto-transformer Equivalent Circuit

Auto transformer ohmic impedance measured across circuit 1 when circuit 2 is short circuited (winding impedance) as shown in (b) and (c) is given by:

$$\text{Winding Impedance } Z_{t0} = \frac{V_1}{I_1} \text{ ohms}$$

Auto transformer turns ratio are defined as:

$$N = \frac{V_1}{V_2} = \frac{N_S + N_C}{N_C} = \frac{\text{NOMV1}}{\text{NOMV2}}$$

$$t_1 = \frac{\text{Winding 1 Voltage}}{\text{Winding 1 Nominal Voltage}} = \frac{\text{WINDV1}}{\text{NOMV1}}$$

$$t_2 = \frac{\text{Winding 2 Voltage}}{\text{Winding 2 Nominal Voltage}} = \frac{\text{WINDV2}}{\text{NOMV2}}$$

$$\frac{\text{KVA Winding}}{\text{KVA circuit}} = \frac{\text{N-1}}{N}$$

2.13.2. Two Winding Transformer Zero Sequence Networks

NOTE: * in grounding impedance notations (like $Z_{g1}{}^{*}$) in zero seq/uence network diagrams means PSS®E will automatically multiply that grounding impedance by a factor 3.

CC=1 and CC=11

Series Path, No Ground Path

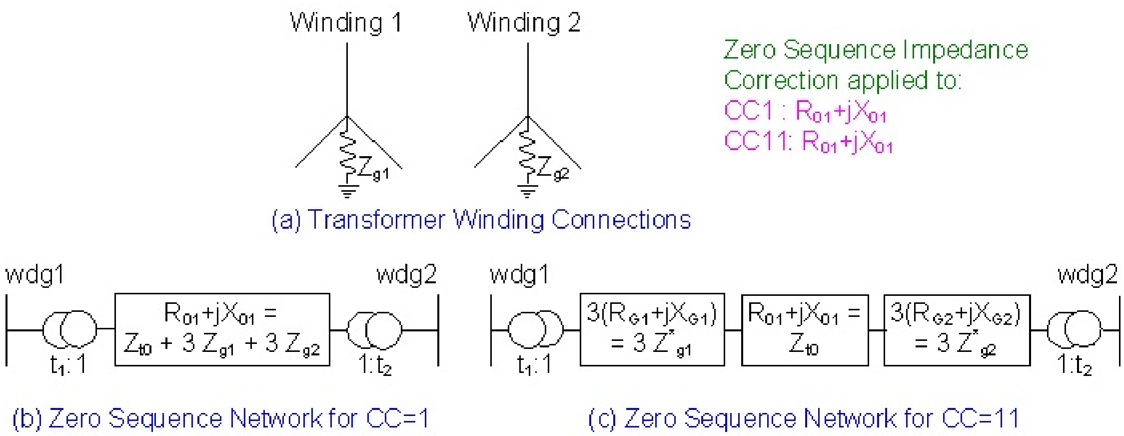


Figure 2.7. YNyn transformer zero sequence network

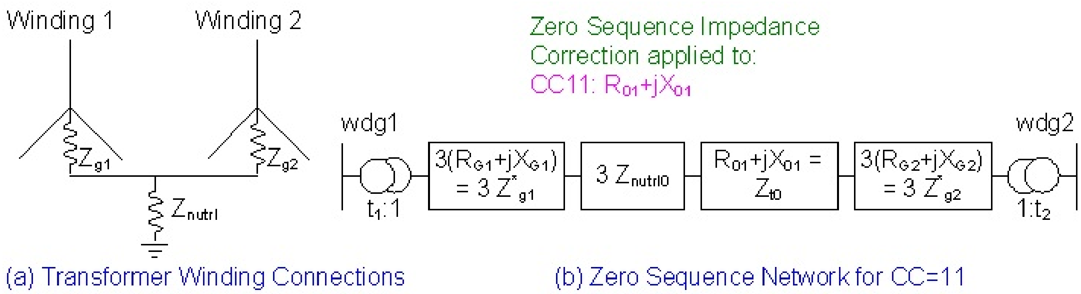


Figure 2.8. YNyn with neutral impedance transformer zero sequence network

CC=11	PSS®E calculates pu Znutrl0 as below:
Set: • R01+jX01 = Z_{t0} • RG1+jXG1 = Z_{g1} • RG2+jXG2 = Z_{g2} • RNUTRL+jXNUTRL = Z_{nutrl}	$Z_{\mathtt{nutrl\ \ pu}} = \dfrac{Z_{\mathtt{nutrl\ \ ohm}} \times S_{\mathtt{base12}}}{\mathtt{wdg1kV}^2}$ $Z_{\mathtt{nutrl0}} = Z_{\mathtt{nutrl\ \ pu}} \dfrac{(N_{21}-1)^2}{N_{21}{}^2}$ $N_{21} = \dfrac{\mathtt{Winding\ 2\ Nominal\ Voltage}}{\mathtt{Winding\ 1\ Nominal\ Voltage}} = \dfrac{\mathtt{NOMV2}}{\mathtt{NOMV1}}$

NOTE: When CC=1, data specified for Zg1 and Zg2 will be ignored. Hint instead use CC=11.

CC=2 and CC=12

No Series Path, Ground Path on Winding 1 side

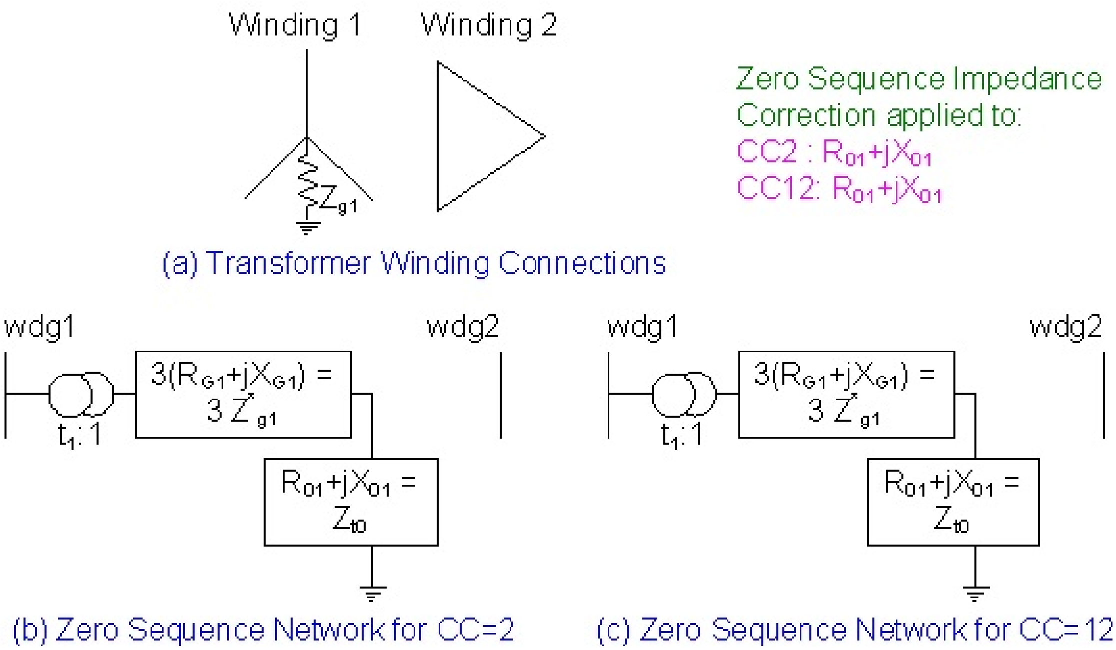


Figure 2.9. YNd transformer zero sequence network

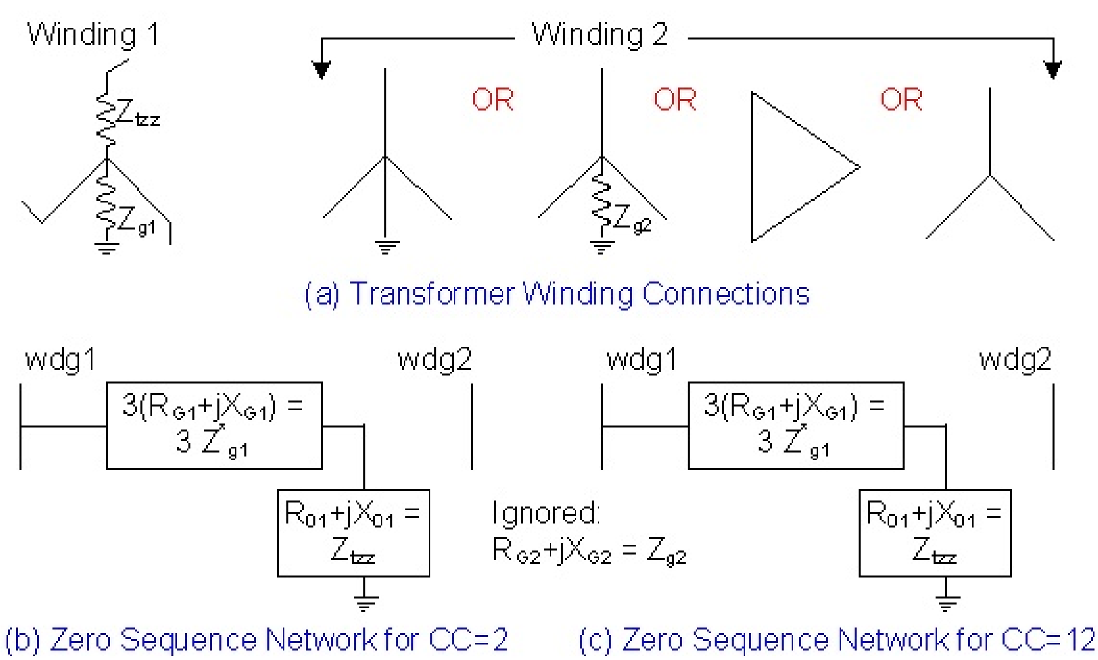


Figure 2.10. Znyn, Zny, or ZNd transformer zero sequence network

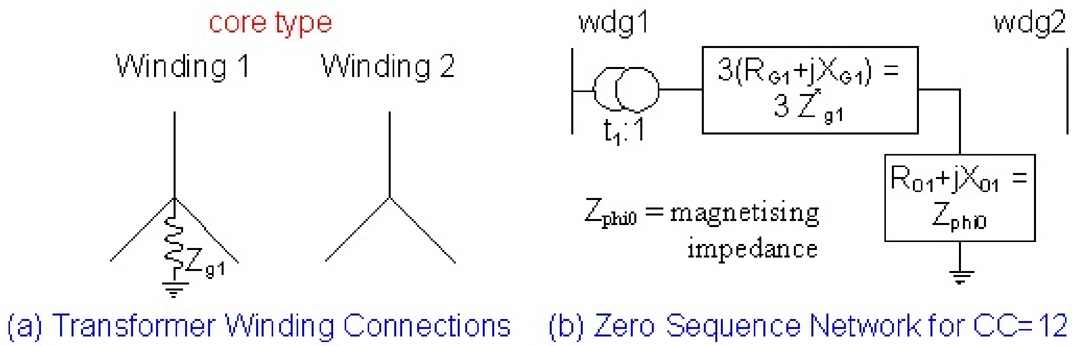


Figure 2.11. YNy core type transformer zero sequence network

NOTE: When CC=2, data specified for Zg1 will be used as grounding impedance of winding 1.

CC=3 and CC=13

No Series Path, Ground Path on Winding 2 side

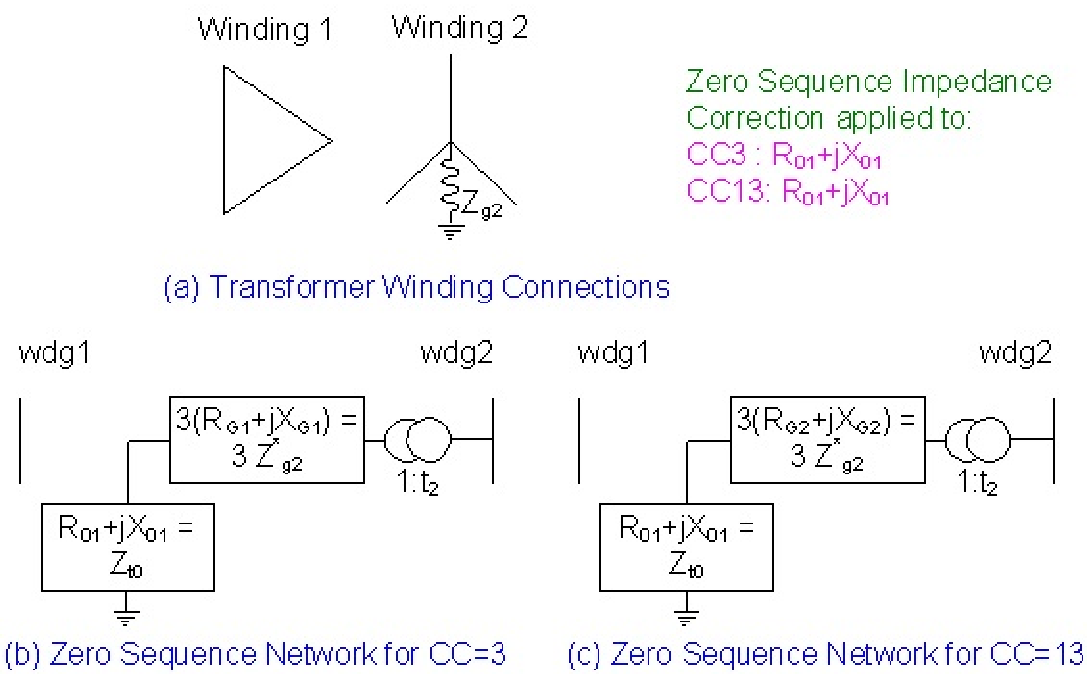


Figure 2.12. Dyn transformer zero sequence network

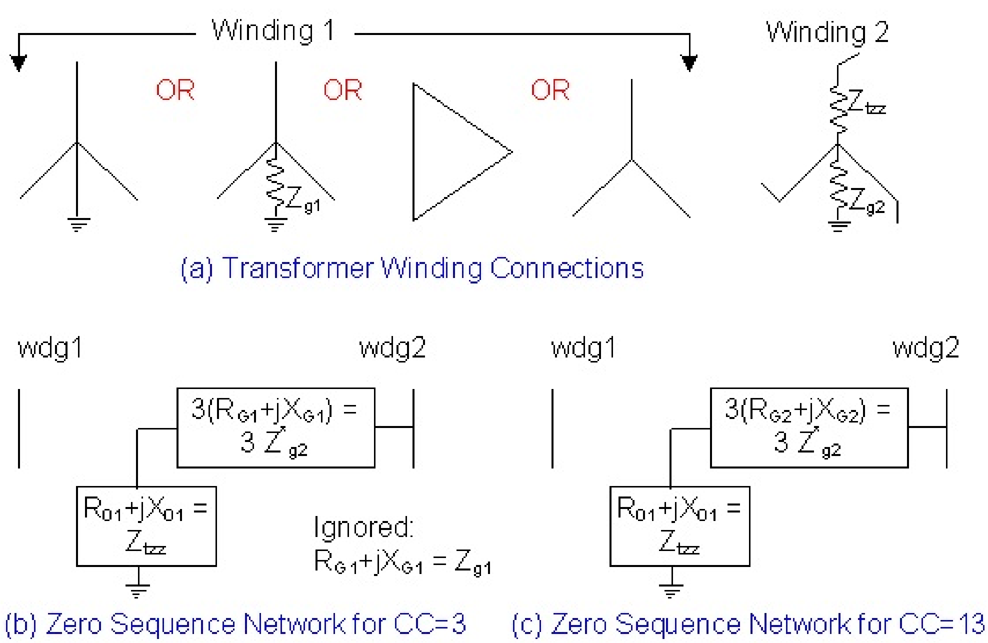


Figure 2.13. YNzn, Yzn or Dzn transformer zero sequence network

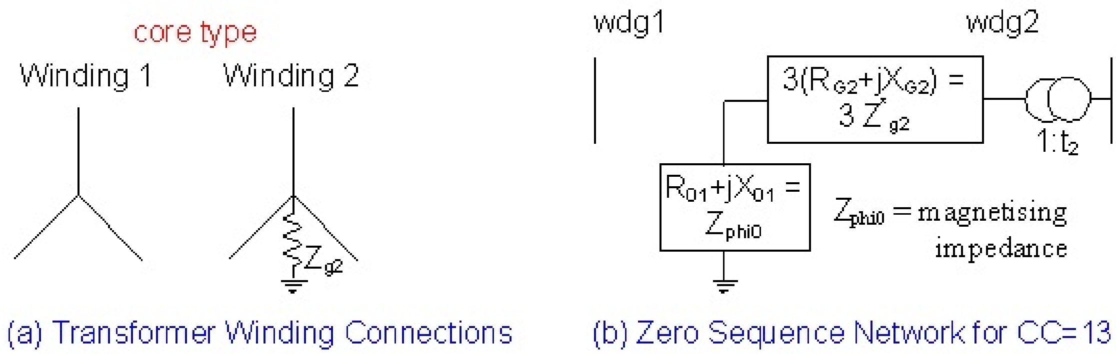


Figure 2.14. Yyn core type transformer zero sequence network

NOTE: To make backward compatible, when CC=3, data specified for Zg1 will be used as grounding impedance of winding 2. Hint instead use CC=13 and specify Zg2.

CC=4 and CC=14

No Series Path, No Ground Path

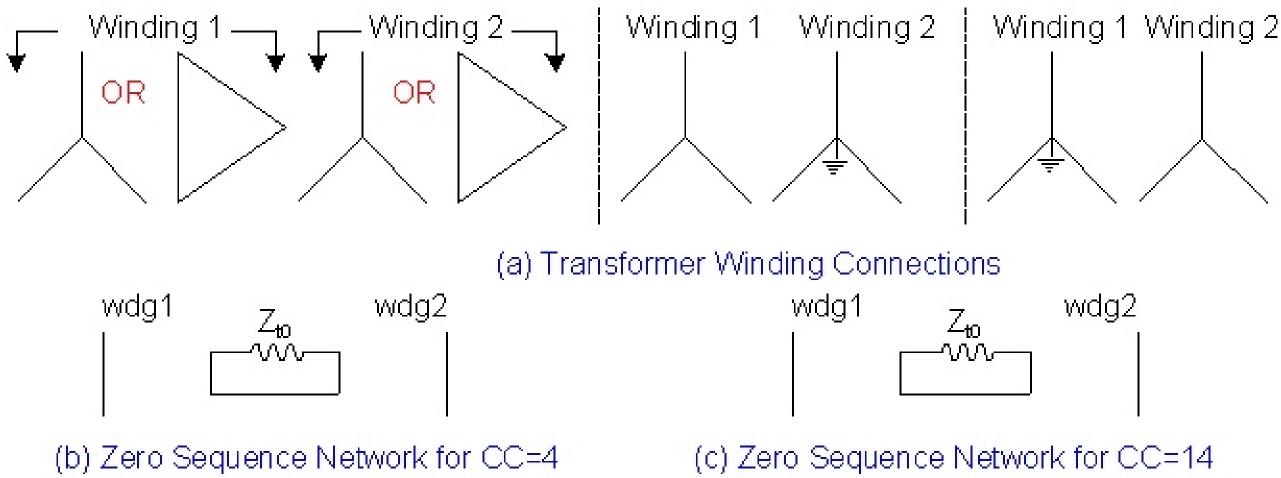


Figure 2.15. Yy, Yd, Dy, Dd, Yyn or YNy transformer zero sequence network

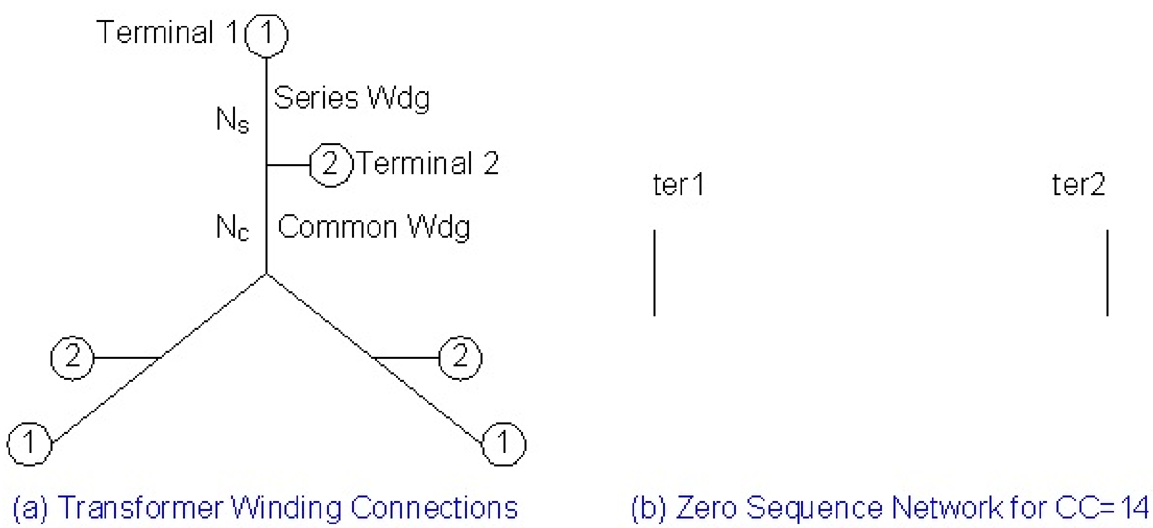


Figure 2.16. Ya ungrounded auto transformer zero sequence network

CC=5 and CC=15

Series Path, Ground Path on Winding 2 side

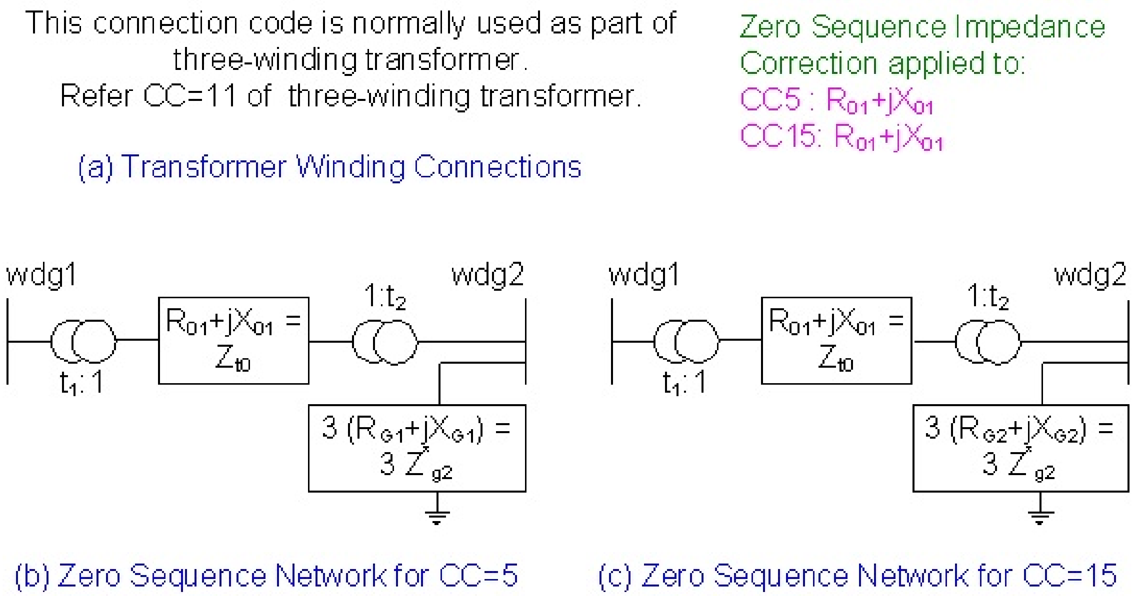


Figure 2.17. CC=5 or CC=15 zero sequence network

NOTE: To make backward compatible, when CC=5, data specified for Zg1 will be used as grounding impedance at winding 2 side. Hint instead use CC=15 and specify Zg2.

CC=6 and CC=16

Wye grounded - delta with an earting transformer

No Series Path, Ground Path on Winding 1 side, Earthing transformer on Winding 2 Side

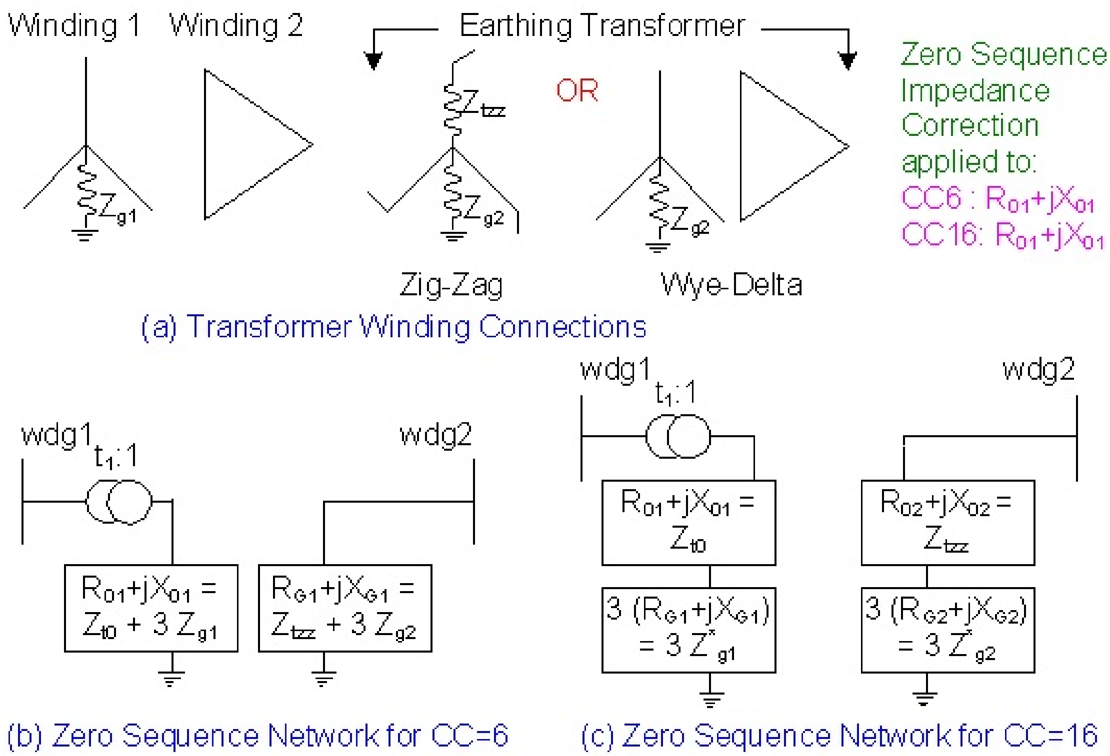


Figure 2.18. YNd transformer with Zigzag or YNd earthing transformer on winding 2 side zero sequence network

Note: Activity IECS applies impedance correction factors to transformer impedances. When main and earthing transformers are modeled separately with CC=2, impedance correction factors are applied to both main and earthing transformers. This is incorrect. The impedance correction factors should not applied to earthing transformer. So model main and earthing transformers correctly using CC=6 or CC=16.

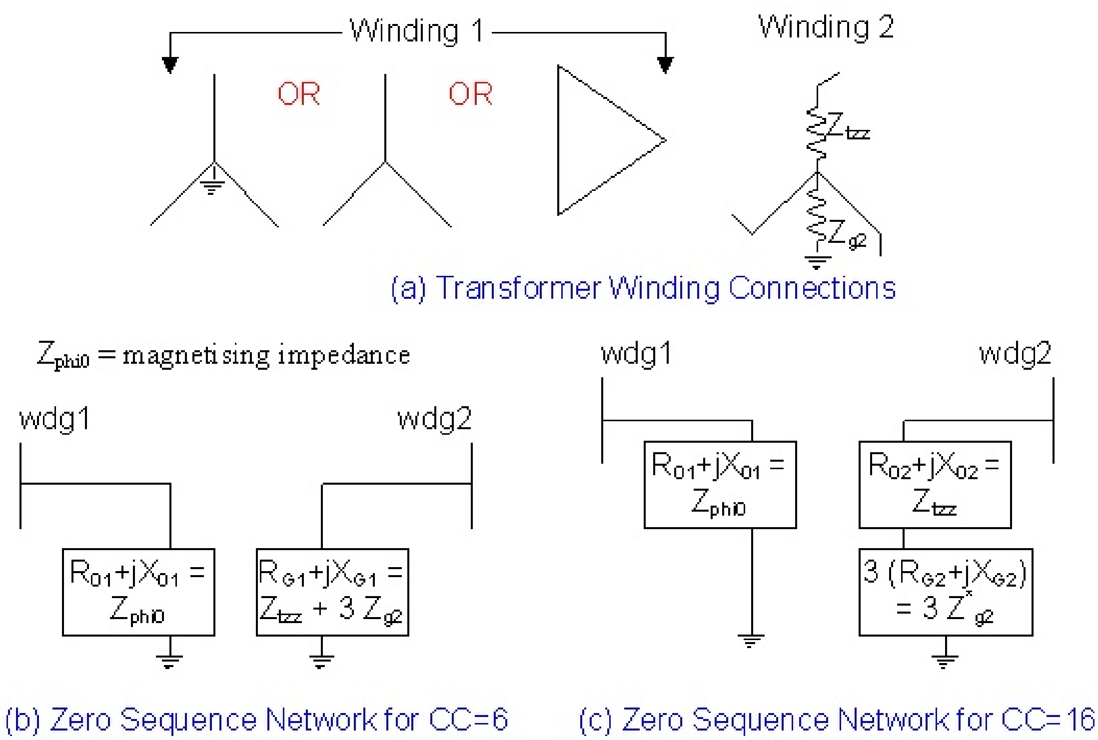


Figure 2.19. YNzn or Dzn core type transformer zero sequence network

CC=7 and CC=17

Delta with an earting transformer - Wye grounded

No Series Path, Earting transformer on Winding 1 Side, Ground Path on Winding 2 side

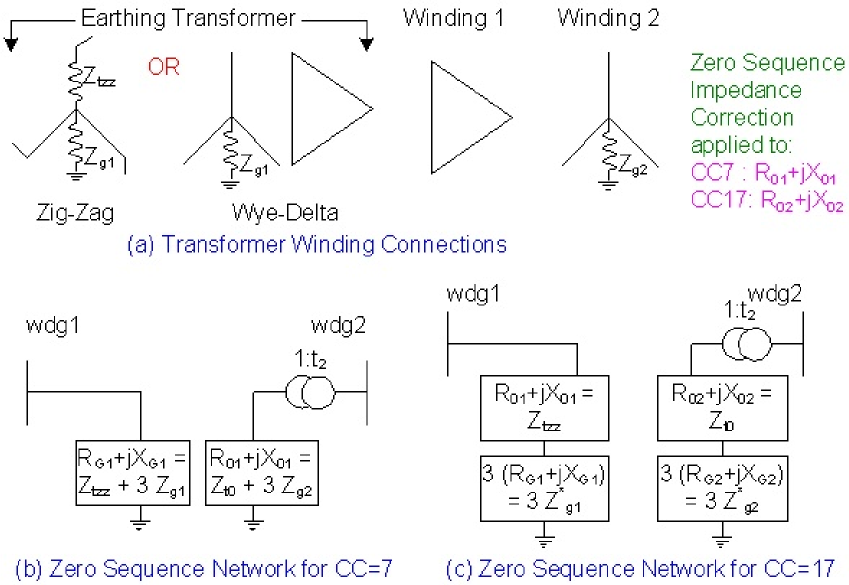


Figure 2.20. Dyn transformer with Zigzag or YNd earthing transformer on winding 1 side zero sequence network

No Series Path, Ground Path on Winding 2 side through core magnetizing impedance

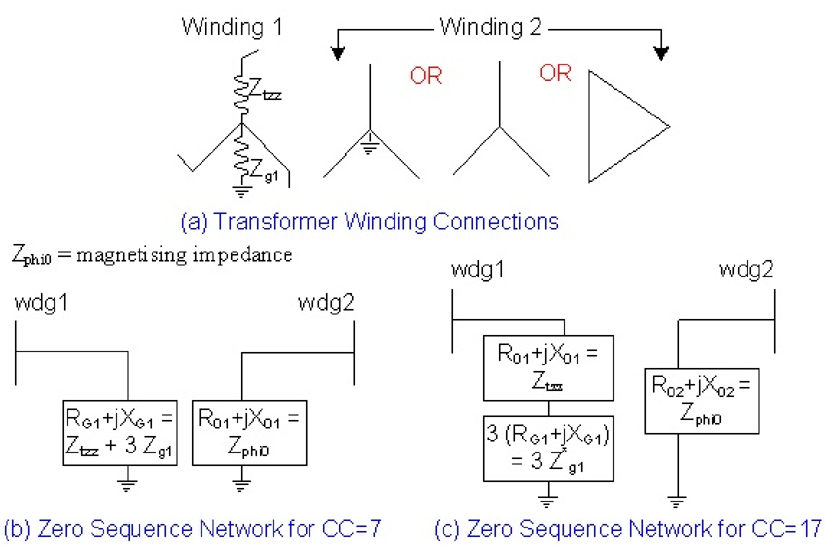


Figure 2.21. ZNyn or ZNd core type transformer zero sequence network

CC=8 and CC=18

Wye grounded - wye grounded three legged core type auto transformer

Series Path, Ground Path each side

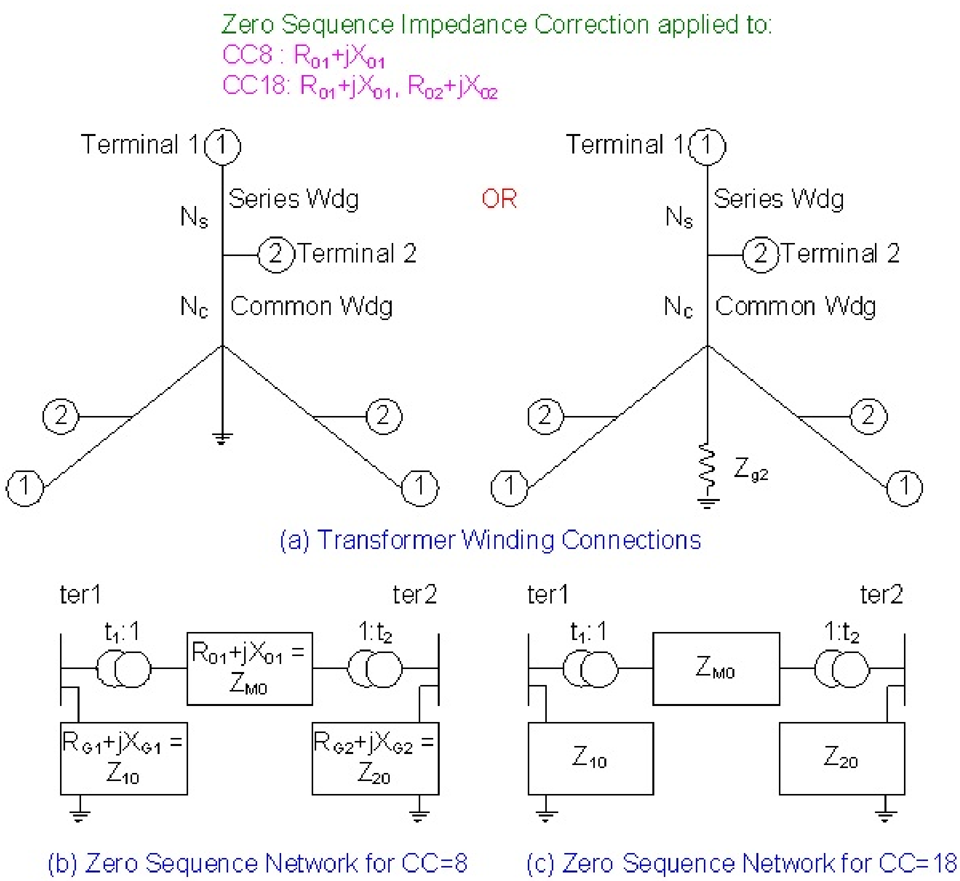


Figure 2.22. YNa core type auto transformer zero sequence network

CC=8 Calculate: Z10, Z20, ZM0 from equations as in CC=18 Set: - R01+jX01 = Z_{M0} - RG1+jXG1 = Z_{10} - RG2+jXG2 = Z_{20} CC=18 Set: - R01+jX01 = Z_{to} - R02+jX02 = Z_{phiC} - RG2+jXG2 = Z_{g2}	CC=18 PSS®E calculates pu values as: $Z_{1S} = \frac{N-2}{2N} Z_{CS} - \frac{3(N-1)}{N^2} Z_{g2}$ $Z_{2S} = \frac{1}{2} Z_{CS} + \frac{3(N-1)}{N} Z_{g2}$ $Z_{SG} = \frac{N}{N-1} Z_{phiC} - \frac{1}{2} Z_{CS} + \frac{3}{N} Z_{g2}$ $Z_{M0} = Z_{1S} + Z_{2S} + \frac{Z_{1S} Z_{2S}}{Z_{SG}}$ $Z_{10} = Z_{1S} + Z_{SG} + \frac{Z_{1S} Z_{SG}}{Z_{2S}}$ $Z_{20} = Z_{2S} + Z_{SG} + \frac{Z_{2S} Z_{SG}}{Z_{1S}}$

Where:

Z_{phiC} is the magnetising (exciting) impedance as measured on the Common Winding with series winding on the same core open circuited and zero sequence voltage is applied to Terminal 2.

Refer auto transformer equivalent circuit represention description for definition of N and Z_{to}.

CC=9 and CC=19

- Series Path on each side, Ground Path at the junction point of the two series paths
- Wye grouned - wye grounded three legged core type auto transformer

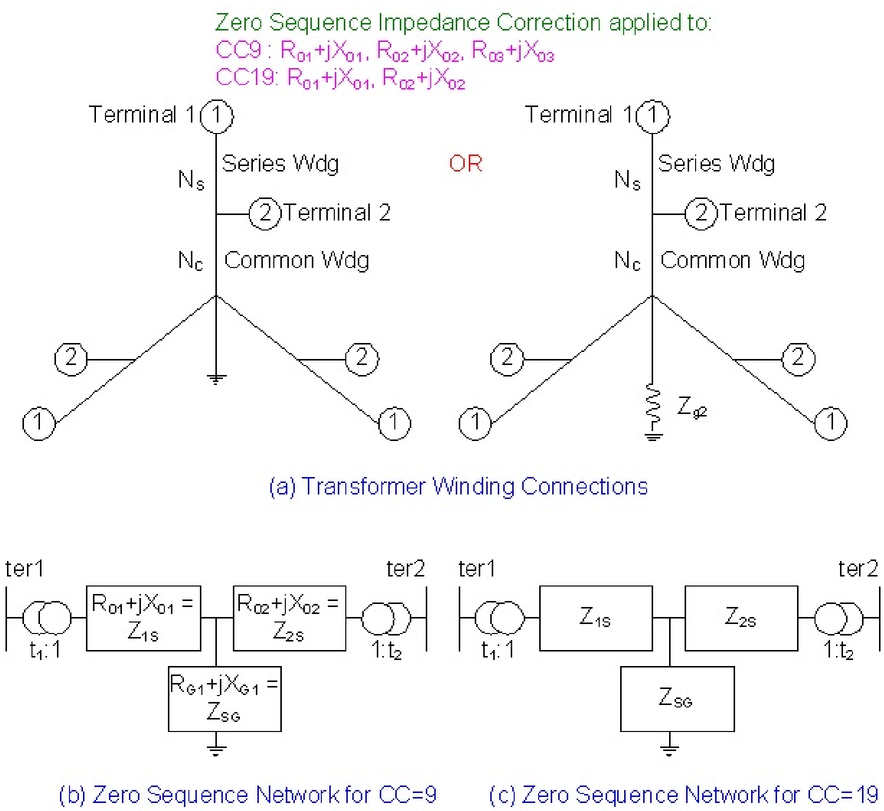


Figure 2.23. YNa core type auto transformer zero sequence network

CC=9	CC=19
Calculate: Z_{1S}, Z_{2S}, Z_{SG} from equations as in CC=19 Set: - R01+jX01 = Z_{1S} - R02+jX02 = Z_{2S} - RG1+jXG1 = Z_{SG}	Set: - R01+jX01 = Z_{to} - R02+jX02 = Z_{phiC} - RG2+jXG2 = Z_{g2} PSS®E calculates pu values as: $Z_{1S} = \frac{N-2}{2N} Z_{to} - \frac{3(N-1)}{N^2} Z_{g2}$ $Z_{2S} = \frac{1}{2} Z_{to} + \frac{3(N-1)}{N} Z_{g2}$ $Z_{SG} = \frac{N}{N-1} Z_{phiC} - \frac{1}{2} Z_{to} + \frac{3}{N} Z_{g2}$

Where:

Z_{phiC} is the magnetising (exciting) impedance as measured on the Common Winding with series winding on the same core open circuited and zero sequence voltage is applied to Terminal 2.

Refer auto transformer equivalent circuit representation description for definition of N and Z_{CS}.

CC=20

- Series Path on each side, Ground Path at the junction point of the two series paths
- Wye grouned - wye grounded core type transformer

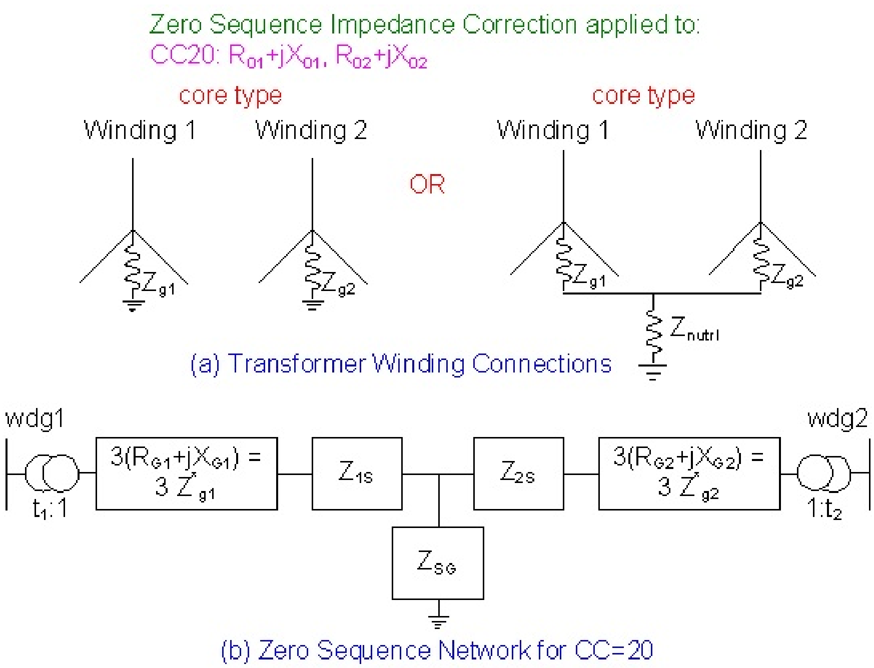


Figure 2.24. YNyn with or without neutral impedance core type transformer zero sequence network

Set:	PSS®E calculates pu values as:
- R01+jX01 = Zt0 - R02+jX02 = Zphi0 - RG1+jXG1 = Zg1 - RG2+jXG2 = Zg2 - RNUTRL+jXNUTRL = Znutrl	$N_{21} = \frac{\text{Winding 2 Nominal Voltage}}{\text{Winding 1 Nominal Voltage}} = \frac{\text{NOMV2}}{NOMV1}$ $Z_{\text{nutrl}} = Z_{\text{nutrl pu}} = Z_{\text{nutrl ohm}} \frac{S_{BASE12}}{wdg1kV^2}$ $Z_{1s} = \frac{1}{2} Z_{t0} - 3\frac{N_{21} - 1}{N_{21}{}^2} Z_{\text{nutrl}}$ $Z_{2s} = \frac{1}{2} Z_{t0} + 3\frac{N_{21} - 1}{N_{21}} Z_{\text{nutrl}}$ $Z_{SG} = Z_{phi0} - \frac{1}{2} Z_{t0} + 3\frac{1}{N_{21}} Z_{nutrl}$

Where:

Z_{phi1} is the magnetising (exciting) impedance as measured on Winding 1 with winding 2 on the same core open circuited and zero sequence voltage is applied to Winding 1.

Z_{phi2} is the magnetising (exciting) impedance as measured on Winding 2 with winding 2 on the same core open circuited and zero sequence voltage is applied to Winding 2.

$Z_{phi0} = Z_{phi1}$ or Z_{phi2}, if $Z_{phi1} = Z_{phi2}$

$Z_{phi0} = 0.5(Z_{phi1} + Z_{phi2})$ if $Z_{phi1} \neq Z_{phi2}$

CC=21

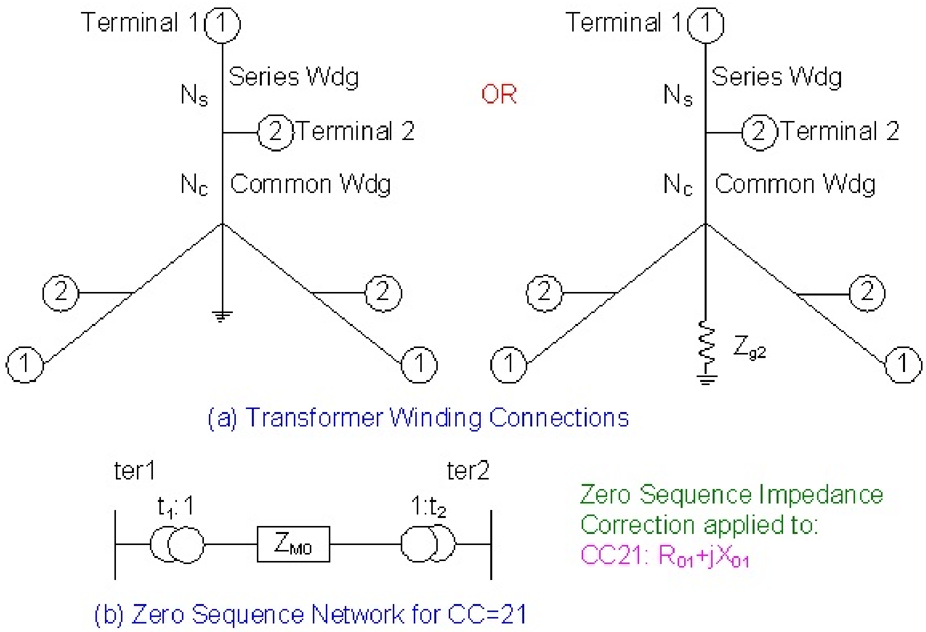


Figure 2.25. YNa auto transformer zero sequence network

Set:	PSS®E calculates pu values as:
- R01+jX01 = Zto - RG2+jXG2 = Zg2	$Z_{M0} = Z_{t0}\left(\frac{N-1}{N}\right) + 3\left(\frac{N-1}{N}\right)^2 Z_{g2}$

Refer auto transformer equivalent circuit represention description for definition of N and Z_{to}.

CC=22

Wye - wye ungrounded core type auto transformer

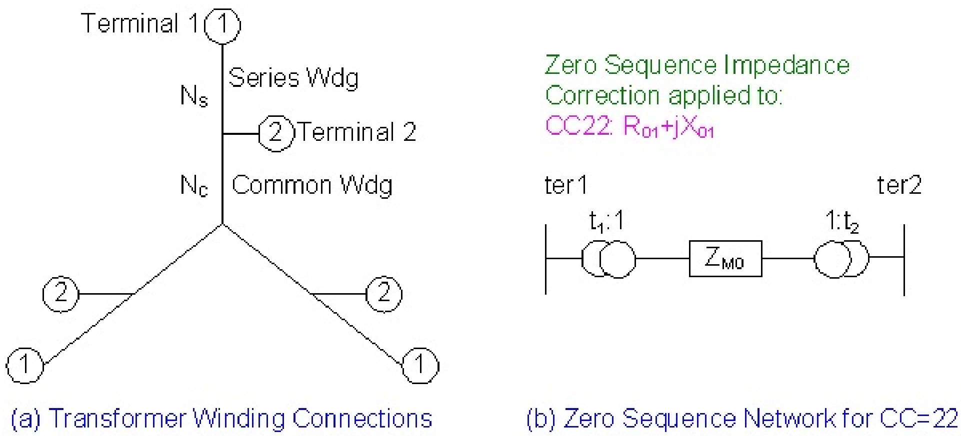


Figure 2.26. Ya ungrounded core type auto transformer zero sequence network

Set:	PSS®E calculates pu values as:
- R01+jX01 = Z_{phiS}	$Z_{M0} = \frac{N-1}{N} \; Z_{phiS}$

Where:

Z_{phiS} is the magnetising (exciting) impedance as measured on the Series Winding with all the other windings on the same core open circuited and zero sequence voltage is applied to Terminal 1.

Refer auto transformer equivalent circuit representation description for definition of N.

2.13.3. Three Winding Transformer Zero Sequence Network

Note:

Impedance Notations used in the Zero Sequence Networks:

$Z_{12}{}^{0}$ = Zero sequence leakage impedance between winding 1 and winding 2

$Z_{23}{}^{0}$ = Zero sequence leakage impedance between winding 2 and winding 3

$Z_{31}{}^{0}$ = Zero sequence leakage impedance between winding 3 and winding 1

Z_{g1} = Winding 1 grounding impedance

Z_{g2} = Winding 2 grounding impedance

Z_{g3} = Winding 3 grounding impedance

Znutrl = Neutral grounding impedance

The three Winding transformer is modeled as T-model in zero sequence network. The impedances of this T-model are calculated from transformer test report in-between winding impedances as below.

$Z_{t1}{}^{0} = 0.5(Z_{12}{}^{0} + Z_{31}{}^{0} - Z_{23}{}^{0})$

$Z_{t2}{}^{0} = 0.5(Z_{12}{}^{0} + Z_{23}{}^{0} - Z_{31}{}^{0})$

$Z_{t3}{}^{0} = 0.5(Z23^{0} + Z_{31}{}^{0} - Z_{12}{}^{0})$

where:

$Z_{t1}{}^{0}$ = Zero sequence impedance between winding 1 and star point

$Zt_{2}{}^{0}$ = Zero sequence impedance between winding 2 and star point

$Zt_{3}{}^{0}$ = Zero sequence impedance between winding 3 and star point

The in-between winding impedances can be calculated from T-model impedances as below:

$Z_{12} = Z_1 + Z_2$

$Z_{23} = Z_2 + Z_3$

$Z_{31} = Z_3 + Z_1$

CC=1 and CC=11 (511)

Series path in all three Windings, Winding 1 ground path at star point bus

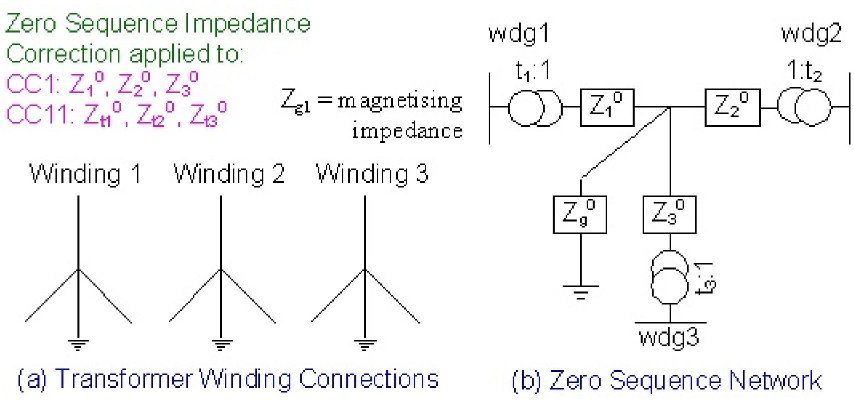


Figure 2.27. YNynyn with magnetising impedance modelled transformer zero sequence network

CC=1 or CC=511	CC=11
Calculate: $Z_1{}^0$, $Z_2{}^0$, $Z_3{}^0$ from equations as in CC=11 Set (pu): - R01+jX01 = $Z_1{}^0$ - R02+jX02 = $Z_2{}^0$ - R03+jX03 = $Z_3{}^0$ - RG1+jXG1 = Z_{g1} Assigned: - $Z_1{}^0$ = R01+jX01 - $Z_2{}^0$ = R02+jX02 - $Z_3{}^0$ = R03+jX03 PSS®E automatically multiplies grounding impedance by 3. - $Z_g{}^0$ = 3(RG1+jXG1)	Set: - R01+jX01 = $Z_{12}{}^0$ - R02+jX02 = $Z_{23}{}^0$ - R03+jX03 = $Z_{31}{}^0$ - RG1+jXG1 = Z_{g1} PSS®E calculates pu values as: - $Z_{t1}{}^0$, $Z_{t2}{}^0$, $Z_{t3}{}^0$ - $Z_1{}^0 = Z_{t1}{}^0$ - $Z_2{}^0 = Z_{t2}{}^0$ - $Z_3{}^0 = Z_{t3}{}^0$ - $Z_g{}^0$ = 3(RG1+jXG1)

CC=2 and CC=12 (113)

Series path in Windings 1 and 2, Winding 3 ground path at star point bus

(For YNad, refer CC=17)

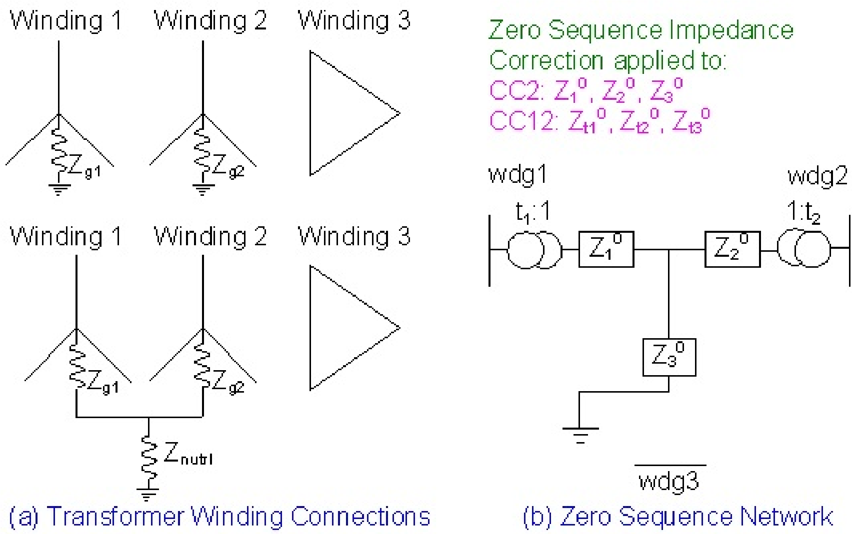


Figure 2.28. YNynd transformer zero sequence network

CC=2 or CC=113	CC=12	Calculated (pu):
Calculate: $Z_{t1}{}^0$, $Z2^0$, $Z3^0$ from equations as in CC=12 Set (pu): - R01+jX01 = $Z_{t1}{}^0$ - R02+jX02 = $Z_2{}^0$ - R03+jX03 = $Z_3{}^0$ - RG1+jXG1 = Z_{g3} Assigned: - $Z1^0$ = R01+jX01 - $Z2^0$ = R02+jX02 - $Z3^0$ = R03+jX03+ $3Z_{g3}$	Set: - R01+jX01 = $Z_{12}{}^0$ - R02+jX02 = $Z_{23}{}^0$ - R03+jX03 = $Z_{31}{}^0$ - RG1+jXG1 = Z_{g1} - RG2+jXG2 = Z_{g2} Calculated (pu): (no Znutrl) - $Z_{t1}{}^0$, $Z_{t2}{}^0$, $Z_{t3}{}^0$ - $Z_1{}^0 = Zt_1{}^0 + 3Z_{g1}$ - $Z_2{}^0 = Z_{t2}{}^0 + 3Zg_2$ - $Z_3{}^0 = Z_{t3}{}^0$	(with Znutrl) $N_{21} = \frac{Winding\ 2\ Nominal\ Voltage}{Winding\ 1\ Nominal\ Voltage} = \frac{NOMV2}{NOMV1}$ $Z_1{}^0 = Z_{t1}{}^0 + 3Z_{g1} + 3\frac{N_{21}-1}{N_{21}}Z_{nutrl}$ $Z_2{}^0 = Z_{t2}{}^0 + 3Z_{g2} - 3\frac{N_{21}-1}{N_{21}{}^2}Z_{nutrl}$ $Z_3{}^0 = Z_{t3}{}^0 + 3\frac{1}{N_{21}}Z_{nutrl}$

Note: When CC=2 or CC=113, Z_{g3} assigned is a fictious grounding impedance derived from T-model.

CC=3 and CC=13 (313)

Series path in Windings 2, ground paths from Windings 1 and 3 at star point bus

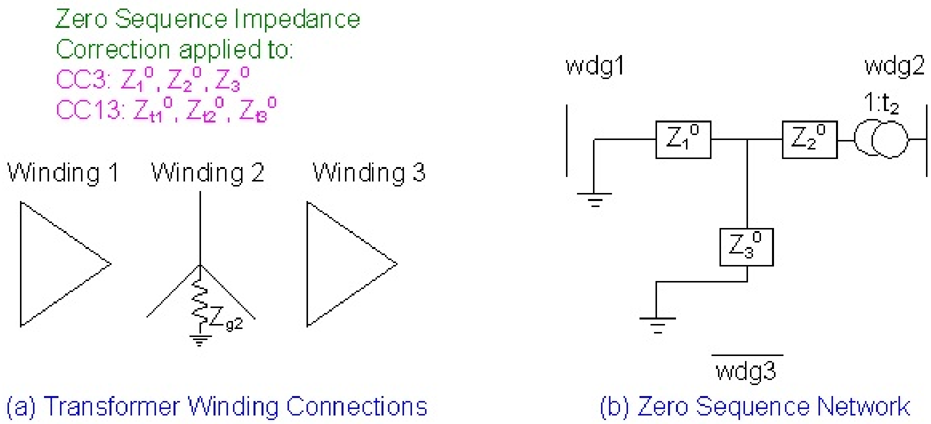


Figure 2.29. Dynd transformer zero sequence network

CC=3 or CC=313	CC=13
Calculate: $Z_1{}^0, Z_2{}^0, Z_3{}^0$ from equations as in CC=13 Set (pu): - R01+jX01 = $Z_1{}^0$ - R02+jX02 = $Z_2{}^0$ - R03+jX03 = $Z_3{}^0$ - RG1+jXG1 = Z_{g1} Assigned: - $Z_1{}^0$ = R01+jX01 + $3Z_{g1}$ - $Z_2{}^0$ = R02+jX02 - $Z_3{}^0$ = R03+jX03	Set: - R01+jX01 = $Z_{12}{}^0$ - R02+jX02 = $Z_{23}{}^0$ - R03+jX03 = $Z_{31}{}^0$ - RG2+jXG2 = Z_{g2} Calculated (pu): - $Z_{t1}{}^0, Z_{t2}{}^0, Z_{t3}{}^0$ - $Z_1{}^0 = Z_{t1}{}^0$ - $Z_2{}^0 = Z_{t2}{}^0$ + 3(RG2+jXG2) - $Z_3{}^0 = Z_{t3}{}^0$

Note: When CC=3 or CC=313, Z_{g1} assigned is a fictious grounding impedance derived from T-model.

CC=4 and CC=14 (333)

No series paths, ground paths from all three Windings at the star point bus

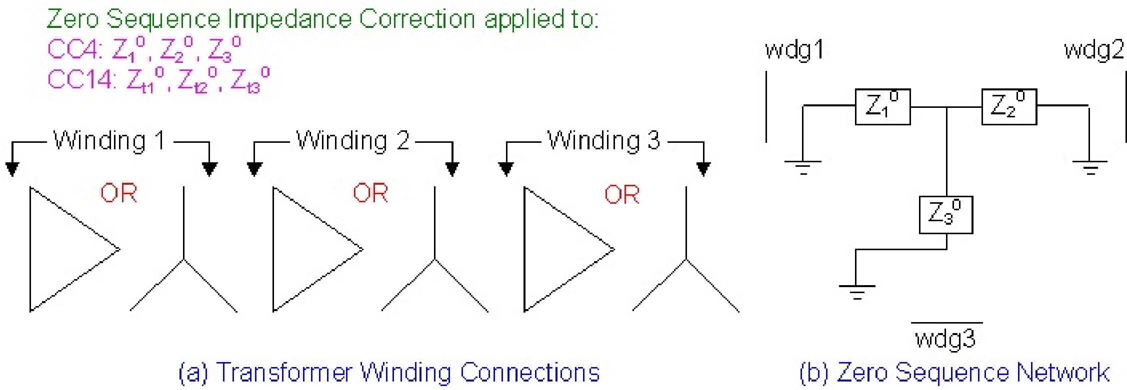


Figure 2.30. Ddd, Ddy, Dyd, Dyy, Ydd, Ydy, Yyd or Yyy transformer zero sequence network

CC=4 or CC=333	CC=14
Calculate: $Z_1{}^0$, $Z_2{}^0$, $Z_3{}^0$ from equations as in CC=14 Set (pu): - R01+jX01 = $Z_1{}^0$ - R02+jX02 = $Z_2{}^0$ - R03+jX03 = $Z_3{}^0$ Assigned: - $Z_1{}^0$ = R01+jX01 - $Z_2{}^0$ = R02+jX02 - $Z_3{}^0$ = R03+jX03	Set: - R01+jX01 = $Z_{12}{}^0$ - R02+jX02 = $Z_{23}{}^0$ - R03+jX03 = $Z_{31}{}^0$ Calculated (pu): - $Z_{t1}{}^0$, $Z_{t2}{}^0$, $Z_{t3}{}^0$ - $Z_1{}^0$ = $Z_{t1}{}^0$ - $Z_2{}^0$ = $Z_{t2}{}^0$ - $Z_3{}^0$ = $Z_{t3}{}^0$

CC=5 and CC=15 (121)

Series path in Windings 1 and 3, ground path at Winding 2 side bus

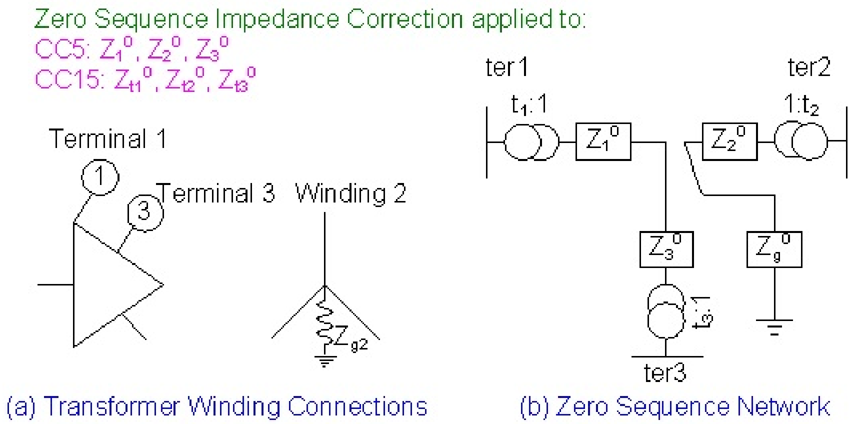


Figure 2.31. Dynd auto transformer zero sequence network

CC=5 or CC=121	**CC=15**
Calculate: $Z_1{}^0$, $Z_2{}^0$, $Z_3{}^0$ from equations as in CC=15 Set (pu): - R01+jX01 = $Z_1{}^0$ - R02+jX02 = $Z_2{}^0$ - R03+jX03 = $Z_3{}^0$ - RG2+jXG2 = Z_{g2} Assigned: - $Z_1{}^0$ = R01+jX01 - $Z_2{}^0$ = R02+jX02 - $Z_3{}^0$ = R03+jX03 Calculated (pu) - $Z_g{}^0$ = 3(RG2+jXG2)	Set: - R01+jX01 = $Z_{12}{}^0$ - R02+jX02 = $Z_{23}{}^0$ - R03+jX03 = $Z_{31}{}^0$ - RG2+jXG2 = Z_{g2} Calculated (pu): - $Z_{t1}{}^0$, $Z_{t2}{}^0$, $Z_{t3}{}^0$ - $Z_1{}^0$ = $Z_{t1}{}^0$ - $Z_2{}^0$ = $Z_{t2}{}^0$ - $Z_3{}^0$ = $Z_{t3}{}^0$ - $Z_g{}^0$ = 3(RG2+jXG2)

CC=6 and CC=16 (111)

Series path in all three Windings, no ground path

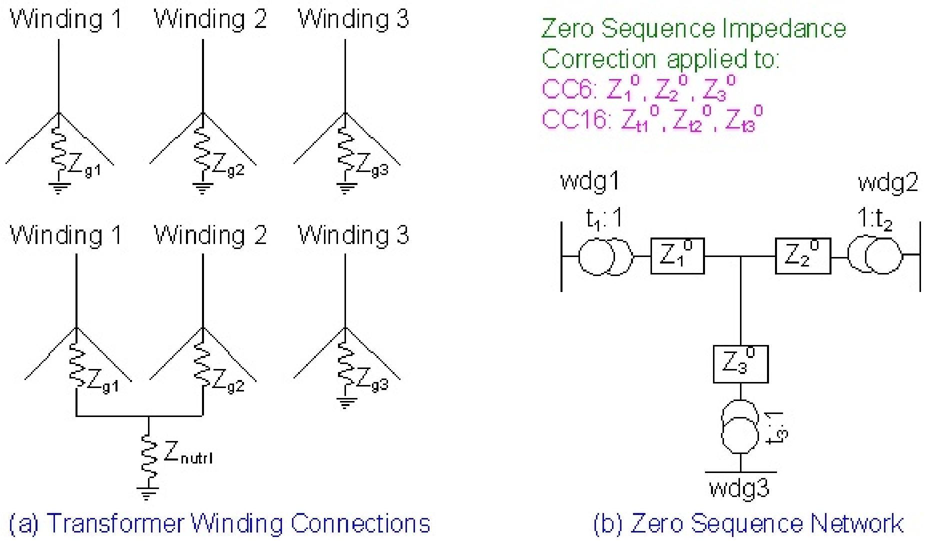


Figure 2.32. YNynyn transformer zero sequence network

CC=6 or CC=111	CC=16	Calculated (pu):
Calculate:	Set:	(with Znutrl)
Z_1^0, Z_2^0, Z_3^0 from equations as in CC=16	- R01+jX01 = Z_{12}^0	- Calculate Z_{t1}^0, Z_{t2}^0, Z_{t3}^0
	- R02+jX02 = Z_{23}^0	$N_{21} = \frac{NOMV2}{NOMV1}$
Set (pu):	- R03+jX03 = Z_{31}^0	
- R01+jX01 = Z_1^0	- RG1+jXG1 = Z_{g1}	$-Z_1^0 = Z_{t1}^0 + 3Z_{g1} + 3\frac{N_{21}-1}{N_{21}}Znutrl$
- R02+jX02 = Z_2^0	- RG2+jXG2 = Z_{g2}	
- R03+jX03 = Z_3^0	- RG3+jXG3 = Z_{g3}	$-Z_2^0 = Z_{t2}^0 + 3Z_{g2} - 3\frac{N_{21}-1}{N_{21}^2}Znutrl$
Assigned:	Calculated (pu):	
- Z_1^0 = R01+jX01	(without Znutrl)	$-Z_3^0 = Z_{t3}^0 + 3Z_{g3} + 3\frac{1}{N_{21}}Znutrl$
- Z_2^0 = R02+jX02	- Z_{t1}^0, Z_{t2}^0, Z_{t3}^0	
- Z_3^0 = R03+jX03	- $Z_1^0 = Z_{t1}^0$ + 3 (RG1+jXG1)	
	- $Z_2^0 = Z_{t2}^0$ + 3 (RG2+jXG2)	
	- $Z_3^0 = Z_{t3}^0$ + 3 (RG3+jXG3)	

CC=17

Series path in Windings 1 and 2, Winding 3 ground path at star point bus

(For wye grounded - wye grounded - delta non auto transformer, refer CC=12)

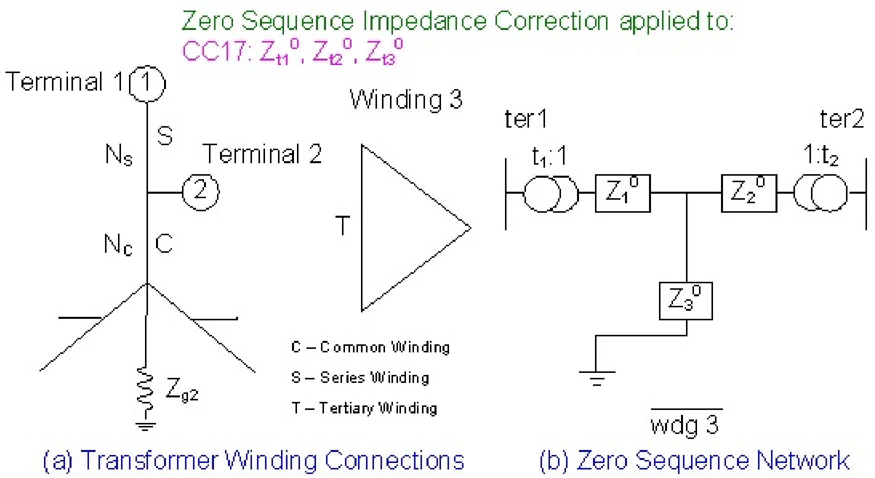


Figure 2.33. Ynad (grounded) auto transformer zero sequence network

CC=17	Calculated (pu):
Set: - R01+jX01 = $Z_{12}{}^0$ - R02+jX02 = $Z_{23}{}^0$ - R03+jX03 = $Z_{31}{}^0$ - RG2+jXG2 = Z_{g2}	$-\,calculate\, Z_{t1}{}^0, Z_{t2}{}^0, Z_{t3}{}^0$ $Z_1{}^0 = Z_{t1}{}^0 - \frac{3(N-1)}{N^2} Z_{g2}$ $Z_2{}^0 = Z_{t2}{}^0 + \frac{3(N-1)}{N} Z_{g2}$ $Z_3{}^0 = Z_{t3}{}^0 + \frac{3}{N} Z_{g2}$

For auto transformers with one/two neutral connections taken out, IEEE Std C57.12.90-2015 standard provides the test procedure and T-model impedance calculations from that test data.

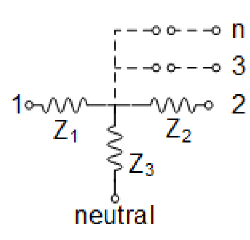


Figure 2.34. Equivalent zero sequnce network for a transformer with two externally available neutrals and 0^o phase shift between windings 1 and 2

Following four test results are used to determine zero sequence network:

- Test 1 - Apply voltage winding 1 and its neutral. All other windings are open-circuited. The measured zero sequence is represented by Z_{1N0}.
- Test 2 - Apply voltage winding 1 and its neutral. Short Winding 2 and its neutral. All other windings may be open-circuited or shorted. The measured zero sequence is represented by Z_{1Ns}.
- Test 3 - Apply voltage winding 2 and its neutral. All other windings are open-circuited. The measured zero sequence is represented by Z_{2N0}.
- Test 4 - Apply voltage winding 2 and its neutral. Short Winding 1 and its neutral. All other windings may be open-circuited or shorted. The measured zero sequence is represented by Z_{2Ns}.

The zero sequence network T-model impedances are calculated as below.

$$Z_3 = +\sqrt{Z_{2N0}(Z_{1N0} - Z_{1Ns})} = +\sqrt{Z_{1N0}(Z_{2N0} - Z_{2Ns})}$$
$$Z_2 = Z_{2N0} - Z_3$$
$$Z_1 = Z_{1N0} - Z_3$$

Set PSSE seqence data as below.

- $R_{01} + j\,X_{01} = Z_{12}{}^{0} = Z_1 + Z_2$
- $R_{02} + j\,X_{02} = Z_{23}{}^{0} = Z_2 + Z_3$
- $R_{03} + j\,X_{03} = Z_{31}{}^{0} = Z_3 + Z_1$

CC=18

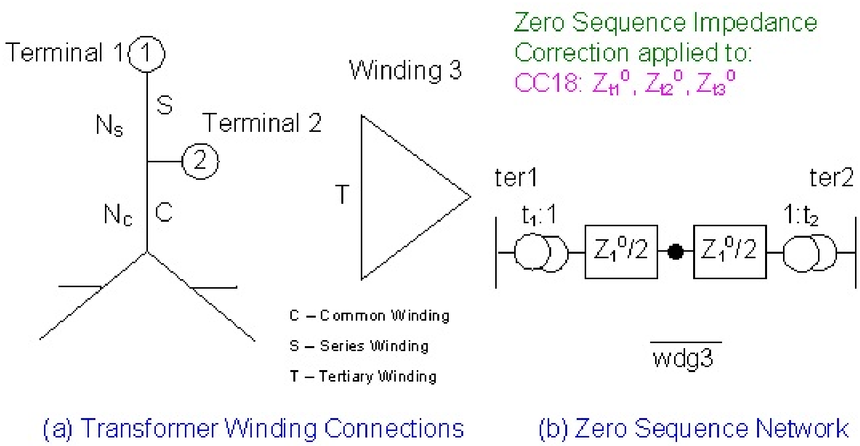


Figure 2.35. Yad (ungrounded) auto transformer zero sequence network

Set:

- R01+jX01 = $Z_{12}{}^{0}$

- R02+jX02 = $Z_{23}{}^{0}$

- R03+jX03 = $Z_{31}{}^{0}$

Calculated (pu):

Calculate $Z_{t1}{}^{0}$, $Z_{t2}{}^{0}$, $Z_{t3}{}^{0}$

$$Z_1{}^0 = \left(\frac{N-1}{N}\right) Z_{31}{}^0 - \left(\frac{N-1}{N^2}\right) Z_{23}{}^0 + \frac{1}{N} Z_{12}{}^0$$

Chapter 3

Optimal Power Flow Data Contents

3.1. Overview

The input stream to activity ROPF is a Optimal Power Flow Data File containing 17 groups of records with each group specifying a particular type of OPF data or constraint definition required for OPF work (see Figure 3-1). Any piece of equipment for which OPF data is to be entered in activity ROPF must be represented as power flow data in the working case. That is, activity ROPF will not accept data for a bus, generator, branch, switched shunt or fixed shunt not contained in the working case.

All data is read in free format with data items separated by a comma or one or more blanks. Each category of data except the change code is terminated by a record specifying an I value of zero. Termination of all data is indicated by a value of Q.

Change Code	
Bus Voltage Constraint Data	
Adjustable Bus Shunt Data	
Bus Load Data	
Adjustable Bus Load Table Data	
Generator Dispatch Data	
Active Power Dispatch Data	
Generation Reserve Data	
Generation Reactive Capability Data	
Adjustable Branch Reactance Data	
Piece-wise Linear Cost Data	
Piece-wise Quadratic Cost Data	
Polynomial and Exponential Cost Table	

Period Reserve Constraint Data	
Branch Flow Constraint Data	
Interface Flow Constraint Data	
Linear Constraint Dependency Data	

Optimal Power Flow Raw Data File Structure

3.2. Change Code

The OPF data modification code indicates whether a new set of optimal power flow data records are to be loaded into the working case, or whether the existing optimal power flow data is to be modified or appended with updated information. This value is only used within the OPF Raw Data File.

Within the OPF Raw Data File, this record contains one data field entered as follows:

```
ICODE
```

ICODE	ICODE = 0. All data within the OPF Raw Data File is treated as new data and entered into the working case. Any optimal power flow data that may have previously existed within the working case is erased prior to the reading of the rest of the data records contained within the OPF Raw Data File. ICODE = 1. All data within the OPF Raw Data File is to supersede values that currently exist in the working case. Any data records introduced through the OPF Raw Data File which do not correspond to an existing record within the working case, are automatically appended to the data records already within the current working case. Data records which do correspond to an entry within the working case are simply updated to reflect the new values.

3.3. Bus Voltage Constraint Data

OPF Bus Voltage Constraint records define lower and upper voltage limits at each bus existing within the PSSE power flow data model. Constraints may only be applied to existing buses; no new buses may be added through the Bus Voltage Constraint record.

By default, all buses within the working case automatically have OPF Bus Voltage Constraint records defined. The OPF Bus Voltage records of out of service (Type 4) buses can be modified but the bus and all bus associated models (voltage constraints, bus shunts, loads, etc.) will not be utilized by the optimal power flow solution process.

3.3.1. Bus Voltage Attribute Record

The format for each OPF Bus Voltage Attribute record is:

```
BUS, VNMAX, VNMIN, VEMAX, VEMIN, LTYP, SLPEN
```

When entered in the OPF Raw Data File each field must be separated by either a space or a comma. Any blank fields must be delineated by commas. A bus value of zero (0) indicates that no further bus voltage constraint records are to be processed.

Each bus voltage constraint record is uniquely identified by a bus identifier. The values for each record is defined as follows:

BUS	A bus number between 1 and 999997. The specified bus number must correspond to a bus already defined within the power flow working case.
VNMAX	The maximum bus voltage magnitude value, entered in pu. The normal and emergency OPF bus voltage limits are independent of the normal and emergency bus voltage limits in the main network bus data. The OPF bus voltage limits may be initialized to those of the network bus voltage limits through either the OPF bus and bus subsystem spreadsheets, or through the OPF bus API commands. VNMAX = 9999.0 by default
VNMIN	The minimum bus voltage magnitude value, entered in pu. VNMIN = -9999.0 by default
VEMAX	The maximum emergency bus voltage magnitude value, entered in pu. To enforce recognition of the minimum and maximum emergency voltage limits during the OPF solution, select the *Impose emergency bus voltage limits* solution option. Otherwise the normal voltage limits, as entered above, will be utilized. Refer to Impose Emergency Bus Voltage Limits for more information. VEMAX = 9999.0 by default
VEMIN	The minimum emergency bus voltage magnitude value, entered in pu. VEMIN = -9999.0 by default
LTYP	One of four limit types may be enforced during the OPF solution: • Reporting only (0),Only report on violations of the bus voltage limits, taking no action if the voltage falls outside of limits. • Hard limit (1). Strictly enforce the specified bus voltage magnitude limits through the use of barrier terms. • Soft limit with a linear penalty (2). Permit bus voltages to go outside of their specified voltage magnitude limits, but penalize excursions linearly. The Soft limit penalty weight, `SLPEN`, is used in conjunction with this penalty to indicate severity of excursion. • Soft limit with a quadratic penalty (3). Permit bus voltages to go outside of their specified voltage limits, but penalize excursions along a quadratic curve. The Soft limit penalty weight, `SLPEN`, is used in conjunction with this penalty to indicate severity of excursion. Refer to Section 14.7.2 Accommodating Inequality Constraints for more information on the limit type options. LTYP = 1 (Hard limit) by default

SLPEN	The soft limit penalty weight value applied to either the linear or quadratic soft limit penalty functions. The larger the number, the higher the penalty for voltage excursions outside of limits. SLPEN = 1.0 by default

3.4. Adjustable Bus Shunt Data

Adjustable Bus Shunt Records define candidate bus locations for shunt compensation. These records are unique to the PSSE OPF but do impact bus shunts within the power flow data model after an OPF solution. If a corresponding bus and bus shunt identifier is found, then the BINIT value will be updated with the new OPF solution value; otherwise a new bus shunt will be added to the power flow network data. The switched shunt data records defined within the PSSE power flow data model are not affected by the OPF Adjustable Bus Shunt data.

The maximum and minimum var limits specified in the Adjustable Bus Shunt records are used in conjunction with the Minimize Adjustable Bus Shunts objective function. Details of the adjustable bus shunt model can be found in Section 14.6.2 Adjustable Bus Shunt.

An individual bus may have one or more adjustable bus shunts defined, each differentiated by a unique bus shunt identifier.

The format for each Adjustable Bus Shunt record is:

```
BUS, ID, BINIT, BMAX, BMIN, BCOST, STATUS, CTYP, CTBL
```

When entering records in the OPF Raw Data File, each field must be separated by either a space or a comma and any fields left blank must be delineated by commas. A bus value of zero indicates that no further Adjustable Bus Shunt records are to be processed.

The bus number and shunt identifier uniquely identifies each Adjustable Bus Shunt record. The values for each record are described as follows:

BUS	A bus number between 1 and 999997. The specified bus number must correspond to an existing bus within the power flow working case.
ID	A one or two character identifier that uniquely identifies the bus shunt at the bus. If this field is left blank, the bus shunt identifier will default to a value of '1'. The bus number and bus shunt identifier may optionally correspond to a fixed shunt record within the power flow network. If so, then the corresponding fixed shunt data record will be updated after an OPF solution.
BINIT	The initial additional shunt value, entered in Mvar at nominal voltage. BINIT = 0.0 by default.
BMAX	The maximum bus shunt limit, entered in Mvar. To define an initial fixed shunt component, deployed at no cost, enter the desired value into the main power flow model as a fixed bus shunt with the same bus number and shunt identifier. BMAX = 0.0 by default.
BMIN	The minimum bus shunt limit, entered in Mvar. Negative or positive shunt values may be entered for the maximum and minimum bus shunt susceptance to indicate inductors or capacitors respectively.

	BMIN = 0.0 by default.
BCOST	The cost coefficient, entered in cost units per Mvar. This coefficient assigns a cost value to each Mvar employed during the solution process. For example, one application for the cost scale coefficient is to assign a relatively low cost to an Adjustable Bus Shunt record representing an existing var installation, and a high cost to an Adjustable Bus Shunt record representing a potentially new installation. This higher cost may take into consideration the additional costs associated with the purchase of new equipment and the labor required for installation. This setup ensures that vars from the existing installation will likely be employed during solution before any new vars are applied. BCOST = 1.0 by default.
STATUS	The status switch determines whether the specified bus shunt control should be considered active or not. Only in-service bus shunts are recognized as candidates for var control. • In-service (1) • Out of service (0) STATUS = 1 (In-service) by default.
CTYP	Cost curve type. This value is not currently utilized by the program.
CTBL	Cost curve table number. This value is not currently utilized by the program.

3.5. Bus Load Data

Each OPF Bus Load Data record points to an Adjustable Bus Load table (Section 3.6 Adjustable Bus Load Table Data) that, in turn, defines load limits for use in load adjustment studies (i.e., load shedding, power transfer). These records are used in conjunction with the Minimize Adjustable Bus Loads objective function.

By default, all bus loads within the working case are initialized with default OPF Bus Load data. When a new bus load is added to the power flow network, a corresponding OPF Bus Load data record will automatically be created with default values. These data values may be updated. Bus loads connected to buses that are out of service can have their OPF Bus Load Data modified, but the load will not be acknowledged by the optimal power flow solution process.

3.5.1. Bus Load Record

The format for each OPF Bus Load record is as follows:

```
BUS, LOADID, LOADTBL
```

Within the OPF Raw Data File each field must be separated by either a space or a comma. A bus value of zero indicates that no further adjustable bus load records are being entered.

The bus number and load identifier uniquely identify each adjustable bus load record. The values for the record are described as follows:

BUS	A bus number between 1 and 999997. The specified bus number must correspond to an existing bus within the power flow working case.

LOADID	A one or two character load identifier that uniquely identifies the load at the bus. If left blank, a default bus load identifier of '1' is assumed.
LOADTBL	The adjustable bus load table reference number, as presented in Section 3.6 Adjustable Bus Load Table Data. An adjustable bus load table number of zero indicates that the corresponding bus load is not being utilized within any OPF Adjustable Bus Load models. Multiple OPF bus load records may reference the same adjustable bus load table number.

3.6. Adjustable Bus Load Table Data

Adjustable Bus Load Table records define load scaling limits for use in load adjustment studies (load shedding, power transfer). They are referenced by the OPF Bus Load records defined in Section 3.5 Bus Load Data and are used in conjunction with the Minimize Adjustable Bus Loads objective. Details of the load adjustment model are covered in Section 14.6.3 Load Adjustment.

An Adjustable Bus Load Table must be defined before it can be referenced by an OPF Bus Load record. Not all Adjustable Bus Load Tables however have to be referenced by an adjustable bus load record. Those tables which are defined but not referenced are ignored during the OPF solution process. There may be up to 1000 Adjustable Bus Load Table records defined within the working case.

3.6.1. Adjustable Bus Load Table Record

The format of each Adjustable Bus Load Table record is:

```
TBL, LM, LMMAX, LMMIN, LR, LRMAX, LRMIN, LDCOST, CTYP, STATUS, CTBL
```

When entering data in the OPF Raw Data File each field must be separated by either a space or a comma. Any fields left blank must be delineated with commas. A load table value of zero indicates that no further adjustable bus load table records are to be processed.

The adjustable bus load table number uniquely identifies each adjustable bus load table record. The values for the record are defined as follows:

TBL	Adjustable bus load table number is an integer number. A value less than four digits in length is most suitable for reporting purposes.
LM	Load multiplier. The initial load adjustment variable, as indicated by Yi in the load adjustment model of Section 14.6.3 Load Adjustment. LM = 1.0 by default
LMMAX	The maximum load adjustment multiplier, used to establish an upper limit for the load multiplier Y. To represent a load shedding model, `YMAX` should be between 0.0 and 1.0 and larger than `YMIN`. For a load addition model, `YMAX` should be greater than 1.0. LMMAX = 1.0 by default
LMMIN	The minimum load adjustment multiplier, used to establish a lower limit for the load multiplier Y. This value should be less than or equal to the value defined for the maximum load multiplier.

	LMMIN = 1.0 by default
LR	Load ratio multiplier. This value is not presently utilized by the program.
LRMAX	Maximum load ratio multiplier. This value is not presently utilized by the program.
LRMIN	Minimum load ratio multiplier. This value is not presently utilized by the program.
LDCOST	Cost scale coefficient. The cost, in $/pu MW, assigned to each OPF bus load participating in this adjustable bus load group. LDCOST = 1.0 by default
CTYP	Cost curve type. This value is not presently utilized by the program.
STATUS	The status switch determines whether the specified Adjustable Bus Load Table should be considered active or not. Only in-service Adjustable Bus Load Tables and their associated OPF Bus Loads will be recognized as adjustable bus load candidates. • In-service (1) • Out of service (0) STATUS = 1 (In-service) by default
CTBL	Cost table cross-reference number. This value is not presently utilized by the program.

3.7. Generator Dispatch Data

Generator Dispatch Data records reference Active Power Dispatch Tables (Section 3.8 Active Power Dispatch Data) which, in turn, reference Cost Curves (Sections 3.12 to 3.14). These relationships, in conjunction with the Minimize Fuel Cost objective, introduce active power controls for generator dispatch studies.

All or a portion of the generating unit's capacity may be made available for dispatch. The active power dispatch model, including the minimum and maximum active power limits, is defined within the active power dispatch table record, described in Section 3.8 Active Power Dispatch Data.

By default, all machines within the working case that do not already have generator dispatch data defined, are initialized with default data. When a new generator is added to the power flow network, a corresponding OPF Generator Dispatch record is automatically created with default values.

3.7.1. Generator Dispatch Data Record

The format for each OPF Generator Dispatch data record is:

```
BUS, GENID, DISP, DSPTBL
```

When entering data in the OPF Raw Data File each field must be separated by either a space or a comma. A bus value of zero indicates that no further generator dispatch records are being entered. Any blank fields must be delineated by commas.

The bus number and machine identifier uniquely identifies each Generator Dispatch record. The values for each Generator Dispatch data record are described as follows:

BUS	A bus number between 1 and 999997. The specified bus number must correspond to a bus already defined within the power flow working case.
GENID	A one or two character machine identifier that uniquely identifies the machine at the bus. If left blank, a default machine identifier of '1' is assumed.

DISP	The fractional dispatch value of the machine's total active power output available for participation in the active power dispatch control. A value of 1.0 indicates that 100% of the current active power output at the machine will be employed in the associated active power control.The sum of the dispatch fractions for all of the generator dispatch records that reference the same active power dispatch table should add up to 1.0 for typical applications. DISP = 1.0 by default
DSPTBL	The table number of the active power dispatch control table. Multiple generator dispatch records may reference the same active power dispatch table. An active power dispatch table number of zero implies that the generator is not participating as an active power control. DSPTBL = 1 by default

3.8. Active Power Dispatch Data

Active Power Dispatch Table records define the maximum and minimum active power dispatch limits.

Each Active Power Dispatch Table references a Cost Curve (Sections 3.12- 3.14) that specifies the costs associated with dispatching generation between the defined active power limits. Active Power Dispatch Table records in turn are referenced by Generator Dispatch records (Section 3.7 Generator Dispatch Data). The combination of these data records are used in conjunction with the Minimize Fuel Cost objective to perform dispatch studies.

3.8.1. Active Power Dispatch Record

The format for each Active Power Dispatch Table data record is:

```
TBL, PMAX, PMIN, FUELCOST, CTYP, STATUS, CTBL
```

When entering data in the OPF Raw Data File each field must be separated by either a space or a comma. Any fields left blank must be delineated with commas. A table value of zero indicates that no further active power dispatch table records are to be processed.

Each active power dispatch table is uniquely identified by a numerical identifier. The values of each record are defined as follows:

TBL	Active power dispatch table number is an integer number. A number less than four digits is most suitable for reporting purposes.
PMAX	The upper limit on the total amount of active power available for dispatch, specified in MW. PMAX = 9999.0 by default
PMIN	The lower limit on the total amount of active power available for dispatch, specified in MW. PMIN = -9999.0 by default
FUELCOST	Fuel cost scale coefficient. A value chosen such that when the product between this value and the associated cost curve coordinate value produces a result that has cost units of (cost units)/hour.

	As an example, if the cost curve table coordinate value has units of MBTU/hour, then the fuel cost scale coefficient should be entered with units of (cost units)/MBTU. FUELCOST = 1.0 by default
CTYP	One of three cost curve models may be specified to represent the fuel dispatch curves of the generator units. 1. Polynomial and exponential curve 2. Piece-wise linear curve 3. Piece-wise quadratic curve CTYP = 1 (Polynomial and exponential curve) by default
STATUS	The status switch indicates whether the active power dispatch record is an active control within the OPF problem statement or not. Only in-service active power dispatch tables and their associated generators will be recognized as active power dispatch candidates. • 1 - In-service • 0 - Out of service STATUS = 1 (In-service) by default
CTBL	The table number of the cost curve to employ. Multiple active power dispatch table records may reference the same cost curve. A cost curve table number of zero indicates that the active power dispatch record, along with its participating generators will not be utilized within the OPF solution. CTBL = 0 by default

3.9. Generation Reserve Data

Generation Reserve records define a generating unit's MW output capability and ramp rate. These records are used in conjunction with the Period Reserve Constraint records (Section 3.15 Period Reserve Constraint Data) to introduce MW reserve constraints into the optimal power flow problem.

Generation Reserve records may be utilized by one or more generation Period Reserve Constraint records. The period reserve constraint model, as described in Section 14.6.6 Generator Period Reserve, provides a means of imposing a specified MW reserve within a certain time limit (i.e., 200 MW in 10 minutes) by the participating generator reserve units.

3.9.1. Generation Reserve Record

The format for each Generation Reserve record is:

```
BUS, GENID, RAMP, RTMWMAX
```

When entering records into the OPF Raw Data File, each field must be separated by either a space or a comma. A bus number of zero indicates that no further generator reserve records are being entered. Any blank fields must be delineated by commas.

The bus number and machine identifier uniquely identifies each Generation Reserve record. The values for each record are defined as follows:

BUS	A bus number between 1 and 999997. The specified bus number must correspond to a bus defined within the power flow working case.
GENID	A one or two character machine identifier that uniquely identifies the machine at the bus. If left blank, a default machine identifier of '1' is assumed.
RAMP	Unit ramp rate. The rate at which it takes the generator to reach its maximum MW capability, specified in MW / minute. RAMP = 9999.0 by default
RTMWMAX	The maximum unit reserve contribution, specified in MW RTMWMAX = 9999.0 by default

3.10. Generation Reactive Capability Data

Generation Reactive Capability records define the limits in the armature reaction and stator current magnitude.

Whereas the conventional generator model provides for constant reactive generation limits, the reactive capability model represents generator armature reaction (Efd) behind synchronous reactance (Xd). With limits applied to armature reaction magnitude and stator current magnitude, the reactive power capability of the unit is recognized in a manner which is independent of any assumptions in terminal voltage magnitude or active power generation. This is further discussed in Section 14.6.5 Generator Reactive Capability.

3.10.1. Generation Reactive Capability Record

The format for each Reactive Capability record is:

```
BUS, GENID, XD, ISMAX, PFLAG, PFLEAD, QLIMIT, STATUS
```

When entering records in the OPF Raw Data File each field must be separated by either a space or a comma and any fields left blank must be delineated with commas. A bus number of zero indicates that no further generator reactive capability records are being entered.

A bus number and machine identifier is used to uniquely identify each Generation Reactive Capability record. The values for each record are defined as follows:

BUS	A bus number between 1 and 999997. The specified bus number must correspond to a bus already defined within the power flow working case.
GENID	The one or two character machine identifier of a valid machine within the working case. If this field is left blank, a default machine identifier of '1' will be assumed.
XD	The direct axis synchronous reactance of the machine, entered in pu on machine base. XD = 1.0 by default
ISMAX	The generator stator current limit, entered in pu on machine base. ISMAX = 1.0 by default

PFLAG	Real value generator rated lagging power factor. PFLAG = 1.0 by default
PFLEAD	Real value generator rated leading power factor. PFLEAD = 1.0 by default
QLIMIT	The maximum reactive absorption limit at zero power factor, entered in pu on machine base. QLIMIT = 1.0 by default
STATUS	Reactive Capability Limit Status: • 0 - Out-of-service. The program will employ reactive generation limits directly from the power flow data. • 1 - Enabled. The generator is fully enabled with no reactive generation limits. • 2 - Enabled with +DEfd inhibited. The generator is in service and any increase in the field voltage is inhibited. • 3 - Enabled with -DEfd inhibited. The generator is in service and any decrease in the field voltage is inhibited. • 4 - Enabled with Efd fixed. The generator is in service with an invariant field voltage. The limit status determines how the specified reactive capability record should be employed in the optimal power flow problem. STATUS = 4 (Enabled with Efd fixed) by default

3.11. Adjustable Branch Reactance Data

Adjustable Branch Reactance records define the reactive compensation limits and associated costs of adding series var compensation. The data records are used in conjunction with the Minimize Adjustable Branch Reactances objective to identify candidate branches for use in series var compensation studies. A full description of the adjustable branch reactance model is presented in Section 14.6.4 Adjustable Branch Reactance.

3.11.1. Adjustable Branch Reactance Record

The format for each Adjustable Branch Reactance record is:

```
IBUS, JBUS, CKT, XMLT, XMLTMAX, XMLTMIN, XCOST, CTYP, STATUS, CTBL
```

Each field must be separated by either a space or a comma and any fields left blank must be delineated by commas. An IBUS number of zero indicates that no further adjustable branch reactance records are being entered.

The from bus, to bus and circuit identifier uniquely identify each Adjustable Branch Reactance record. The values for each record are defined as follows:

IBUS	The sending bus, specified by a number between 1 and 999997. The number must correspond to a bus already contained within the power flow working case.

JBUS	The receiving bus, specified by a number between 1 and 999997. The number must correspond to a bus already contained within the power flow working case.
CKT	The one or two character branch identifier of an existing branch between the from bus and the to bus. If this field is left blank a default circuit identifier of '1' is assumed.
XMLT	The multiplier applied to the current reactance of the branch to yield the initial series compensation value. A value of 1.0 implies that the initial reactance will be the current reactance of the branch as obtained from the working case. XMLT = 1.0 by default
XMLTMAX	The maximum multiplier value applied to the reactance of the branch. The calculated value determines the upper limit on the amount of available branch reactance compensation. It is specified as a fraction of the branch reactance. Values over 1.0 are allowed for situations where a potential increase in reactance is desired. XMLTMAX = 1.0 by default
XMLTMIN	The minimum multiplier value applied to the reactance of the branch. The calculated value determines the lower limit on the amount of available branch reactance compensation. It is specified as a fraction of the branch reactance. For example, if the minimum reactance multiplier is specified as 0.3 and the maximum reactance multiplier is specified as 1.0 then 70% of the branch reactance is available as compensation. The minimum value cannot be less than 0.1 to ensure that compensation does not exceed 90% of the branch impedance. XMLTMIN = 1.0 by default
XCOST	The adjustable branch reactance cost in cost units / pu ohms. XCOST = 1.0 by default
CTYP	This value is not presently utilized by the program
STATUS	• 1 - In-service • 0 - Out-of-service The status determines whether the specified Adjustable Branch Reactance record should be considered active or not. Only in-service Adjustable Branch Reactance records are recognized as candidates for series var adjustment. STATUS = 1 (In-service) by default
CTBL	This value is not presently utilized by the program

3.12. Piece-wise Linear Cost Data

The Cost Curve data record provides essential information on the fuel cost characteristics of each participating generator unit. It is used specifically in conjunction with the Minimize Fuel Cost objective and the Active Power Dispatch tables (Section 3.8 Active Power Dispatch Data) for generator dispatch analysis.

The Piece-wise Linear cost model defines a linear relation between a cost, in cost units (i.e., dollars, pounds, etc.), and a particular control variable value. For example, an active power dispatch model may reference a piece-wise linear cost curve in order to obtain the relative fuel cost for dispatching a participating generator unit at a certain active power dispatch level.

3.12.1. Piece-wise Linear Cost Record

The format for each Piece-wise Linear Cost Table data record is a multi-line record as follows:

```
LTBL, LABEL, NPAIRS, X1, Y1...XN, YN
```

Each field must be separated by either a space or a comma and any fields left blank must be delineated by commas.

The total number of pairs entered must equal the value specified for NPAIRS.

An LTBL number of zero indicates that no further piece-wise linear cost table records are to be processed.

Each Piece-wise Linear Cost Curve Table record is uniquely identified by a linear cost table number. The values for each record are defined as follows:

LTBL	The piece-wise linear cost table number is an integer number. A number less than four digits in length is most suitable for reporting purposes. Note that the same cost table number may be used for multiple cost curve tables, provided that each table represents a different cost curve type (i.e., quadratic or polynomial).
LABEL	A descriptive label of the piece-wise linear cost table, containing at most, 12 characters. This label is strictly used for reporting purposes. LABEL = '' by default
NPAIRS	The number of cost pairs. The total number of xi, yi coordinate pairs being entered. This value is only used when entering raw data records in the OPF Raw Data File format or when using PSSE Automation commands. NPAIRS = 0 by default
Coordinate Pairs	The individual coordinate pairs. Each pair (X_1, Y_1 through X_N, Y_N) defines one segment of the piece-wise linear cost curve. • X_1... X_N The control variable value. In the typical situation where the cost curve is representing fuel cost characteristics, this value would define the active power generation, in MW. • Y_1... Y_N The total cost or energy consumption. For the fuel cost model, this value would typically be entered in cost units / hour.

The Piece-wise Linear Cost Table displays all Piece-wise Linear Cost Tables in the working case. The subsystem filter has no effect on the list displayed. If there are no Piece-wise Linear Cost Tables in the working case, the Tables list will be blank.

3.13. Piece-wise Quadratic Cost Data

The Cost Curve data record provides essential information on the fuel cost characteristics of each participating generator unit. It is used specifically in conjunction with the Minimize Fuel Cost objective and the Active Power Dispatch tables (Section 3.8 Active Power Dispatch Data).

The Piece-wise Quadratic Cost Curve model presents the cost, in cost units (i.e., dollars, pounds, etc.), as a quadratic function of a control variable value. For example, an active power dispatch model may reference a piece-wise quadratic cost curve to obtain the relative fuel costs for dispatching a participating generator unit at a certain active power dispatch level.

3.13.1. Piece-wise Quadratic Cost Record

The format for each Piece-wise Quadratic Cost Table data record is a multi-line record as follows:

QTBL, LABEL, COST, NPAIRS, X_1, Y_1... X_N, Y_N

Each field of the data record must be separated by either a space or a comma, with any blank fields being delineated by commas.

The total number of pairs entered must equal the value specified for NPAIRS.

A QTBL number of zero indicates that no further Piece-wise Quadratic Cost Table records are to be entered.

Each Piece-wise Quadratic Cost Curve Table is uniquely identified by a quadratic cost table number. The data values for each record are defined as follows:

QTBL	The piece-wise quadratic cost table number is an integer number. A number less than four digits in length is most suitable for reporting purposes. Note that the same cost table number may be used for multiple cost curve tables, provided that each table represents a different cost curve type (i.e., quadratic or polynomial).
LABEL	A descriptive label of the piece-wise linear cost table, containing at most, 12 characters. This label is strictly used for reporting purposes. LABEL = '' by default
COST	The cost or energy integration constant used to calculate the total fuel cost. When this value is used in conjunction with the active power dispatch table, it should be defined in units which, when its product is taken with the fuel cost scale coefficient defined in the active power dispatch table record, the resultant units are cost units / hour. For example, if the fuel cost scale coefficient in the active power dispatch table has units of $/MBTU, then the integration constant should be specified in units of MBTU/hour. COST = 0.0 by default
NPAIRS	The number of cost pairs. The total number of xi, yi coordinate pairs being entered. This value is only used when entering raw data records in the OPF Raw Data File format or when using PSSE Automation commands. NPAIRS = 0 by default
Coordinate Pairs	The individual coordinate pairs. Each pair (X_1, Y_1 through X_N, Y_N) defines one segment of the piece-wise quadratic cost curve. • X_1... X_N The control variable value. In the typical situation where the cost curve is representing fuel cost characteristics, this value would define the active power generation, in MW.

	• $Y_1 \ldots Y_N$ The incremental cost or energy consumption. For the fuel cost model, this value would typically be entered in cost units / MW.

The Piece-wise Quadratic Cost Table editor displays in the editor all Piece-wise Quadratic Cost Curve Tables in the working case. The subsystem filter has no effect on the list displayed. If no Piece-wise Quadratic Cost Curve Tables exist in the working case, the editor will be blank.

3.14. Polynomial and Exponential Cost Table

The Cost Curve data records provide essential information on the fuel cost characteristics of each participating generator unit. It is used specifically in conjunction with the Minimize Fuel Cost objective and the Active Power Dispatch tables (Section 3.8 Active Power Dispatch Data) for generator dispatch analysis.

The Polynomial and Exponential Cost Curve model describes the cost, in cost units (i.e., dollars, pounds, etc.), as a polynomial equation in terms of a control variable value. Similar to the linear and quadratic cost curve models, an active power dispatch model may reference a polynomial cost curve in order to obtain the relative fuel cost to dispatch a participating generator unit at a certain active power dispatch level. The following equation is employed:

$$Cost = \left(Cost_0 + A \bullet P_{gen} + B \bullet P^2_{gen} + C \bullet \varepsilon^{DP_{gen}} \right) VAL$$

where:

$Cost_0$	=	Fuel cost integration constant
A	=	Linear cost coefficient
B	=	Quadratic cost coefficient
C	=	Exponential cost coefficient
D	=	Exponent scale factor
VAL	=	The cost scale coefficient. In the example of the active power dispatch model, this value is the fuel cost scale coefficient.

Polynomial Cost Equation

3.14.1. Polynomial and Exponential Record

The format for each Polynomial and Exponential Cost Curve Table record is:

```
PTBL, LABEL, COST, COSTLIN, COSTQUAD, COSTEXP, EXPN
```

Each field of the data record must be separated by either a space or a comma with blank fields delineated by commas. A PTBL number of zero indicates that no further polynomial and exponential cost table records are being entered.

Each Polynomial and Exponential Cost Curve Table record is uniquely identified by a polynomial and exponential cost table number.

PTBL	The plynomial and exponential cost table number is an integer number. A number less than four digits in length is most suitable for reporting purposes. Note that the same cost table number may be used for multiple cost curve tables, provided that each table represents a different cost curve type (i.e., linear or quadratic).
LABEL	A descriptive label of the piece-wise linear cost table, containing at most, 12 characters. This label is strictly used for reporting purposes. LABEL = '' by default
COST	The cost or energy integration constant used to calculate the total fuel cost. COST = 0.0 by default
COSTLIN	The linear cost coefficient as indicated by A in the equation given in Figure 3-2. COSTLIN = 0.0 by default
COSTQUAD	The quadratic cost coefficient as indicated by B in the equation given in Figure 3-2. COSTQUAD = 0.0 by default
COSTEXP	The exponential cost coefficient as indicated by C in the equation given in Figure 3-2. COSTEXP = 0.0 by default
EXPN	The scale factor value which may be applied to the exponent of the exponential term as indicated by D in the equation given in Figure 3-2. EXPN = 0.0 by default

The values for the integration constant and each of the coefficients should be specified in units that will allow them to be multiplied by a cost scale value. When the polynomial and exponential table is used in conjunction with the active power dispatch table, the coefficients and integration constant should be defined in units which, when a product is taken with the fuel cost scale coefficient defined in the active power dispatch table record, the resulting value is in units of cost units / hour. For example, if the fuel cost scale coefficient in the active power dispatch table has units of $/MBTU, then the integration constant should be specified in units of MBTU / hour.

The Polynomial and Exponential Cost Table displays in the editor all Polynomial and Exponential Cost Curve Tables that exist in the working case. The subsystem filter has no effect on the list displayed. If no Polynomial and Exponential Cost Curve Tables exist in the working case, the editor will simply show a blank record.

3.15. Period Reserve Constraint Data

Period Reserve Constraint data records are used in conjunction with the Generation Reserve records (Section 3.9 Generation Reserve Data) to impose MW reserve limits.

The period reserve constraint model, as described in Section 14.6.6 Generator Period Reserve, defines a MW reserve that must be met within a stated time limit (i.e., 200 MW in 10 minutes). Some or all of a group of participating generator units may be deployed to meet this requirement.The maximum reserve contribution in MWand the unit ramp rate in MW/minute are defined for each participating generator unit as part of the generation reserve data presented in Section 3.9 Generation Reserve Data. The period reserve records described here define the desired reserve limit and the time limit in which the reserve limit must be met.

3.15.1. Period Reserve Constraint Record

The format for each Period Reserve data record is a multi-line record as follows:

```
RSVID, MWLIMIT, T, STATUS

BUS, GENID

...

BUS, GENID

0
```

Each field of the data record must be separated by either a space or a comma and any fields left blank must be delineated by commas. For each complete period reserve record entered, a single zero must be placed on the line immediately following the last generator unit entered, or immediately after the main RSVID record if no participating units are specified. A RSVID value of zero indicates that no further period reserve records are being entered.

Each Period Reserve record is uniquely identified by a reserve identification number between one and fifteen. The values for each record are defined as follows:

RSVID	The Reserve identifier is a number between one and fifteen, inclusive.
MWLIMIT	The reserve requirement, in MW. If the sum of maximum reserves for all of the units participating in the Period Reserve data record is less than the specified reserve limit, then the constraint cannot be satisfied. The solution will terminate if this situation arises. If the reserve limit is set to 0.0, the reserve constraint will not be employed as part of the optimal power flow problem statement. MWLIMIT = 0.0 by default
T	The time constraint for which the reserve requirement must be fulfilled, in minutes. T = 9999.0 by default
STATUS	• 1 - In-service • 0 - Out-of-service The status switch indicates whether the specified period reserve record should be included within the OPF problem statement. Only in-service period reserve records will be included as a reserve constraint. STATUS = 1 (In-service) by default
Participating Units	A list of participating generator reserve units available to the period reserve constraint. Each unit must already have a corresponding generator reserve data record defined. Each participating unit is uniquely specified by the following identifiers: • BUS - The bus number of the bus where the unit is located. When using the spreadsheet, this value may need to be entered as a bus name, depending upon the input mode currently in effect.

	• GENID - The generator unit identifier of the participating generator. A default identifier of 1 is assumed if left blank.

The Period Reserve data editor displays all Period Reserve data records within the working case. The subsystem filter has no effect on the list displayed. If no Period Reserve records exist in the working case, the editor will be blank.

3.16. Branch Flow Constraint Data

Branch Flow Constraint records define upper and lower flow limits on selected non zero impedance branches. Four different flow limits may be imposed: MW, MVar, MVA and Ampere. More than one branch flow constraint type may be defined for the same branch.

3.16.1. Branch Flow Constraint Record

The format of each Branch Flow Constraint record is:

```
IBUS, JBUS, CKT, BFID, FMAX, FMIN, EFMAX, EFMIN, FTYP, LTYP, LPEN, KBUS
```

Each field of the data record must be separated by either a space or a comma and any fields left blank must be delineated by commas. An IBUS number of zero indicates that no further branch flow constraint records are being entered.

The from bus, to bus, third bus (for three-winding transformers), circuit id and flow id uniquely identify each Branch Flow Constraint record. The values for each record are defined as follows:

IBUS	The sending bus, specified by a number from 1 through 999997. The number must correspond to an existing bus within the power flow working case. If a three-winding transformer is being specified, the from bus defines the winding for which the flow constraint is being introduced.
JBUS	The receiving bus, specified by a number from 1 through 999997. The number must correspond to an existing bus within the power flow working case.
CKT	A one or two character identifier used to differentiate between multiple connecting lines between the from bus, to bus and third bus (if three-winding transformer). If this field is left blank, a circuit identifier of '1' is assumed.
BFID	A single character identifier to differentiate between multiple branch flow constraints defined at the same branch. If this field is left blank, a flow identifier of '1' is assumed.
FMAX	The maximum normal flow limit on the specified branch. Values are specified in physical units appropriate to the flow limit type being specified; Ampere constraints are specified in MVA. If the difference between the specified upper and lower branch flow limits is less than 0.0001 then the specified flow constraint is *fixed* at the indicated limit. This value, along with the minimum normal limit defined below, is used to define one of two possible flow limits assigned to the branch. An alternate set of emergency limits is defined below. By default, the normal flow limits are employed during the OPF solution unless the Impose Emergency Branch Flow Limits solution option is selected. FMAX = 0.0 by default

FMIN	The minimum normal flow limit on the specified branch. Values are specified in physical units appropriate to the flow limit type being specified; Ampere constraints are specified in MVA. If the difference between the specified upper and lower branch flow limits is less than 0.0001 then specified flow constraint is treated as *fixed* at the indicated limit. FMIN = 0.0 by default
EFMAX	The maximum emergency flow limit on the specified branch. This limit, in conjunction with the minimum emergency limit, defines an optional alternate set of flow limits. Values are specified in physical units appropriate to the flow limit type being specified; Ampere constraints are specified in MVA. To enforce recognition of the minimum and maximum emergency flow limits as opposed to the normal flow limits during the OPF solution, select the Impose Emergency Branch Flow Limits solution option. EFMAX = 0.0 by default
EFMIN	The minimum emergency flow limit on the specified branch. This limit, in conjunction with the maximum emergency limit, defines an optional alternate set of flow limits. Values are specified in physical units appropriate to the flow limit type being specified; Ampere constraints are specified in MVA. If emergency limits are employed during the OPF solution and the difference between the specified upper and lower emergency branch flow limits is less than 0.0001, then the specified flow constraint is treated as *fixed* at the indicated limit. EFMIN = 0.0 by default
FTYP	One of four different flow types specified for the constraint: • 1 - MW • 2 - MVar • 3 - MVA • 4 - Ampere (4) FTYP is 4 (Ampere) by default
LTYP	One of four constraint limit types enforced during the OPF solution: • 0 - Reporting only. Only report on violations of the specified branch flow limits, taking no action if the branch flow falls outside of limits. • 1 - Hard limit. Strictly enforce the specified branch flow limits through the use of barrier terms. • 2 - Soft limit with a linear penalty. Permit branch flows to go outside of their specified branch flow limits, but penalize excursions along a linear curve. The *Soft limit penalty weight*, as defined below, is used in conjunction with this penalty to indicate severity of excursion.

	• 3 - Soft limit with a quadratic penalty. Permit branch flow limit to go outside of their specified flow limits, but penalize excursions along a quadratic curve. The *Soft limit penalty weight*, as defined below, is used in conjunction with this penalty to indicate severity of excursion. Refer to Section 14.7.2 Accommodating Inequality Constraints for more information on the limit type options. LTYP is 1 (Hard limit) by default
LPEN	The penalty weight value applied to either the linear or quadratic soft limit penalty functions. The larger the number, the higher the penalty for branch flow excursions outside of limits. LPEN is 1.0 by default
KBUS	The third bus of a three-winding transformer, specified by a number from 1 through 999997. The number must correspond to an existing bus within the power flow working case. If a three-winding transformer is not being entered, this value is zero.

3.17. Interface Flow Constraint Data

Interface flow records introduce MW or MVar flow constraints across a defined interface. These limits are only enforced when the Constrain Interface Flows option is enabled, otherwise they are ignored during the OPF solution. In conjunction with both the interface flow constraint records and the directive to Constrain Interface Flows, the Minimize Interface Flows objective may be employed to either minimize or maximize flows across an interface.

An interface consists of a collection of branches that may include the tie lines between two areas, the flows through a particular transmission corridor, or the collection of lines emanating from an area. Each interface flow constraint record defines a set of branches included in the interface and the flow limits that are to be imposed on that set during the optimization process. By default, the interface flow definitions are for informational purposes only. They do not automatically introduce constraint equations or objective terms in the optimization problem unless one or both of the corresponding Constrain Interface Flows or Minimize Interface Flows options are enforced.

The format for each Interface Flow Constraint data record is a multi-line record as follows:

```
IFLWID, LABEL, FMAX, FMIN, FTYP, LTYP, LPEN

IBUS, JBUS, CKT, KBUS

IBUS, JBUS, CKT, KBUS

...

0
```

Each field of the data record must be separated by either a space or a comma, with any blank fields delineated by commas. For each interface flow record entered, a single zero must be placed on the line immediately following the last participating branch entered, or immediately after the main IFLWID record if no participating branches are specified.

An IFLWID value of zero indicates that no further interface flow records are to be processed.

Each Interface Flow Constraint record is uniquely identified by an interface flow identifier. The values for each record are defined as follows:

IFLWID	The interface flow identifier is an integer number. A value less than four digits in length is most suitable for reporting purposes.
LABEL	A string containing a maximum of 32 characters used to describe the interface. This label is only used for reporting purposes. LABEL is '' by default
FMAX	The maximum flow limit across the interface, specified in the physical units appropriate for the specified flow limit type defined below. If the range between the maximum and minimum interface MW flow limits is less than 0.001, then the maximum interface flow limit is set to the average of the two interface flow limit values plus 0.1. FMAX is 0.0 by default
FMIN	The minimum flow limit across the interface, specified in the physical units appropriate for the specified flow limit type defined below. If the range between the maximum and minimum interface MW flow limits is less than 0.001, then the minimum interface flow limit is set to the average of the two interface flow limit values minus 0.1. FMIN is 0.0 by default
FTYP	One of two valid flow types: • 1 - MW • 2 - MVar FTYP is 1 (MW) by default
LTYP	One of four different limit types: • 0 - Reporting only. Only report on violations of the specified interface flow limits, taking no action if the interface flow falls outside of limits. • 1 - Hard limit. Strictly enforce the specified interface flow limits through the use of barrier terms. • 2 - Soft limit with a linear penalty. Permit interface flows to go outside of the specified interface flow limits, but penalize excursions along a linear curve. The *Soft limit penalty weight*, as defined below, is used in conjunction with this penalty to indicate severity of excursion. • 3 - Soft limit with a quadratic penalty. Permit interface flows to go outside of the specified interface flow limits, but penalize excursions along a quadratic curve. The *Soft limit penalty weight*, as defined below, is used in conjunction with this penalty to indicate severity of excursion.

	Refer to Section 14.7.2 Accommodating Inequality Constraints for more information on the limit type options. LTYP is 1 (Hard limit) by default
LPEN	The penalty weight value applied to either the linear or quadratic soft limit penalty functions. The larger the number, the higher the penalty for interface flow excursions outside of the defined interface flow limits. LPEN is 1.0 by default
Participating Branches	A list of branches defining the interface. Each branch is individually specified by the following identifiers: • IBUS - From bus number. The sending bus number (1 through 999997). When using the spreadsheet, this value may optionally be entered as a bus name, provided that *names* input mode is in effect. • JBUS - To bus number. The receiving end bus number (1 through 999997). When using the spreadsheet, this value may optionally be entered as a bus name, provided that *names* input mode is in effect. • CKT - Circuit ID. The one or two character circuit identifier. If no circuit identifier is entered, a default value of '1' is assumed. • KBUS - Third bus number. The third bus number (1 through 999997) if a three winding transformer is specified; zero (0) otherwise. When using the spreadsheet, this value may optionally be entered as a bus name, provided that *names* input mode is in effect.

The Interface Flow Constraint editor displays all Interface Flow Constraint records within the working case in the data table. The subsystem filter has no effect on the list displayed. If there are no Interface Flow Constraint records in the working case, then the editor window will be blank.

3.18. Linear Constraint Dependency Data

Linear Constraint Dependency records provide a way to introduce customized linear constraint equations into the optimal power flow problem statement. Each dependency equation may be comprised of any number of variables, selected from a group of previously defined records. Details of the linear constraint dependency equation model are discussed in Section 14.6.8 Linear Constraint Dependency Equation.

3.18.1. Linear Constraint Dependency Record

The format of each Linear Constraint Dependency data record is a multi-lined record as follows:

```
EQID, LABEL, SLKMAX, SLKMIN

VTYP, "ID FIELDS", COEFF

VTYP, "ID FIELDS", COEFF

...

0
```

Each field of the data record must be separated by either a space or a comma, with any blank fields delineated by commas. For each Linear Constraint Equation record entered, a single zero must be placed on the line immediately following the last participating variable record entered, or immediately after the main EQID record if no participating variables are specified.

An EQID value of zero indicates that no further linear constraint dependency records are to be processed.

Each Linear Constraint Dependency record is uniquely identified by a constraint equation identifier. The values for each field within the record are defined as follows:

EQID	The linear constraint equation identifier is an integer number. A value less than four digits in length is most suitable for reporting purposes.
LABEL	A string containing a maximum of 32 characters used to describe the linear constraint dependency equation being defined. This label is only used for reporting purposes. LABEL is '' by default
SLKMAX	The constraint equation maximum slack variable limit SLKMAX is 0.0 by default.
SLKMIN	The constraint equation minimum slack variable limit SLKMIN is 0.0 by default.
VTYP	A number (1 through 10) corresponding to the type of dependency variable being added to the constraint equation. The numerical values associated with each variable type are as follows: 1. voltage magnitude, in pu 2. voltage angle, in radians (degrees/57.29578) 3. active power generation, in per unit of reactive power based on system base(i.e. 400 MW limit base on a system base of 100 is entered as 4.0) 4. reactive power generation, in per unit of reactive power based on system base(i.e. 400 Mvar limit base on a system base of 100 is entered as 4.0) 5. transformer tap ratio, entered as the inverse of the tap ratio; or transformer phase shift angle, in radians 6. branch flow, in per unit flow value based on system base 7. interface flow, in per unit flow value based on system base 8. adjustable bus shunt, in per unit Mvar value based on system base 9. switched shunt, in per unit Mvar value based on system base 10. load adjustment, entered in terms of the load multiplier (i.e. 0.8 for 80% of load or 1.8 for 180% of load
"ID FIELDS"	Depending upon the variable type code selected above, one or more identification fields must be specified in order to uniquely identify the record to be employed as the variable entry. The identification fields corresponding to each of the variable type codes defined above, are as follows:

	1. Bus number (1 through 999997) 2. Bus number (1 through 999997) 3. Active power dispatch table number 4. Bus number (1 through 999997) Generator identifier [" 1"] 5. From bus number To bus number Circuit identifier [" 1"] Third bus number, if a three-winding transformer is specified; placed after the Coeff value [0] 6. From bus number To bus number Circuit identifier [" 1"] Branch flow identifier ["1"] Third bus number, if a three-winding transformer is specified; placed after the Coeff value [0] 7. Interface flow identifier 8. Bus number (1 through 999997) Adjustable bus shunt identifier [" 1"] 9. Bus number (1 through 999997) 10. Adjustable bus load table number Depending upon the variable type code selected above, one or more identification fields must be specified in order to uniquely identify the record to be employed as the variable entry. The identification fields corresponding to each of the variable type codes defined above, are as follows: When using the linear constraint equation table editor, bus identifiers may alternately be entered as extended bus names instead of bus number, provided that the *names* input mode option is in effect.
COEFF	A real variable coefficient applied to the dependency variable specified above. COEFF is 1.0 by default.

Any number of participating variables may be included in the linear constraint dependency equation. The variable identifiers must correspond to a record that already exists within the working case.

The Linear Constraint Dependency Equation data table displays in the editor all Linear Constraint Dependency Equation records within the working case. The subsystem filter has no effect on the list displayed. If there are no Linear Constraint Dependency Equation records in the working case, the editor window will be blank.

Chapter 4
GIC Data File Contents

4.1. Overview

The geomagnetic induced currents can flow through transformer winding and substation ground paths. For power flow calculations and substation ground paths data is not required. So this data is not available in power flow data. This additional data is provided in GIC data file (extension .gic). The accuracy of GIC calculations will depend on the data provided in GIC data file.

Depending on the size of the power flow network studied, this data could be large. It is recommended to create a GIC data template with one of the following ways and edit/modify that:

1. Using activity GIC GUI, GIC data file from Excel GIC data templates
   - GIC > Excel template for GIC data file
   - GIC > Create GIC data file from Excel template
2. Python module “gicdata” (See PSSE Application Program Interface (API) manual)

All data is read in free format with data items separated by a comma or one or more blanks. Each category of data except the change code is terminated by a record specifying an I value of zero. Termination of all data is indicated by a value of Q.

File Identification Data	
Substation Data	
Bus Substation Data	
Transformer Data	
Fixed Bus Shunt Data	
Branch Data	
User Earth Model Data	
Switched Shunt Data	
Two-Terminal DC Data	

VSC DC Data	
Multi-Terminal DC Data	
FACTS Device Data	
Load Data	
Q Record	

GIC Data Input Structure

4.2. File Identification Data

This record contains only one data item which is specified as:

```
GICFILEVRSN=vernum
```

GICFILEVRSN	GICFILEVRSN is the keyword to specify the GIC data file version number. vernum is an integer value specifying GIC data file version number. No default allowed. Allowed, GICFILEVRSN = 4 GICFILEVRSN = 5 Note: The first release of the GIC data file did not have this record and is treated as file version 1

At PSSE version 35.0.0, network equipment location information is consolidated in one source which is base case data. To faciliate that:

- The substation location information is moved from the GIC data file to the Base Case data (power flow data).
- When GIC data file version 4 is read, "Single Bus" substation configuration is added to each bus-substation data record and non Node-Breaker base case is converted to Node-Breaker base case.
- For this to work without any data conflicts, GIC data file version 4 is allowed to be read into base case that has no Node-Breaker configurations.

4.3. Substation Data

Some text here.

Each substation data record has the following format:

GICFILEVRSN 4

```
I, NAME, UNIT, LATITUDE, LONGITUDE, RG, EARTHMDL, RGFLAG
```

GICFILEVRSN 5

```
I, RG, EARTHMDL, RGFLAG
```

I	Substation number (1 through 999997) No default allowed.
NAME	Alphanumeric identifier assigned to substation I. NAME may be up to 40 characters and may contain any combination of blanks, uppercase letters, numbers and special characters, but the first character must not be a minus sign. NAME must be enclosed in single or double quotes if it contains any blanks or special characters. NAME = "" by default.
UNIT	Unit for geophysical location (longitude and longitude) data • 0 - degrees UNIT = 0 by default.
LATITUDE	Substation latitude, positive for North and negative for South. When UNIT = 1, latitude is specified in degrees. No default allowed.
LONGITUDE	Substation longitude, positive for East and negative for West. When UNIT = 1, longitude is specified in degrees. No default allowed.
RG	Substation grounding DC resistance in ohms. If RG <= 0.0 or RG > = 99.0, it is assumed that the substation is ungrounded. RG = 0.1 by default.
EARTHMDL	Name of the earth model. EARTHMDL may be up to 32 characters. • When specified this earth model will be used in determining Benchmark GMD event earth model scaling factor (beta) and Non-uniform GMD event calculations • When not specified, the earth model specified in GIC API is used. EARTHMDL = "" by default.
RGFLAG	Method used to specify RG value. RGFLAG may be up to 40 characters. It is used for informational purposes only. Possible methods: • "Assumed" • "Measured" • "Calculated" • "Brief comment of your choice" RGFLAG = "Assumed" by default.

4.4. Bus Substation Data

Each bus substation data record has the following format::

GICFILEVRSN 4

```
BUSNUM, SUBNUM
```

GICFILEVRSN 5

There is no bus substation data group.

BUSNUM	Bus number. Bus BUSNUM must be present in the working case. No default allowed.
SUBNUM	Substation number (1 through 999997). This is the substation number to which bus BUSNUM belongs to. SUBNUM must be previously defined in "Substation Data" record group. The following restrictions apply when assigning bus and its substation: • Generally two buses connected by a transmission line (non-transformer branch) reside in two different substations. Exception to this would be short lines between two buses of same substation. Those short branches are treated as zero length branches with no GMD induced voltage in those. • Two buses connected by a two winding transformer must be in same substation. • Three buses connected by a three winding transformer must be in same substation. • Two buses connected by zero impedance line must have same substation number. No default allowed.

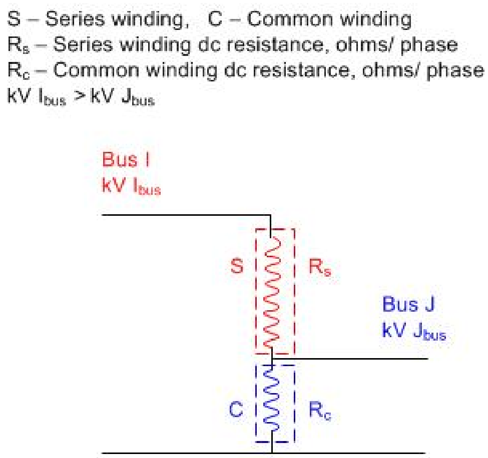
4.5. Transformer Data

The transformer specified by buses "I, J, K, CKT" must exist in the working case. Also the winding bus order must be same as in the working case.

Note 1 : For two and three winding auto transformers WRI, WRJ and WRK could represent per phase dc resistances of series winding (Rs) or common winding (Rc).

For example, as shown in figure below:

- Bus I is series winding bus, WRI=Rs
- Bus J is common winding bus, WRJ=Rc

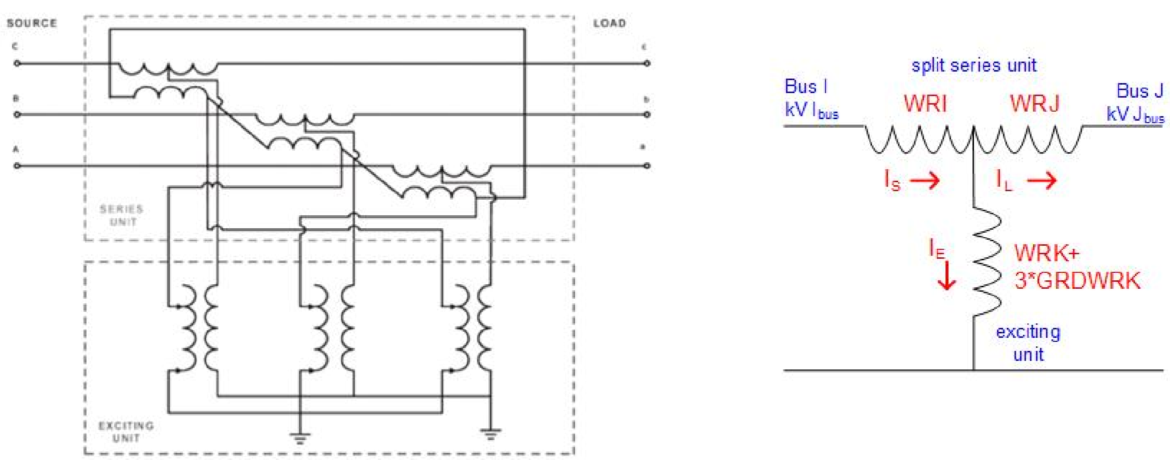


Two winding auto transformer circuit

Note 2 : Figure below shows generic Phase Angle Regulator (PAR) connections where series unit has split tap. It is represented as T model in GIC calculation DC network. The series unit is connected between Bus I and Bus J. In GIC data file:

- WRI is dc resistance of series unit section connected to Bus I
- WRJ is dc resistance of series unit section connected to Bus J
- WRK is dc resistance of exciting unit

It is imperative that WRI, WRJ and WRK values are calculated and specified in GIC data file for correct modeling of such a transformer.



(a) AC Connections

(b) GIC Equivalent DC Circuit T Model

Split Series Winding Phase Angle Regulator Circuit

Each transformer data record has the following format:

```
I, J, K, CKT, WRI, WRJ, WRK, GICBDI, GICBGJ, GICBDK, VECGRP, CORE, KFACTOR,
GRDWRI, GRDWRJ, GRDWRK, TMODEL
```

I	The bus number of the bus to which Winding 1 is connected. It must be same Winding 1 bus for the same transformer in the working case. No default allowed
J	The bus number of the bus to which Winding 2 is connected. It must be same Winding 2 bus for the same transformer in the working case. No default allowed
K	The bus number of the bus to which Winding 3 is connected. It must be same Winding 3 bus for the same transformer in the working case. K = 0 for two winding transformers. No default allowed for three winding transformers.
CKT	One- or two-character branch circuit identifier. CKT = '1' by default
WRI	DC resistance of Winding 1 in ohms/phase. When WRI is not specified, working case resistance is used to determine WRI. DC resistance of series unit of PAR (see Note 2). WRI = 0.0 by default
WRJ	DC resistance of Winding 2 in ohms/phase. When WRJ is not specified, working case resistance is used to determine WRJ. DC resistance of series unit of PAR (see Note 2). WRJ = 0.0 by default
WRK	DC resistance of Winding 3 in ohms/phase. For three-winding transformers, when WRK is not specified, working case resistance is used to determine WRK. DC resistance of exiciting unit of PAR (see Note 2). WRK = 0.0 by default
GICBDI	GIC blocking device in neutral of Winding 1 • 0 - no GIC blocking device present • 1 - GIC blocking device present For an auto-transformers, if either GICBDI = 1 or GICBDJ = 1, that auto-transformer is treated as if it has GIC blocking device present. GICBDI = 0 by default
GICBDJ	GIC blocking device in neutral of Winding 2 • 0 - no GIC blocking device present • 1 - GIC blocking device present For an auto-transformers, if either GICBDI = 1 or GICBDJ = 1, that auto-transformer is treated as if it has GIC blocking device present.

	GICBDJ = 0 by default
GICBDK	GIC blocking device in neutral of Winding 3 • 0 - no GIC blocking device present • 1 - GIC blocking device present GICBDK = 0 by default. GICBDK = 0 for two-winding transformers.
VECGRP	Alphanumeric identifier specifying vector group based on transformer winding connections and phase angles. If vector group is specified in power flow data that data will be used and it is not needed to be specified here. As far as GIC calculations are concerned, winding grounding connection information is used; its clock angles are not used. Refer to POM Sections "Two Winding Transformer Vector Groups" and "Three Winding Transformer Vector Groups" for allowed vector groups. • When bus number orders in GIC data file record are different than the bus number orders in power flow RAW data file, the bus number orders in power flow RAW data file is used to assign winding configuration as per vector group specified. • For auto-transformers, bus with lower base bus voltage is treated as common winding bus. • For three-winding auto-transformers, windings on bus I and bus J form auto-transformer. VECGRP = "" by default
CORE	Number of cores in transformer core design. This information is used to calculate transformer reactive power loss from GIC flowing its winding. • -1 - three phase shell form • 0 - unknown core design • 1 - single phase core • 3 - three phase 3-legged core form • 5 - three phase 5-legged core form CORE = 0 by default
KFACTOR	Factor to calculate transformer reactive power loss from GIC flowing its winding (MVAR/AMP) KFACTOR = 0.0 by default
GRDWRI	Winding 1 grounding DC resistance in ohms GRDWRI = 0.0 by default (no grounding resistance; solidly grounded)
GRDWRJ	Winding 2 grounding DC resistance in ohms GRDWRJ = 0.0 by default (no grounding resistance; solidly grounded)

GRDWRK	Winding 3 grounding DC resistance in ohms DC resistance of exciting unit grounding of PAR (see Note 2). GRDWRK = 0.0 by default (no grounding resistance; solidly grounded)
TMODEL	Number of cores in transformer core design. This information is used to calculate transformer reactive power loss from GIC flowing its winding. • 0 - two/three/auto transformer model as defined by its vector group • 1 - transformer as T model in DC network (See Note 2) TMODEL = 0 by default

4.6. Fixed Bus Shunt Data

Only in-service fixed bus shunts provided on this data record are modeled in the GIC DC network.

Each fixed bus shunt data record has the following format:

```
I, ID, R, RG
```

I	Bus number of the bus to which the fixed shunt is connected. It must be present in the working case. No default allowed
ID	One- or two-character fixed bus shunt identifier. ID = '1' by default
R	DC resistance in ohms/phase. It must be > 0.0. Fixed bus shunt records with R = 0.0 will be ignored. No default allowed
RG	Grounding DC resistance in ohms RG = 0.0 by default (no grounding resistance; solidly grounded)

4.7. Branch Data

Only in-service branches are modeled in the GIC DC network.

Each user branch data record has the following format:

```
I, J, CKT, RBRN, INDVP, INDVQ, RLNSHI, RLNSHJ
```

I	Branch from bus number No default allowed
J	Branch to bus number No default allowed
CKT	One- or two-character transformer circuit identifier; a transformer with circuit identifier CKT between buses I and J must be in the working case.

	CKT = '1' by default
RBRN	Branch DC resistance in ohms/phase. When RBRN is not specified or RBRN=0.0, power flow data branch resistance in pu is converted to ohms/phase and used. There is no temperature correction applied. RBRN = 0.0 by default
INDVP	Real part of total branch GMD induced electric field in volts. See note below on how to specify this value.
INDVQ	Imaginary part of total branch GMD induced electric field in volts. See note below on how to specify this value.
	Note 1 : Total branch GMD induced electric field, INDUCEDV = INDVP + j INDVQ volts Branch INDUCEDV is determined as below: • When INDUCEDV is not specified, GIC activity calculates this according to its options specified • When INDUCEDV is specified, it is used as GMD induced on that branch • When INDUCEDV is specified as INDVP = 0.0 and INDVQ = 0.0, then that branch is treated as part of the GIC DC network but does not have GMD induced voltage, like “underground pipe-type cables (cables enclosed in the steel pipe).” For uniform filed modeling INDUCEDV will be real value, but for non-uniform field modeling this will be complex value. This voltage will have positive polarity at branch To Bus (J bus). Note 2 : • When the Branch INDVP + j INDVQ is specified, it is used as is. There are no other scaling factors applied to this voltage. • When INDVP + j INDVQ is specified for all branches, specified GMD event option is ignored during GIC calculations. • When INDVP + j INDVQ is specified for few branches, the induced Efield for remaining branches in study subsystem is calculated using the GMD event option specified.
RLNSHI	DC resistance in ohms/phase of the line shunt at the bus I end of the branch. It must be > 0. When RLNSHI = 0 or not specified, there will be no ground path for this line shunt. No default allowed
RLNSHJ	DC resistance in ohms/phase of the line shunt at the bus J end of the branch. It must be > 0. When RLNSHJ = 0 or not specified, there will be no ground path for this line shunt. No default allowed

4.8. User Earth Model Data

Activity GIC models US and Canada Earth Models (Ref...). However, if any other Earth Model is required, use this data to define such an earth model. A total of up to 50 user earth models are allowed. Also each earth model may have up to 25 layers. Use as many records needed to specify the data. The thickness of the last layer is infinity. This is specified as any value less than 0.0 (= -999.0 for example). The thickness value less than 0.0 is also used as end of earth model data.

Each user earth model data record has the following format:

```
NAME, BETAFTR, DESC, RESISTIVITY1, THICKNESS1, RESISTIVITY2, THICKNESS2, ...,
RESISTIVITY24, THICKNESS24, RESISTIVITY25, THICKNESS25
```

NAME	The non-blank alphanumeric identifier assigned to this earth model. Each earth model must have unique name. NAME may be up to 32 characters. This name should be different than the Standard US and Canada Earth Models defined (Refer ...). No default allowed
BETAFTR	Earth Model scaling factor used when calculating branch induced electric field for Benchmark GMD event. BETAFTR = 1 by default
DESC	Description of the earth model. NAME may be up to 72 characters. This is used for information purpose only DESC = "" by default
$RESISTIVITY_1$	Layer 1 resistivity in ohm-m No default allowed
$THICKNESS_1$	Layer 1 thickness in km No default allowed
$RESISTIVITY_N$	Nth layer resistivity in ohm-m. Up to 25 layers are allowed No default allowed
$THICKNESS_N$	Nth layer 1 thickness in km. Up to 25 layers are allowed. The thickness of the last layer is infinity. This is specified as any value less than 0 (= -999.0 for example). No default allowed

4.9. Switched Shunt Data

Only in-service switched shunts provided on this data record are modeled in the GIC DC network.

Each switched shunt data record has the following format:

GICFILEVRSN 4

```
I, R, RG
```

GICFILEVRSN 5

```
I, ID, R, RG
```

I	Bus number; bus I must be present in the working case with positive sequence switched shunt data.

R	DC resistance in ohms/phase. It must be > 0.0. Switched shunt records with R = 0.0 will be ignored. No default allowed
RG	Grounding DC resistance in ohms. No grounding resistance; solidly grounded. RG = 0.0 by default

4.10. Two-Terminal DC Data

The rectifier and inverter converter stations are connected to ac network through converter transformers. If these converter transformers are not explicitly modeled in the power flow, then use this data record to specify the GIC DC network data for them.

Provide DC resistance data of grounded windings of converter transformers.

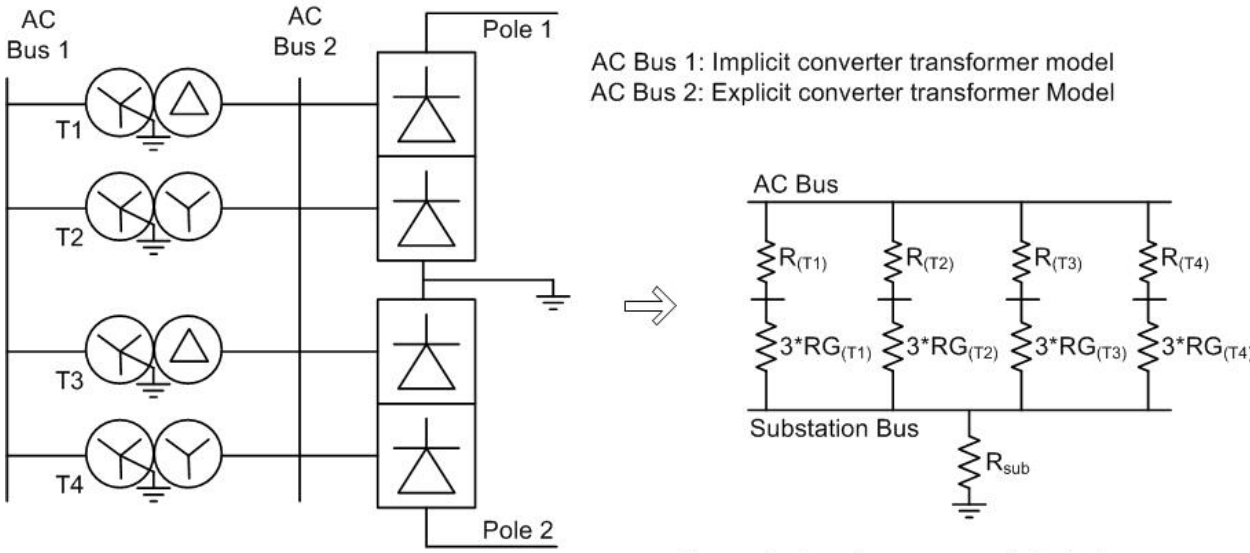
The status (blocked or in-service) of two-terminal DC lines from power flow data is not considered. The DC data provided on this data record is modeled in the GIC DC network. Up to 10 GIC DC network elements are allowed per DC line.

Each two-terminal DC data record has the following format:

```
NAME, I, ID, R, RG
```

NAME	The non-blank alphanumeric identifier assigned to this DC line. It must be present in the working case. NAME may be up to 12 characters. No default allowed
I	Bus number of the rectifier (IPR) or inverter (IPI) converter AC bus. It must be present in the working case. No default allowed
ID	One- or two-character non-blank alphanumeric identifier. There could be more than one ground path at rectifier or inverter ac bus. This ID is used to be able to specify more than one ground path. This is specific to GIC data and it does not exist in the working case. No default allowed
R	DC resistance in ohms/phase of grounded winding of converter transformers. It must be > 0.0. R = 0.0 or not specified means there will be no ground path. No default allowed
RG	Grounding DC resistance in ohms RG = 0.0 by default (no grounding resistance; solidly grounded)

Two-terminal DC data input is terminated with a record specifying a bus number of zero.



Typical HVDC Converter station

Converter transformer grounded windings representation in GIC DC network

4.11. VSC DC Data

The rectifier and inverter converter stations are connected to ac network through converter transformers. If these converter transformers are not explicitly modeled in the power flow, then use this data record to specify the GIC DC network data for them.

Provide DC resistance data of grounded windings of converter transformers.

The status (blocked or in-service) of VSC DC lines from power flow data is not considered. The DC data provided on this data record is modeled in the GIC DC network. Up to 10 GIC DC network elements are allowed per DC line.

Each VSC DC data record has the following format:

```
NAME, I, ID, R, RG
```

NAME	The non-blank alphanumeric identifier assigned to this VSC DC line. It must be present in the working case. NAME may be up to 12 characters. No default allowed
I	Bus number of the rectifier (IPR) or inverter (IPI) converter AC bus. It must be present in the working case. No default allowed
ID	One- or two-character non-blank alphanumeric identifier. There could be more than one ground path at rectifier or inverter ac bus. This ID is used to be able to specify more than one ground path. This is specific to the GIC data and it does not exist in the working case. No default allowed
R	DC resistance in ohms/phase of grounded winding of converter transformers. It must be > 0.0. R = 0.0 or not specified means there will be no ground path.

	No default allowed
RG	Grounding DC resistance in ohms RG = 0.0 by default (no grounding resistance; solidly grounded)

VSC DC data input is terminated with a record specifying a bus number of zero.

4.12. Multi-Terminal DC Data

The multi-terminal converters are connected to ac network through converter transformers. If these converter transformers are not explicitly modeled in the working case, then use this data record to specify the GIC DC network data for them.

Provide DC resistance data of grounded windings of converter transformers.

The status (blocked or in-service) of multi-terminal DC lines in the working case is not considered. The DC data provided on this data record is modeled in the GIC DC network. Up to 10 GIC DC network elements are allowed per DC line.

Each multi-terminal DC data record has the following format:

```
NAME, I, ID, R, RG
```

NAME	The non-blank alphanumeric identifier assigned to this Multi-Terminal DC line. It must be present in the working case. NAME may be up to 12 characters. No default allowed
I	Converter ac bus number (IB). It must be present in the working case. No default allowed
ID	One- or two-character non-blank alphanumeric identifier. There could be more than one ground path at ac bus. This ID is used to be able to specify more than one ground path. This is specific to the GIC data and it does not exist in the working case. No default allowed
R	DC resistance in ohms/phase of grounded winding of converter transformers. It must be > 0.0. R = 0.0 or not specified means there will be no ground path. No default allowed
RG	Grounding DC resistance in ohms RG = 0.0 by default (no grounding resistance; solidly grounded)

Multi-Terminal DC data input is terminated with a record specifying a bus number of zero.

4.13. FACTS Device Data

The FACTS device converters are connected to ac network through converter transformers. If these converter transformers are not explicitly modeled in the working case, then use this data record to specify the GIC DC network data for them.

Provide DC resistance data of grounded windings of converter transformers.

The status (in-service or out-of-service) of FACTS device from power flow data is not considered. The DC data provided on this data record is modeled in the GIC DC network. Up to 10 GIC DC network elements are allowed per DC line.

Each multi-terminal DC data record has the following format:

```
NAME, I, ID, R, RG
```

NAME	The non-blank alphanumeric identifier assigned to this FACTS device. It must be present in the working case. NAME may be up to 12 characters. No default allowed
I	FACTS device sending end bus number (IBUS). It must be present in the working case. No default allowed
ID	One- or two-character non-blank alphanumeric identifier. There could be more than one ground path at ac bus. This ID is used to be able to specify more than one ground path. This is specific to the GIC data and it does not exist in the working case. No default allowed
R	DC resistance in ohms/phase of grounded winding of converter transformers. It must be > 0.0. R = 0.0 or not specified means there will be no ground path. No default allowed
RG	Grounding DC resistance in ohms RG = 0.0 by default (no grounding resistance; solidly grounded)

FACTS device data input is terminated with a record specifying a bus number of zero.

4.14. Load Data

Only in-service loads provided on this data record are modeled in the GIC DC network.

Each load data record has the following format:

```
I, ID, R, RG
```

I	Bus number of the bus to which load is connected. It must be present in the working case. No default allowed
ID	One- or two-character non-blank alphanumeric load identifier. ID = '1' by default
R	DC resistance in ohms/phase of grounded loads. It must be > 0.0. R = 0.0 or not specified means there will be no ground path. No default allowed

RG	Grounding DC resistance in ohms RG = 0.0 by default (no grounding resistance; solidly grounded)

Load data input is terminated with a record specifying a bus number of zero.

Chapter 5
Harmonics Data File Contents

5.1. Overview

To perform network frequency scan or run harmonic analayis following data is needed.

1. power flow data (.raw file)
2. sequence flow data (.seq file)
3. network elements frequency dependency data
4. harmonic sources data

These additional data items (3) and (4) are provided in Harmonics data text file (.har) or xml file (.xhar). The accuracy of Harmonic analysis will depend on the quality this additional data provided.

This section describes the format of .har file. All data in .har file is read in free format with data items separated by a comma or one or more blanks. Each category of data except the File Identification is terminated by a record specifying a value of zero as first value on that data record. Termination of all data is indicated by a value of Q.

File Identification Data	
Impedance Characteristics Data	
Voltage Sources Data	
Current Sources Data	
Load Data	
Generator (Synchronous Machine) Data	
Non-Transformer Branch Data	
Transformer Data	
Two-Terminal DC Data	
VSC DC Data	

FACTS Device Data	
Induction Machine (Asynchronous Machine) Data	
Q Record	

5.2. File Identification Data

This record contains only one data item which is specified as:

`HARFILEVRSN=vernum`

HARFILEVRSN	HARFILEVRSN is the keyword to specify the harmonics data file version number. vernum is an integer value specifying harmonics data file version number. No default allowed. Allowed, HARFILEVRSN = 1

5.3. Impedance Characteristics Data

The frequency dependency of various network elements is defined in this table. The resistance (R), inductance (L) and capacitance (C) at harmonic number 'N' is specified as ratio of its value at that harmonic to its fundamental (system) frequency value (RN/R0, LN/L0 and CN/C0).

There is no limit on number of harmonics modeled in each impedance characteristics table. The table data can span on more than one text line. End of data for the table is specified by specifying 0 value for harmonic number.

Each Impedance Characteristics data table has the following format:

```
NAME, FREQ1, R1/R0, L1/LO, C1/C0, FREQ2, R2/R0, L2/LO, C2/C0, .., FREQN, RN/
R0, LN/LO, CN/C0, 0
```

NAME	The non-blank alphanumeric identifier assigned to table. Each Impedance Characteristics table must have unique NAME. The NAME may be up to 40 characteristics and may contain any combination of blanks, uppercase letters, numbers and special characters, but the first character must not be a minus sign. The NAME must be enclosed in single or double quotes if it contains any blanks or special characters. No default allowed.
FREG	Frequency No default allowed. HN = 0 means end of table data

RN/R0	Ratio of resistance at harmonic number 'N' to its resistance at fundamental frequency. No default allowed.
LN/L0	Ratio of inductance at harmonic number 'N' to its inductance at fundamental frequency. No default allowed.
CN/C0	Ratio of capacitance at harmonic number 'N' to its capacitance at fundamental frequency. No default allowed.

Impedance Characteristics Data input is terminated with a record specifying table NAME as 0 (zero).

5.4. Voltage Sources Data

The harmonic voltage sources are defined in this table.

There is no limit on number of harmonics modeled in each voltage sources table. The table data can span on more than one text line. End of data for the table is specified by specifying 0 value for harmonic number.

Each Voltage Sources data table has the following format:

```
NAME, ANGLE, H1, V1/V0, ANG1, H2, V2/V0, ANG2, .., HN, VN/V0, ANGN, 0
```

NAME	The non-blank alphanumeric identifier assigned to table. Each Voltage Sources table must have unique NAME. The NAME may be up to 40 characteristics and may contain any combination of blanks, uppercase letters, numbers and special characters, but the first character must not be a minus sign. The NAME must be enclosed in single or double quotes if it contains any blanks or special characters. No default allowed.
ANGLE	Default angle determination • 0 - No • 1 - Yes ANGLE = 0 by default SINCAL value = Flag_DefAngle
HN	Harmonic Number, N No default allowed. HN = 0 means end of table data
VN/V0	Ratio of voltage at harmonic number 'N' to voltage at fundamental frequency. No default allowed.
ANGN	Angle in degrees at harmonic number 'N'.

	No default allowed.

Voltage Sources Data input is terminated with a record specifying table NAME as 0 (zero).

5.5. Current Sources Data

The harmonic current sources are defined in this table.

There is no limit on number of harmonics modeled in each current sources table. The table data can span on more than one text line. End of data for the table is specified by specifying 0 value for harmonic number.

Each Current Sources data table has the following format:

```
NAME, CURTYP, ANGLE, H1, I1/I0, ANG1, H2, I2/I0, ANG2, .., HN, IN/I0, ANGN, 0
```

NAME	The non-blank alphanumeric identifier assigned to table. Each Current Sources table must have unique NAME. The NAME may be up to 40 characteristics and may contain any combination of blanks, uppercase letters, numbers and special characters, but the first character must not be a minus sign. The NAME must be enclosed in single or double quotes if it contains any blanks or special characters. No default allowed.
CURTYP	Current source state • 1 - Current in A • 2 - Current in % CURTYP = 2 by default SINCAL value = Flag_I
ANGLE	Default angle determination • 0 - No • 1 - Yes ANGLE = 1 by default SINCAL value = Flag_DefAngle
HN	Harmonic Number, N No default allowed. HN = 0 means end of table data
IN/I0	Ratio of current at harmonic number 'N' to current at fundamental frequency. No default allowed.
ANGN	Angle in degrees at harmonic number 'N'. No default allowed.

Current Sources Data input is terminated with a record specifying table NAME as 0 (zero).

5.6. Load Data

The frequency dependency behavior and harmonics contribution of only in-service loads provided on this data record are modeled.

Each load data record has the following format:

```
I, ID, HSTATE, HTYPE, HQUALITY, HIREG, HPK, ZHARM_TABLE, VHARM_TABLE, IHARM_TABLE
```

I	Bus number of the bus to which the load is connected. It must be present in the working case. No default allowed
ID	One- or two-character load identifier. ID = '1' by default
HSTATE	Current control state • 0 - Not active in harmonics • 1 - Active in harmonics HSTATE = 1 by default
HTYPE	Harmonic type • 0 - No frequency dependency • 1 - Quality - R constant (serial) • 2 - Quality - X/R constant (serial) • 3 - Impedance characteristics • 4 - Quality - X/R constant (parallel) • 5 - CIGRE • 6 - Quality - R constant (parallel) • 9 - Infinite HTYPE = 1 by default SINCAL value = Flag_Har
HQUALITY	Harmonic quality constant HQUALITY = 1.0 by default.
HIREG	Control current HCTRLCUR = 0.0 by default

	SINCAL value = Ireg
HPK	Reference Compensation Power HPK = 0.0 by default SINCAL value = pk
ZHARM_TABLE	Previously defined Harmonic Impedance Characteristics table name. The frequency behavior of the load is modeled using the impedance characteristics specified in this table. When table is not found or specified as blank, the frequency dependency of the load is ignored. ZHARM_TABLE = '' by default.
VHARM_TABLE	Previously defined Harmonic Voltage Source table name. When modeled the load will inject the voltage harmonics to the network at bus 'I'. The voltage source value at harmonic 'N' is calculated using the voltage source characteristics specified in this table. When table is not found or specified as blank, the voltage harmonics by the load are ignored. VHARM_TABLE = '' by default.
IHARM_TABLE	Previously defined Harmonic Current Source table name. When modeled the load will inject the current harmonics in the network at bus 'I'. The Current source value at harmonic 'N' is calculated using the current source characteristics specified in this table. When table is not found or specified as blank, the current harmonics by the load are ignored. IHARM_TABLE = '' by default.

Load Data input is terminated with a record specifying bus number 0 (zero).

5.7. Generator Data

The frequency dependency behavior and harmonics contribution of only in-service generators provided on this data record are modeled.

Each generator data record has the following format:

```
I, ID, HSTATE, HTYPE, HQUALITY, ZHARM_TABLE, VHARM_TABLE, IHARM_TABLE
```

I	Bus number of the bus to which the generator is connected. It must be present in the working case. No default allowed
ID	One- or two-character generator identifier. ID = '1' by default
HSTATE	Current control state • 0 - Not active in harmonics • 1 - Active in harmonics

	HSTATE = 1 by default
HTYPE	Harmonic type • 0 - No frequency dependency • 1 - Quality - R constant (serial) • 2 - Quality - X/R constant (serial) • 3 - Impedance characteristics • 4 - CIGRE model - A • 5 - CIGRE model - B • 9 - Infinite HTYPE = 1 by default SINCAL value = Flag_Har
HQUALITY	Harmonic quality constant HQUALITY = 1.0 by default.
ZHARM_TABLE	Previously defined Harmonic Impedance Characteristics table name. The frequency behavior of the generator is modeled using the impedance characteristics specified in this table. When table is not found or specified as blank, the frequency dependency of the generator is ignored. ZHARM_TABLE = '' by default.
VHARM_TABLE	Previously defined Harmonic Voltage Source table name. When modeled the generator will inject the voltage harmonics to the network at bus 'I'. The voltage source value at harmonic 'N' is calculated using the voltage source characteristics specified in this table. When table is not found or specified as blank, the voltage harmonics by the generator are ignored. VHARM_TABLE = '' by default.
IHARM_TABLE	Previously defined Harmonic Current Source table name. When modeled the generator will inject the current harmonics in the network at bus 'I'. The Current source value at harmonic 'N' is calculated using the current source characteristics specified in this table. When table is not found or specified as blank, the current harmonics by the generator are ignored. IHARM_TABLE = '' by default.

Generator Data input is terminated with a record specifying bus number 0 (zero).

5.8. Non-Transformer Branch Data

The frequency dependency behavior of only in-service non-transformer branches provided on this data record are modeled.

Each non-transformer branch data record has the following format:

```
I, J, CKT, HSTATE, HTYPE, HQUALITY, ZHARM_TABLE
```

I	Branch from bus number. It must be present in the working case. No default allowed
J	Branch to bus number. It must be present in the working case. No default allowed
CKT	One- or two-character non-transformer branch identifier. A branch with cicuit identifier CKT between buses I and J must be in the working case. CKT = '1' by default
HSTATE	Current control state • 0 - Not active in harmonics • 1 - Active in harmonics HSTATE = 1 by default
HTYPE	Harmonic type • 0 - No frequency dependency • 1 - Quality - R constant • 2 - Quality - X/R constant • 3 - Impedance characteristics • 4 - CIGRE HTYPE = 1 by default SINCAL value = Flag_Har
HQUALITY	Harmonic quality constant HQUALITY = 1.0 by default.
ZHARM_TABLE	Previously defined Harmonic Impedance Characteristics table name. The frequency behavior of the non-transformer branch is modeled using the impedance characteristics specified in this table. When table is not found or specified as blank, the frequency dependency of the non-transformer branch is ignored. ZHARM_TABLE = '' by default.

Non-Transformer Branch Data input is terminated with a record specifying bus number 0 (zero).

5.9. Transformer Data

The frequency dependency behavior and harmonics contribution of only in-service transformers provided on this data record are modeled.

Each transformer data record has the following format:

```
I, J, K, CKT, HSTATE, HTYPE, HQUALITY, ZHARM_TABLE, IHARM_TABLE
```

I	Transformer Winding 1 bus number. It must be present in the working case. No default allowed
J	Transformer Winding 2 bus number. It must be present in the working case. No default allowed
K	Transformer Winding 3 bus number. K is specified as 0 (zero) to indicate that no third winding is present. When K specified is non-zero, it must be present in the working case. K = 0 by default.
CKT	One- or two-character transformer identifier. A transformer with cicuit identifier CKT between buses I and J (and K if K is non-zero) must be in the working case. CKT = '1' by default
HSTATE	Current control state • 0 - Not active in harmonics • 1 - Active in harmonics HSTATE = 1 by default
HTYPE	Harmonic type • 0 - No frequency dependency • 1 - Quality - R constant (serial) • 2 - Quality - X/R constant (serial) • 3 - Impedance characteristics • 4 - CIGRE model - A • 5 - CIGRE model - B HTYPE = 1 by default SINCAL value = Flag_Har
HQUALITY	Harmonic quality constant HQUALITY = 1.0 by default.
ZHARM_TABLE	Previously defined Harmonic Impedance Characteristics table name. The frequency behavior of the transformer is modeled using the impedance characteristics specified in this table. When table is not found or specified as blank, the frequency dependency of the transformer is ignored. ZHARM_TABLE = '' by default.
IHARM_TABLE	Previously defined Harmonic Current Source table name. When modeled the transformer will inject the current harmonics in the network at bus 'I'. The Current source

	value at harmonic 'N' is calculated using the current source characteristics specified in this table. When table is not found or specified as blank, the current harmonics by the transformer are ignored. IHARM_TABLE = '' by default.

Transformer Data input is terminated with a record specifying bus number 0 (zero).

5.10. Two-Terminal DC Data

The voltage and current harmonics contribution of only in-service two-terminal dc lines provided on this data record are modeled.

Each two-terminal dc line data record has the following format:

```
NAME, ACBUS, HSTATE, VHARM_TABLE, IHARM_TABLE
```

NAME	The non-blank alphanumeric two-terminal dc line name. It must be present in the working case. No default allowed
ACBUS	Two-terminal dc line rectifier or inverter converter AC bus number. A two-terminal dc line 'NAME' with 'ACBUS' as one of the rectifier or inverter buses must be in the working case. No default allowed
HSTATE	Current control state • 0 - Not active in harmonics • 1 - Active in harmonics HSTATE = 1 by default
VHARM_TABLE	Previously defined Harmonic Voltage Source table name. When modeled the two-terminal dc line will inject the voltage harmonics to the network at bus 'ACBUS'. The voltage source value at harmonic 'N' is calculated using the voltage source characteristics specified in this table. When table is not found or specified as blank, the voltage harmonics by the two-terminal dc line are ignored. VHARM_TABLE = '' by default.
IHARM_TABLE	Previously defined Harmonic Current Source table name. When modeled the two-terminal dc line will inject the current harmonics in the network at bus 'ACBUS'. The Current source value at harmonic 'N' is calculated using the current source characteristics specified in this table. When table is not found or specified as blank, the current harmonics by the two-terminal dc line are ignored. IHARM_TABLE = '' by default.

Two-Terminal DC Data input is terminated with a record specifying NAME as 0 (zero).

5.11. VSC DC Data

The voltage and current harmonics contribution of only in-service VSC dc lines provided on this data record are modeled.

Each VSC dc line data record has the following format:

```
NAME, ACBUS, HSTATE, VHARM_TABLE, IHARM_TABLE
```

NAME	The non-blank alphanumeric VSC dc line name. It must be present in the working case. No default allowed
ACBUS	VSC dc line converter AC bus number. A VSC dc line 'NAME' with 'ACBUS' as one of its converters AC buses must be in the working case. No default allowed
HSTATE	Current control state • 0 - Not active in harmonics • 1 - Active in harmonics HSTATE = 1 by default
VHARM_TABLE	Previously defined Harmonic Voltage Source table name. When modeled the VSC dc line will inject the voltage harmonics to the network at bus 'ACBUS'. The voltage source value at harmonic 'N' is calculated using the voltage source characteristics specified in this table. When table is not found or specified as blank, the voltage harmonics by the VSC dc line are ignored. VHARM_TABLE = '' by default.
IHARM_TABLE	Previously defined Harmonic Current Source table name. When modeled the VSC dc line will inject the current harmonics in the network at bus 'ACBUS'. The Current source value at harmonic 'N' is calculated using the current source characteristics specified in this table. When table is not found or specified as blank, the current harmonics by the VSC dc line are ignored. IHARM_TABLE = '' by default.

VSC DC Data input is terminated with a record specifying NAME as 0 (zero).

5.12. FACTS Device Data

The voltage and current harmonics contribution of only in-service FACTS devices provided on this data record are modeled.

Each FACTS device data record has the following format:

```
NAME, SENDBUS, TERMBUS, HSTATE, HTYPE, HQUALITY, ZHARM_TABLE, VHARM_TABLE,
IHARM_TABLE
```

NAME	The non-blank alphanumeric FACTS device name. It must be present in the working case.

	No default allowed
SENDBUS	FACTS device Sending End AC bus number. A FACTS device 'NAME' with 'SENDBUS' as its sending AC bus must be in the working case. A SENDBUS value must be provided as every FACTS device has as least one bus, making it a shunt device. No default allowed
TERMBUS	FACTS device Terminal End AC bus number. A FACTS device 'NAME' with 'TERMBUS' as its terminal AC bus must be in the working case. A TERMBUS value must be provided if the FACTS device is operating as a serial device. TERMBUS = 0 by default
HSTATE	Current control state • 0 - Not active in harmonics • 1 - Active in harmonics HSTATE = 1 by default
HTYPE	Harmonic type If TERMBUS = 0: • 0 - No frequency dependency • 1 - Quality - R constant (serial) • 2 - Quality - X/R constant (serial) • 3 - Impedance characteristics • 4 - Quality - X/R constant (parallel) • 5 - CIGRE • 6 - Quality - R constant (parallel) • 9 - Infinite If TERMBUS != 0: • 0 - No frequency dependency • 1 - Quality - R constant (serial) • 2 - Quality - X/R constant (serial) • 3 - Impedance characteristics HTYPE = 1 by default SINCAL value = Flag_Har
HQUALITY	Harmonic quality constant

	HQUALITY = 1.0 by default.
ZHARM_TABLE	This item is required if the FACTS device is serial device, SENDBUS AND TERMBUS != 0. Previously defined Harmonic Impedance Characteristics table name. The frequency behavior of the generator is modeled using the impedance characteristics specified in this table. When table is not found or specified as blank, the frequency dependency of the generator is ignored. ZHARM_TABLE = '' by default.
VHARM_TABLE	This item is required if the FACTS device is shunt device, TERMBUS != 0. Previously defined Harmonic Voltage Source table name. When modeled the FACTS device will inject the voltage harmonics to the network at bus 'ACBUS'. The voltage source value at harmonic 'N' is calculated using the voltage source characteristics specified in this table. When table is not found or specified as blank, the voltage harmonics by the FACTS device are ignored. VHARM_TABLE = '' by default.
IHARM_TABLE	This item is required if the FACTS device is shunt device, TERMBUS != 0. Previously defined Harmonic Current Source table name. When modeled the FACTS device will inject the current harmonics in the network at bus 'ACBUS'. The Current source value at harmonic 'N' is calculated using the current source characteristics specified in this table. When table is not found or specified as blank, the current harmonics by the FACTS device are ignored. IHARM_TABLE = '' by default.

FACTS Device Data input is terminated with a record specifying NAME as 0 (zero).

5.13. Induction Machine (Asynchronous machine) Data

The frequency dependency behavior and harmonics contribution of only in-service induction machines provided on this data record are modeled.

Each induction machine data record has the following format:

```
I, ID, HSTATE, HTYPE, HQUALITY, ZHARM_TABLE, VHARM_TABLE, IHARM_TABLE
```

I	Bus number of the bus to which the induction machine is connected. It must be present in the working case. No default allowed
ID	One- or two-character induction machine identifier. ID = '1' by default
HSTATE	Current control state • 0 - Not active in harmonics • 1 - Active in harmonics

	HSTATE = 1 by default
HTYPE	Harmonic type • 0 - No frequency dependency • 1 - Quality - R constant • 2 - Quality - X/R constant • 3 - Impedance characteristics • 9 - Infinite HTYPE = 1 by default SINCAL value = Flag_Har
HQUALITY	Harmonic quality constant HQUALITY = 1.0 by default.
ZHARM_TABLE	Previously defined Harmonic Impedance Characteristics table name. The frequency behavior of the induction machine is modeled using the impedance characteristics specified in this table. When table is not found or specified as blank, the frequency dependency of the induction machine is ignored. ZHARM_TABLE = '' by default.
VHARM_TABLE	Previously defined Harmonic Voltage Source table name. When modeled the induction machine will inject the voltage harmonics to the network at bus 'I'. The voltage source value at harmonic 'N' is calculated using the voltage source characteristics specified in this table. When table is not found or specified as blank, the voltage harmonics by the induction machine are ignored. VHARM_TABLE = '' by default.
IHARM_TABLE	Previously defined Harmonic Current Source table name. When modeled the induction machine will inject the current harmonics in the network at bus 'I'. The Current source value at harmonic 'N' is calculated using the current source characteristics specified in this table. When table is not found or specified as blank, the current harmonics by the induction machine are ignored. IHARM_TABLE = '' by default.

Induction Machine Data input is terminated with a record specifying bus number 0 (zero).

Chapter 6
Machine Capability Curve Data File

6.1. Overview

The input stream to activity REGC consists of a Change Code record, followed by a group of capability curve data records. One such record is specified for each machine whose capability curve is to be read into the working case.

All data is read in free format with data items separated by a comma or one or more blanks. The capability curve data category is terminated by a record specifying an I value of zero.

6.2. Change Code Data

The first record in the Capability Curve Data File contains two data items as follows:

```
IC, REV
```

IC	New capability curve data flag: IC = 0 indicates the initial input of capability curve data for the network contained in the working case. Any capability curves in the case are deleted from the case before adding the capability curves specified in the input file. IC = 1 indicates change case input of capability curve data for the network contained in the working case. If a record is specified for a machine that already has a capability curve, default values for omitted data items are the existing values of the capability curve. IC = 0 by default
REV	PSSE revision number REV = current revision by default

6.3. Capability Curve Data

Each machine to be represented with its capability curve in PSSE must be specified in a capability curve data record. Each data record in this file has the following format:

```
I, ID, P1, QT1, QB1, P2, QT2, QB2, ... P20, QT20, QB20
```

where:

I	Bus number. Bus I must be present in the working case with a plant sequence number assigned to it (refer to Plant and Machine Sequence Numbers).

	No default is allowed
ID	One-or two character machine identifier used to distinguish among multiple machines at a plant (i.e., at a generator bus) ID = 1 by default
P_i	Generator active power output along the MW axis of the machine's capability curve, entered in MW No default is allowed
QT_i	Maximum (i.e., overexcited) reactive power limit at P_i MW, entered in Mvar QT_i = 0.0 by default
QB_i	Minimum (i.e., underexcited) reactive power limit at P_i MW, entered in Mvar QB_i = 0.0 by default

At least two sets of points must be specified for each capability curve; up to 20 sets of points on the capability curve may be entered. When the machine is a generator, the P_i values must be in ascending order with P_1 greater than or equal to zero. When the machine is a motor, the P_i values must be in descending order with P_1 less than or equal to zero.

Capability curves may be specified for non-conventional as well as conventional machines. For a non-conventional machines with a machine control mode (WMOD) greater than 1, the capability curve will not be used to update the machine's reactive power limits; the limits will be determined from the specified power factor (WPF) for mode 2 and 3 machines, and from the machine's fixed reactive power (QG) for mode 4 machines.

Data input is terminated with a record specifying a bus number of zero.

In the PSS®E EXAMPLE directory, there is an example capability curve established for the machines in the *savnw.sav* power flow case. The data file is savnw.gcp, and the contents of the file are listed in Figure 6.1, "Capability Curve Example for savnw.sav Case". A generic plot of the reactive limits for the machine at bus 206 is shown.

I	ID	P1	QT1	QB1	P2	QT2	QB2	P3	QT3	QB3
101	1	0	800	-100	500	650	-100	900	0	0
102	1	0	800	-100	500	650	-100	900	0	0
206	1	100	600	0	500	400	0	1000	0	0
211	1	0	800	-100	500	750	-100	950	0	0
3011	1	100	200	-100	1000	600	-100			
3018	1	130	80	0						
0										

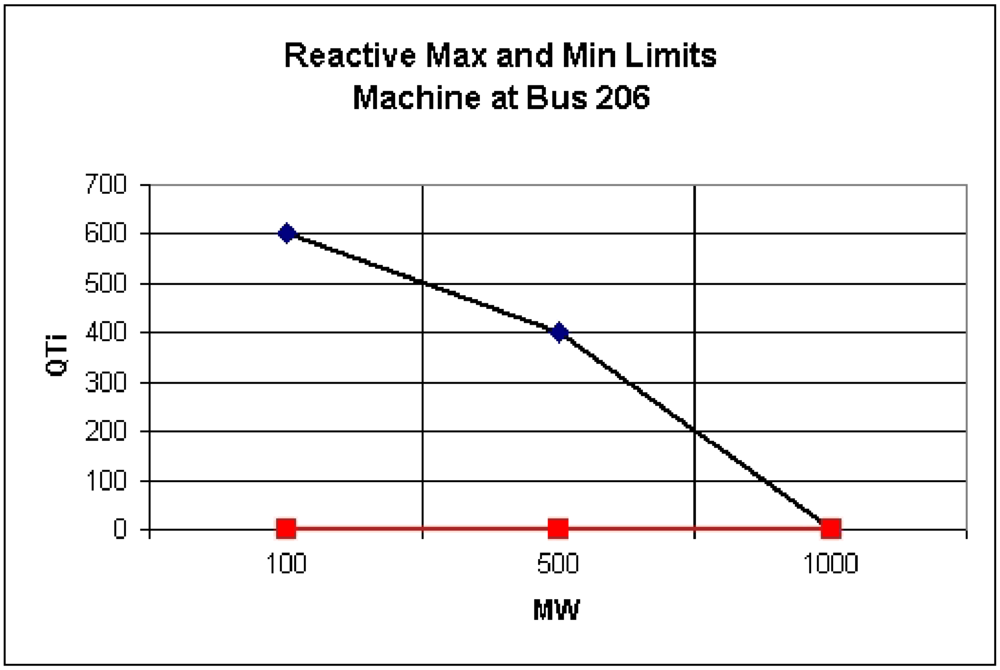


Figure 6.1. Capability Curve Example for savnw.sav Case

Chapter 7
IEC Data File

7.1. Overview

The impedances and admittances of electrical equipment in the working case are modified according to the correction factors defined in IEC 60909-0 (2016 Section 6 or 2001 Section 3).

Generators, equivalent generators, asynchronous motors, wind farms and photovoltaic (PV) farms are represented as sources in the working case. To calculate their impedance correction factors or correct contribution to fault additional data is required. This additional data is provided in IEC data file (.iec).

Additional data is needed in the following cases.

- If a generator model includes a GSU transformer. It is recommended to represent the GSU transformer explicitly as a separate power component so as to be able to correctly modify the generator and transformer impedances as per the IEC 60909 standard.
- If a generator in the working case is an equivalent generator representation.
- If a generator is a used in the modeling of a synchronous motor.
- If a generator is set with QMIN=QMAX, then it is treated as an asynchronous motor. If this is the case, then additional data is not necessary.
- If a transformer winding MVA specified in system MVA base and not nameplate winding MVA.
- If an induction machine base power (MBASE) is specified as mechanical power output (BCODE=1), then power factor and efficiency are needed to calculate base MVA. If an induction machine scheduled active power (PSET) is set as real electrical power drawn by the machine, efficiency is needed to calculate mechanical power output (MW) of the machine.
- If a generator in the working case is a Wind Farm or PV Farm.

There are six groups of records, with each group containing a particular type of data required. Each record is terminated by specifying a bus number of 0.

7.2. File Identification Data

This record contains only one data item which is specified as:

```
IECFILEVRSN=vernum
```

IECFILEVRSN	IECFILEVRSN is the keyword to specify the IEC data file version number. vernum is an integer value specifying IEC data file version number. No default allowed.

	Allowed, IECFILEVRSN = 2 Note: The first release of the IEC data file did not have this record and is treated as file version 1

7.3. GSU, Equivalent Generator and Motor Data

(Induction Motors are specified as part of Generator data category.)

Each data record has the following format:

I, ID, MCTYPE, UrG, PG, PFactor, PolePair, GSUType, Ix, Jx, Kx, Ckt, PT

where:

I	Machine bus number
ID	Machine ID
MCTYPE	Machine type MCTYPE =1, for Generator MCTYPE =2, for Equivalent generator MCTYPE =3, for Induction machines specified as part of generator data category MCTYPE =4, for Wind power station asynchronous generator MCTYPE =5, for Wind power station double fed asynchronous generator MCTYPE =6, for Wind or Photovoltaic power station generator with full size converter
UrG	Rated terminal voltage, line-to-line in kV r.m.s. (this need not be the rated bus voltage)
PG	Range of generator voltage regulation in %, e.g., if PG is ±5%, enter PG=5. PG = (UG -UrG)/UrG, where UG is the scheduled generator terminal voltage = 0 default
PFactor	Generator rated power factor (used only if MCTYPE=1). This is used in impedance correction factor calculations. = 1.0 default
PolePair	Number of pole pairs if machine is induction machine (used only if the machine is modeled as induction machine) Example: If the induction machine has a six pole construction then Polepair=3
GSUType	Generator step-up-transformer type GSUType =0, no GSU, GSU transformer modeled explicitly. GSUType =1, GSU with OLTC

	GSUType =2, GSU without OLTC
Ix	GSU transformer I bus number = 0 by default to specify no GSU transformer
Jx	GSU transformer J bus number = 0 by default to specify no GSU transformer
Kx	GSU transformer K bus number = 0 by default to specify no GSU transformer
Ckt	GSU transformer circuit identifier = blank ('') by default to specify no GSU transformer
PT	Tap range of GSU off-load tap-changer transformer in % of transformer winding rated voltage, e.g., if PT is ±5%, enter PT=5 = 0.0 by default to ignore off-load tap range

7.4. Transformer Nameplate Winding MVA Data

Each data record has the following format:

I, J, K, Ckt, Sbase 1-2, Sbase 2-3, Sbase 3-1

where:

I	Winding 1 bus number
J	Winding 2 bus number
K	Winding 3 bus number (=0 for two-winding transformer)
Ckt	Transformer circuit identifier
Sbase 1-2	Winding 1 to winding 2 Nameplate MVA
Sbase 2-3	Winding 2 to winding 3 Nameplate MVA (not required for two-winding transformer)
Sbase 3-1	Winding 3 to winding 1 Nameplate MVA (not required for two-winding transformer)

7.5. Induction Machine Data

(Induction Motors are specified as part of Induction machine data category)

Each data record has the following format:

I, ID, PolePair, PFactor, Efficiency

where:

I	Machine bus number
ID	Machine ID
PolePair	Number of pole pairs Example: If the induction machine has a six pole construction then Polepair=3
PFactor	Induction Machine rated power factor = 1.0 default
Efficiency	Induction Machine percent efficiency. =100 by default Example: Efficiency=96.5 for 96.5% efficiency.

7.6. Wind Power Station Asynchronous Generator Data

(These equipment are specified as part of Generator data category and modeled as MCTYPE=4 in IEC data file.)

Each data record has the following format:

I, ID, ILR2IR_1, R2X_1, ILR2IR_2, R2X_2, ILR2IR_0, R2X_0

where:

I	Machine bus number
ID	Machine ID
ILR2IR_1	Ratio of Positive Sequence locked rotor current to rated current, no default allowed.
R2X_1	Ratio of Positive Sequence resistance to reactance =0.1 by default
ILR2IR_2	Ratio of Negative Sequence locked rotor current to rated current ILR2IR_2=ILR2IR_1 by default
R2X_2	Ratio of Negative Sequence resistance to reactance R2X_2=R2X_1 by default
ILR2IR_0	Ratio of Zero Sequence locked rotor current to rated current ILR2IR_0=ILR2IR_1 by default
R2X_0	Ratio of Zero Sequence resistance to reactance R2X_0=R2X_1 by default

7.7. Wind Power Station Doubly Fed Asynchronous Generator Data

(These equipment are specified as part of Generator data category, and modeled as MCTYPE=5 in IEC data file.)

Each data record has the following format:

I, ID, IMAX_1, R2X_1, IMAX_2, R2X_2, IMAX_0, R2X_0, KWD, IKWDmax, IKWDmin

where:

I	Machine bus number

ID	Machine ID
IMAX2IR_1	Ratio of Positive Sequence highest instantaneous short circuit value in case of a three-phase short circuit to rated current, no default allowed
R2X_1	Ratio of Positive Sequence resistance to reactance. R2X_1=0.1 by default
IMAX2IR_2	Ratio of Negative Sequence highest instantaneous short circuit value in case of an unbalance short circuit to rated current, IMAX2IR_2=IMAX2IR_1 by default
R2X_2	Ratio of Negative Sequence resistance to reactance. R2X_2=R2X_1 by default
IMAX2IR_0	Ratio of Zero Sequence highest instantaneous short circuit value in case of an unbalance short circuit to rated current, IMAX2IR_0=IMAX2IR_1 by default
R2X_0	Ratio of Zero Sequence resistance to reactance. R2X_0=R2X_1 by default
KWD	Factor for the calculation of the peak short-circuit current, KWD=1.7 by default
IkWDmax	Ratio of maximum steady state short circuit current to rated current, IkWDmax=IMAX2IR_1 by default. This is used in calculation of symmetrical breaking current.
IkWDmin	Ratio of minimum steady state short circuit current to rated current, IkWDmin=IMAX2IR_1 by default. This is used in calculation of symmetrical breaking current.

7.8. Wind and Photovoltaic Power Station Generator with Full Size Converter Data

(These equipment are specified as part of Generator data category, and modeled as MCTYPE=6, 7 in IEC data file.)

Each data record has the following format:

I, ID, IMAX_1, R2X_1, IMAX_2, R2X_2, IMAX_0, R2X_0, IkPFmax, IkPFmin

where:

I	Machine bus number
ID	Machine ID
IMAX2IR_1	Ratio of Positive Sequence short circuit current value to rated current, no default allowed
R2X_1	Ratio of Positive Sequence resistance to reactance. R2X_1=0.1 by default
IMAX2IR_2	Ratio of Negative Sequence short circuit current value to rated current, IMAX2IR_2=IMAX2IR_1 by default
R2X_2	Ratio of Negative Sequence resistance to reactance. R2X_2=R2X_1 by default
IMAX2IR_0	Ratio of Zero Sequence short circuit value in case of an unbalance short circuit to rated current, IMAX2IR_0=IMAX2IR_1 by default
R2X_0	Ratio of Zero Sequence resistance to reactance. R2X_0=R2X_1 by default
IkPFmax	Ratio of maximum steady state short circuit current to rated current, IkPFmax=IMAX2IR_1 by default. This is used in calculation of symmetrical breaking current.
IkPFmin	Ratio of minimum steady state short circuit current to rated current, IkPFmin=IMAX2IR_1 by default. This is used in calculation of symmetrical breaking current.

IEC File Data records for generators, transformers and motors are created only for those units that need IEC data and they may be entered in any order and using a free format with blanks or commas separating each data item in each record group.

Following is an example of IEC data for IEC 60909-4, Section 6 network, refer PAG for details.

```
1  Q1 2
5  Q2 2
6  G3 1 10.5 0.0 0.8
41 G1 1 21.0 0.0 0.85 0 1 4 41 0 T1 12
31 G2 1 10.5 7.5 0.9  0 2 3 31 0 T2
0 / END OF GSU, EQV, GEN, AND INDUCTION MACHINE DATA
0 / END OF TRANSFORMER DATA
7  M1 1 0.88 97.5
7  M2 2 0.89 96.8
7  M3 2 0.89 96.8
0 / END OF INDUCTION MACHINE DATA
Q
```

or

```
IECFILEVRSN=2
1  Q1 2
5  Q2 2
6  G3 6 10.5 0.0 0.8
41 G1 4 21.0 0.0 0.85 0 1 4 41 0 T1 12
31 G2 5 10.5 7.5 0.9  0 2 3 31 0 T2
0 / END OF GSU, EQV, GEN, AND MOTOR DATA
0 / END OF TRANSFORMER DATA
7  M1 1 0.88 97.5
7  M2 2 0.89 96.8
7  M3 2 0.89 96.8
0 / END OF INDUCTION MACHINE DATA
41 G1 5.0 0.2
0 / END OF WIND POWER STATION ASYNCHRONOUS GENERATOR DATA
31 G2 6.0 0.3
0 / END OF WIND POWER STATION DOUBLY FED ASYNCHRONOUS GENERATOR DATA
6 G3 7.0 0.4
0 / END OF WIND AND PHOTOVOLTAIC POWER STATION GENERATOR WITH FULL SIZE CONVERTER DATA
Q
```