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
```

where:

IC — New Case FlagSequence Data Input Structure:

- 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 — PSS®E revision number. REV = current revision (33) 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 this data value.

XFRRAT $\leq$ 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 $\leq$ 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.

Bus Data

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

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

where:

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 is 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 boundary condition) 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

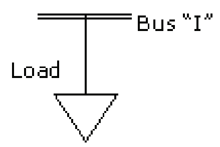
Bus data input is terminated with a record specifying a bus number of zero.

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).

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 Section 6.3.13, Load, activities CONL and RCNL, Section 12.3.1, Modeling Load Characteristics and Section 12.3.2, 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
```

where:

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.

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

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

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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).

At PSS®E 33.0, the interruptible load flag is for informational purposes only.

Constant Power Load Characteristic

The constant power characteristic holds the load power 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 5-2 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 *PSS®E GUI Users Guide*, Section 12.1.1, Boundary Conditions).

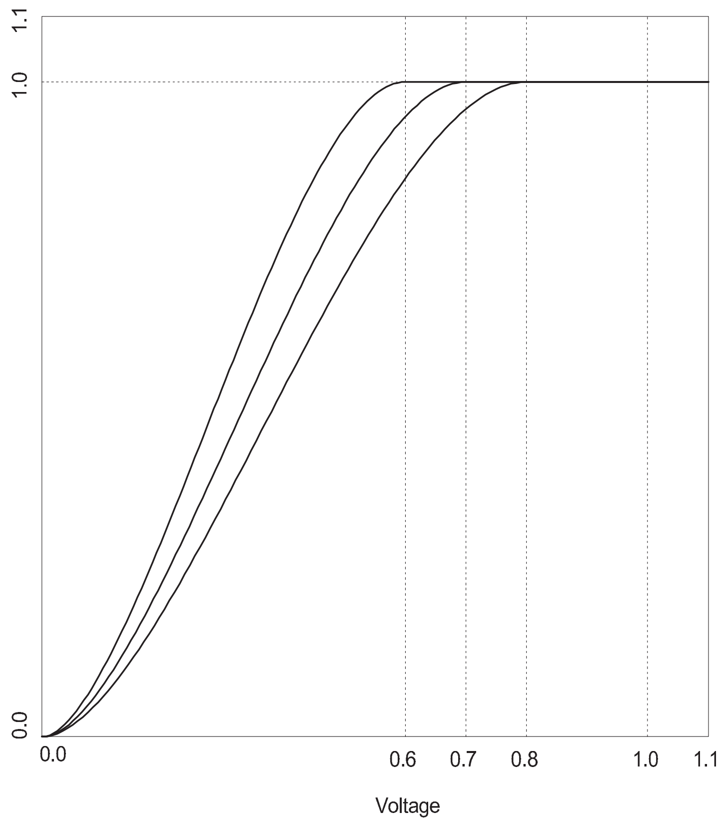


Figure 5-2. Constant Power Load Characteristic

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 5-3 for voltages below 0.5 pu.

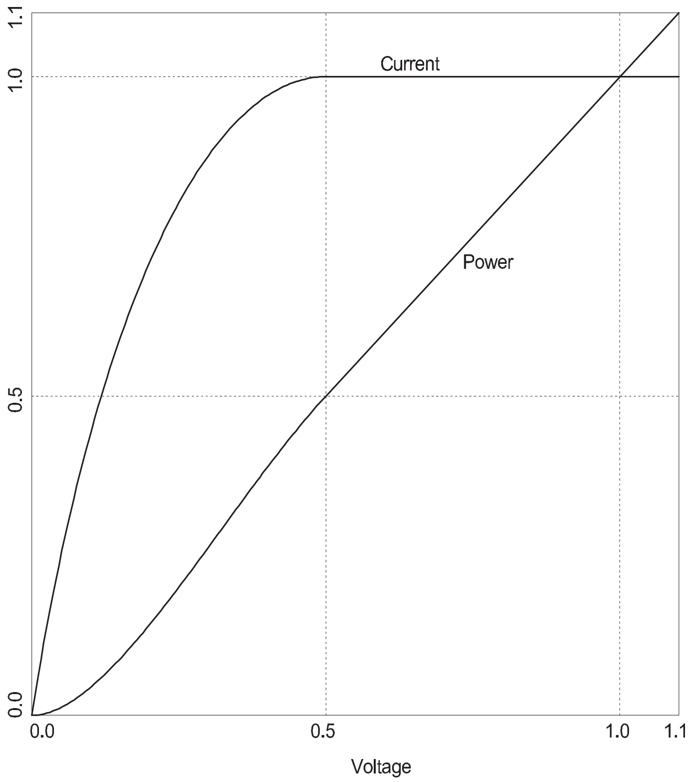
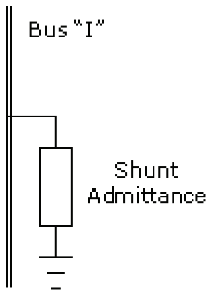


Figure 5-3. Constant Current Load Characteristic

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.



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Each fixed bus shunt data record has the following format:

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

where:

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	Active component 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.

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 11.7, Summarizing Area Totals through Section 11.12, 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.

Generator Data

Each network bus to be represented as a generator or plant bus in PSS®E 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.

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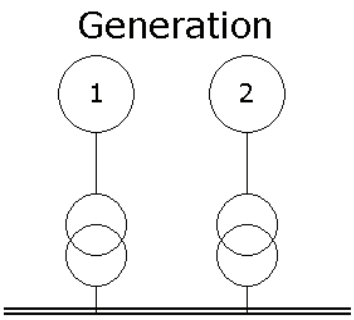

Each generator has a single line data record with the following format:

```
I,ID,PG,QG,QT,QB,VS,IREG,MBASE,ZR,ZX,RT,XT,GTAP,STAT,
                            RMPCT,PT,PB,O1,F1,...,O4,F4,WMOD,WPF
```

where:

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. 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. 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 a remote Type 1 or 2 bus for which voltage is to be regulated by this plant to the value specified by VS. If bus IREG is other than a Type 1 or 2 bus, bus I regulates its own voltage to the value specified by VS. IREG is entered as zero if the plant is to regulate its own voltage and **must** be zero for a Type 3 (swing) 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.

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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 IREG specifies a valid remote bus and there is more than one local or remote voltage controlling device (plant, switched shunt, FACTS device shunt element, or VSC dc line converter) controlling the voltage at bus IREG to a setpoint, or IREG is zero but bus I is the controlled bus, local or remote, of one or more other setpoint mode voltage controlling devices. 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	Wind machine control mode; WMOD is used to indicate whether a machine is a wind machine, and, if it is, the type of reactive power limits to be imposed. 0 for a machine that is not a wind machine. 1 for a wind machine for which reactive power limits are specified by QT and QB. 2 for a wind 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 for a wind 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. WMOD = 0 by default.

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WPF	Power factor used in calculating reactive power limits or output when WMOD is 2 or 3. WPF = 1.0 by default.

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

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 Section 6.3.12, Generation and Section 6.3.18, AC Voltage Control.

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 5-4 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.

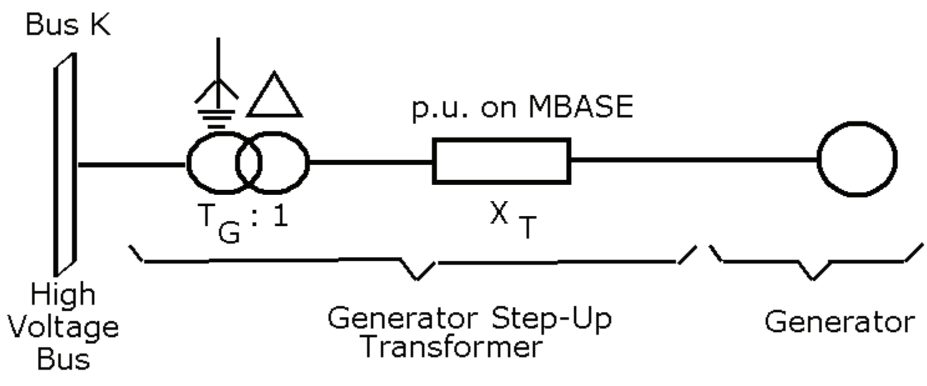

Figure 5-4. Implicit GSU Configuration – Specified as Part of the Generator

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 5-5, 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.

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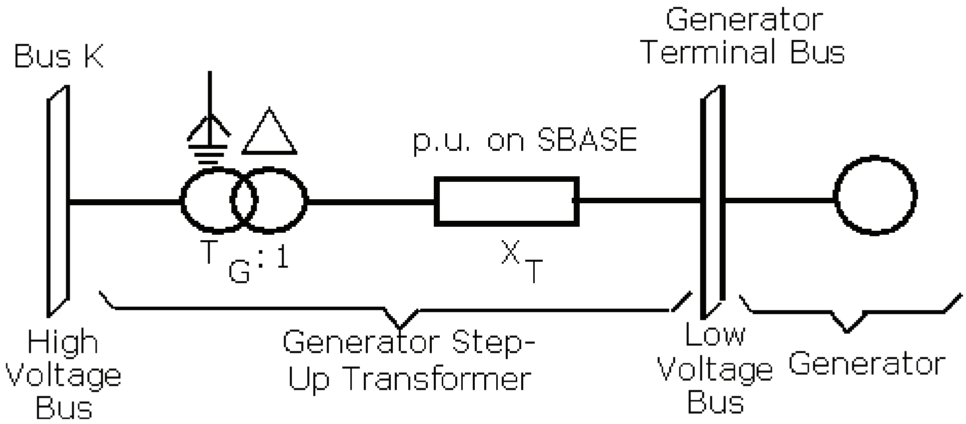

Figure 5-5. Explicit GSU Configuration – Specified Separately from the Generator

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, Reading Power Flow Data Additions from the Terminal, 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 PSS®E 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 5-6 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 5-7 shows the generator data records corresponding to Figure 5-6.

The separate transformer data records for the explicitly represented transformers from buses 1238 and 1239 to bus 1237 are not included in Figure 5-7.

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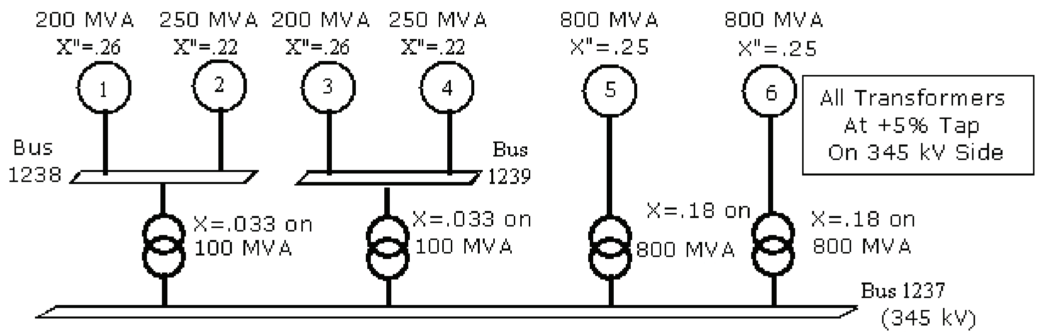

Figure 5-6. Multiple Generators at a Single Plant

(not specified)

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

Figure 5-7. Data Set for the Multiple Generators in Figure 5-6

Non-Transformer Branch Data

Each ac network branch to be represented in PSS®E 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 PSS®E, the basic transmission line model is an Equivalent Pi connected between network buses. Figure 5-8 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.

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

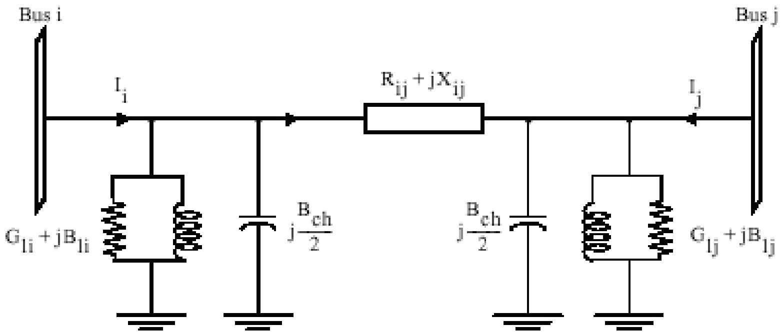

Figure 5-8. Transmission Line Equivalent Pi Model

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

```
I,J,CKT,R,X,B,RATEA,RATEB,RATEC,GI,BI,GJ,BJ,ST,MET,LEN,O1,F1,...,O4,F4
```

where:

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 an at sign (@), the branch is treated as a breaker; if it is an asterisk (*), it is treated as a switch (see Section 6.15.2, Outage Statistics Data File Contents). 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 Section 7.2, GIC Data File Contents). 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.
RATEA	First 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). RATEA = 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.
RATEB	Second 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). RATEB = 0.0 by default.

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RATEC — Third 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). RATEC = 0.0 by default.

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.

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. By default, each Fi is 1.0.

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

Zero Impedance Lines

PSS®E 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.

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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.

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Breaker and Switch Branches

The breakers and switches are represented as non-transformer branches in PSS®E. A non-transformer branch with an at sign '@' or an asterisk '*' in the first character of circuit ID is identified as a breaker or a switch respectively.

Most activities do not honor the breaker and switch circuit ID. Breaker and switch branches are treated as zero impedance lines if they have characteristics of zero impedance lines; otherwise, they are treated as regular non-transformer branches. It is recommended that a non-transformer branch with the breaker circuit ID or switch circuit ID be modeled as a zero impedance line.

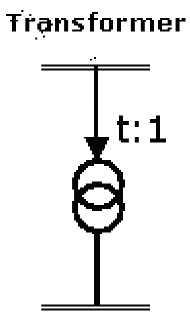
Breaker and switch branches are recognized in Substation Reliability Assessment (refer to Section 6.16, Calculating Substation Reliability) and activity DFAX. Substation Reliability Assessment simulates operations of breakers to isolate faults in a substation and manual switching to restore the service 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, PSS®E is able to handle ring loop arrangement 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 breaker or a switch branch into a network model, connectivity nodes where the terminals of a transmission line connect to the terminals of the breaker or switch must be added too. That 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.

Transformer Data

Each ac transformer to be represented in PSS®E 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 Correction Tables.

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.



$t = t_1 / t_2$; transformer turns ratio

t_1: winding 1 turns ratio in kV or pu on bus voltage base or winding voltage base

t_2: winding 2 turns ratio in kV or pu on bus voltage base or winding voltage base

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Figure 5-9 shows the transformer winding configurations.

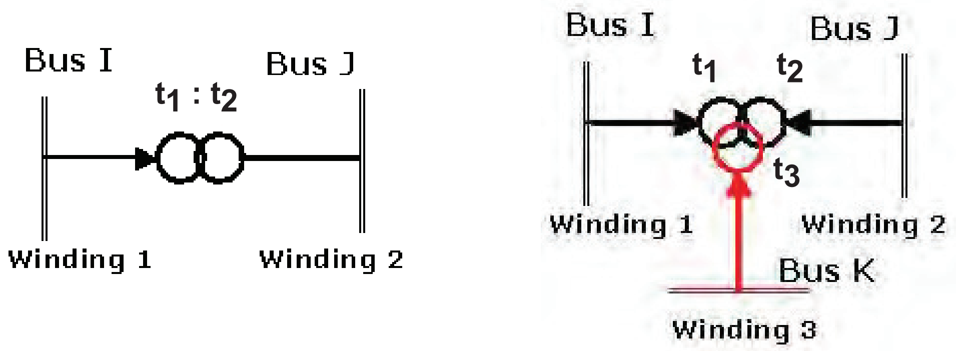

Figure 5-9. Two and Three-winding Transformer Configurations Related to Data Records

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
R1-2,X1-2,SBASE1-2,R2-3,X2-3,SBASE2-3,R3-1,X3-1,SBASE3-1,VMSTAR,ANSTAR
WINDV1,NOMV1,ANG1,RATA1,RATB1,RATC1,COD1,CONT1,RMA1,RMI1,VMA1,VMI1,NTP1,TAB1,CR1,CX1,CNXA1
WINDV2,NOMV2,ANG2,RATA2,RATB2,RATC2,COD2,CONT2,RMA2,RMI2,VMA2,VMI2,NTP2,TAB2,CR2,CX2,CNXA2
WINDV3,NOMV3,ANG3,RATA3,RATB3,RATC3,COD3,CONT3,RMA3,RMI3,VMA3,VMI3,NTP3,TAB3,CR3,CX3,CNXA3
```

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,RATA1,RATB1,RATC1,COD1,CONT1,RMA1,RMI1,VMA1,VMI1,NTP1,TAB1,CR1,CX1,CNXA1
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 PSS®E.

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).

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All data items on the first record are specified for both two- and 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 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. NAME is twelve blanks 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. By default, each Fi is 1.0.
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.

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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.

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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 -180.0º and less than or equal to +180.0º. ANG1 = 0.0 by default.
RATA1, RATB1, RATC1	Winding 1's three 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). RATA1 = 0.0, RATB1 = 0.0 and RATC1 = 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.

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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.

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.

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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 -180.0º and less than or equal to +180.0º. ANG2 = 0.0 by default.
RATA2, RATB2, RATC2	Winding 2's three 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). RATA2 = 0.0, RATB2 = 0.0 and RATC2 = 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.

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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.
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.

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.

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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 -180.0º and less than or equal to +180.0º. ANG3 = 0.0 by default.

RATA3, RATB3, RATC3 Winding 3's three 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). RATA3 = 0.0, RATB3 = 0.0 and RATC3 = 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.

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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.

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.

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

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 PSS®E 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 PSS®E, 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?).

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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.

Example Two-Winding Transformer Data Records

Figure 5-10 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, 01, F1, ..., 04, F4, VECGRP

R1-2, X1-2, SBASE1-2

WINDV1, NOMV1, ANG1, RATA1, RATB1, RATC1, COD1, CONT1, RMA1, RMI1, VMA1, VMI1, NTP1, TAB1, CR1, CX1, CNXA1

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

1.01, 0.0, 0.0, 50.0, 60.0 ,75.0, 1, 6151, 1.1, 0.9, 1.025, 1.0, 33, 0, 0.0, 0.0

1.0, 0.0

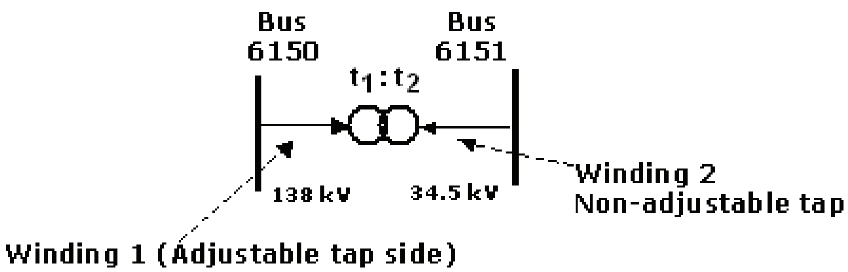

Figure 5-10. Sample Data for Two-Winding Transformer

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Example Three-Winding Transformer Data Records

Figure 5-11 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, 01, F1, ..., 04, F4, VECGRP

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

WINDV1, NOMV1, ANG1, RATA1, RATB1, RATC1, COD1, CONT1, RMA1, RMI1, VMA1, VMI1, NTP1, TAB1, CR1, CX1, CNXA1

WINDV2, NOMV2, ANG2, RATA2, RATB2, RATC2, COD2, CONT2, RMA2, RMI2, VMA2, VMI2, NTP2, TAB2, CR2, CX2, CNXA2

WINDV3, NOMV3, ANG3, RATA3, RATB3, RATC3, COD3, CONT3, RMA3, RMI3, VMA3, VMI3, NTP3, TAB3, CR3, CX3, CNXA3

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, 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

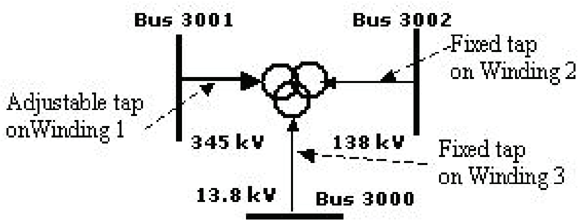

Figure 5-11. Sample Data for Three-Winding Transformer

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Two Winding Transformer Vector Groups

Table 5-1, 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 5-1. 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

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Table 5-1. Examples of Two Winding Transformer Vector Groups

Vector Group	PSSE Phase Angle (ANG1)	Transformer Type	Connection Code (CC)	Transformer Type	Connection Code (CC)
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

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Three Winding Transformer Vector Groups

Table 5-2, 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.

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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

C=11

	Allowed Winding Configurations	Allowed Clock Positions
Winding 1	YN	0, 6
Winding 2	yn	0, 6
Winding 3	yn	0, 6
Examples	YN0yn6d5, ANG1=0, ANG2=180, ANG3=-150	
	YN6yn0d1, ANG1=180, ANG2=0, ANG3=-30	

C=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	
	YN6yn0d1, ANG1=180, ANG2=0, ANG3=-30	

C=13

	Allowed Winding Configurations	Allowed Clock Positions
Winding 1	D	1, 5, 7, 11
Winding 2	yn	0, 6
Winding 3	y	0, 6
	d	1, 5, 7, 11
Examples	D1yn0y6, ANG1=-30, ANG2=0, ANG3=180	
	Y0yn0d5, ANG1=0, ANG2=0, ANG3=-150	

C=14

	Allowed Winding Configurations	Allowed Clock Positions

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Winding 1	Y	0, 6
	D	1, 5, 7, 11
Winding 2	y	0, 6
	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	

C=15

	Allowed Winding Configurations	Allowed Clock Positions
Winding 1*	D	1, 5, 7, 11
Winding 2	yn d	0, 6 1, 5, 7, 11
Winding 3*	d	1, 5, 7, 11
Examples	D1yn0d1, ANG1=-30, ANG2=0, ANG3=-30	
	1yn6d11, ANG1= 30, ANG2=180, ANG3=30	

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

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C=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	

C=17

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

C=18

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

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 PSS®E functions to one or more subsets of the complete power system model. PSS®E 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. PSS®E 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 PSS®E 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.

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Figure 5-12 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.

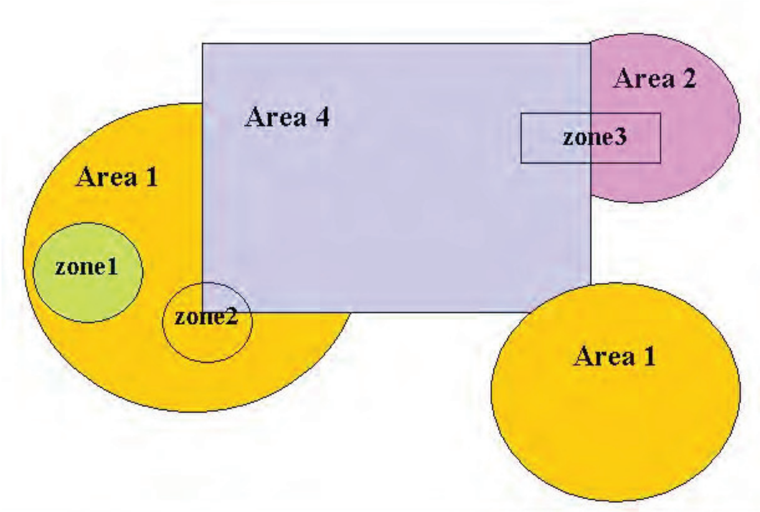

Figure 5-12. Overlapping Areas and Zones

Assigning ownership attributes to buses and other equipment allows an additional subdivision of the network for analysis and documentation purposes. PSS®E 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

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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

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'
```

where:

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.

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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.

Area Interchange Data Notes

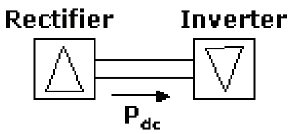
All buses (ac and dc), loads and induction machines can be assigned to an area. The area number is entered as part of the data records for the buses, loads, and induction machines (see Areas, Zones and Owners, Bus Data, Load Data and Multi-Terminal DC Transmission Line Data).

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 PSS®E 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.

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 PSS®E 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,IFR,ITR,IDR,XCAPR
IPI,NBI,ANMXI,ANMNI,RCI,XCI,EBASI,TRI,TAPI,TMXI,TMNI,STPI,ICI,IFI,ITI,IDI,XCAPI
```

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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.

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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	Rectifier firing angle measuring bus number, 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.

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,GAMMX,GAMMN,RCI,XCI,EBASI,TRI,TAPI,TMXI,TMNI,STPI,ICI,IFI,ITI,IDI,XCAPI
```

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

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.

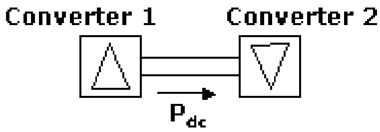
DC line converter buses, IPR and IPI, may be Type 1, 2, or 3 buses. Generators, loads, fixed and switched shunt elements, induction machines other dc line converters, FACTS device sending ends, and GNE devices are permitted at converter buses.

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.

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 PSS®E 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,MAXQ,MINQ,REMOT,RMPCT
IBUS,TYPE,MODE,DCSET,ACSET,ALOSS,BLOSS,MINLOSS,SMAX,IMAX,PWF,MAXQ,MINQ,REMOT,RMPCT
```

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. By default, each Fi is 1.0.

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.

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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.

A_{loss}, B_{loss} — Coefficients of the linear equation used to calculate converter losses:

$$KW_{conv\ loss} = A_{loss} + (I_{dc} * B_{loss})$$

A_{loss} is entered in kW. B_{loss} is entered in kW/amp. A_{loss} = B_{loss} = 0.0 by default.

MIN_{loss} — Minimum converter losses; entered in kW. MIN_{loss} = 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 ($0.0 \le PWF \le 1.0$) 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.

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REMOT	Bus number, or extended bus name enclosed in single quotes (refer to Extended Bus Names), of a remote Type 1 or 2 bus for which voltage is to be regulated by this converter to the value specified by ACSET. If bus REMOT is other than a Type 1 or 2 bus, bus IBUS regulates its own voltage to the value specified by ACSET. REMOT is entered as zero if the converter is to regulate its own voltage. Not used if MODE = 2. REMOT = 0 by default.
RMPCT	Percent of the total Mvar required to hold the voltage at the bus controlled by bus IBUS that is to be contributed by this VSC; RMPCT must be positive. RMPCT is needed only if REMOT specifies a valid remote bus and there is more than one local or remote voltage controlling device (plant, switched shunt, FACTS device shunt element, or VSC dc line converter) controlling the voltage at bus REMOT to a setpoint, or REMOT is zero but bus IBUS is the controlled bus, local or remote, of one or more other setpoint mode voltage controlling devices. Not used if MODE = 2. RMPCT = 100.0 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'.

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.

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 transformer impedance correction data record has the following format:

```
I, T1, F1, T2, F2, T3, F3, ... T11, F11
```

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where:

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	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 by default. The impedances used in calculation of F_i should be expressed in percent or pu on a common MVA and common voltage base.

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

Impedance Correction Table Notes

The T_i values on a transformer impedance correction table record 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 greater than zero. On each record, at least 2 pairs of values must be specified and up to 11 may be entered. For a graphical view of a correction table, see Figure 5-13.

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 winding 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 Transformer Data), or via activity CHNG or the two-winding and three-winding transformer [Spreadsheets]. Each table may be shared among many transformer windings. 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 the impedance of each transformer winding assigned to the table is treated as a function of phase shift angle. Otherwise, the impedances of the transformer windings assigned to the table are made sensitive to off-nominal turns ratio.

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, Reading Power Flow Data Additions from the Terminal, RDCH, CHNG, or the transformer [Spreadsheets] is taken as the nominal value of impedance. Each time the complex tap ratio of a transformer is changed, either automatically by the power flow solution activities or manually by the user, and the transformer winding has been assigned to an impedance correction table, actual transformer winding impedance is 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.

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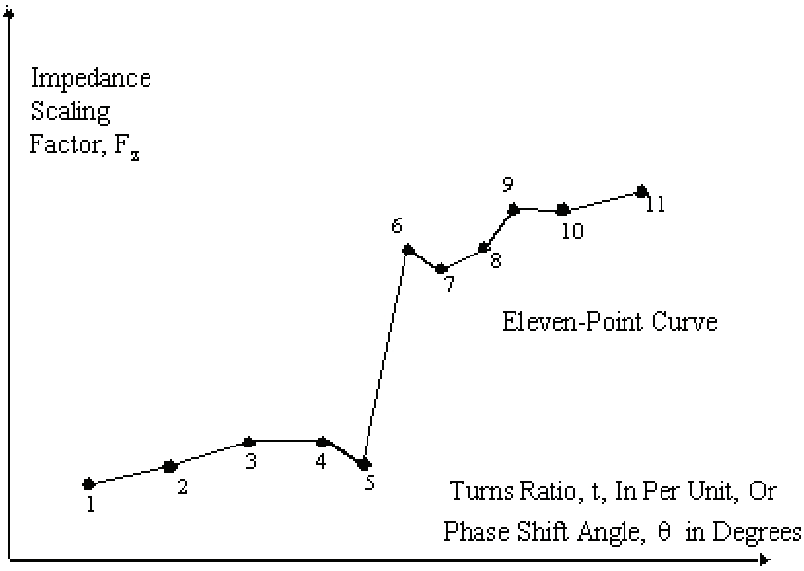
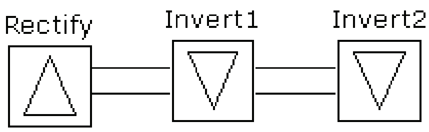


Figure 5-13. Typical Impedance Correction Factor Curve

Multi-Terminal DC Transmission Line Data

PSS®E 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 PSS®E 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
```

where:

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.

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NDCBS	Number of dc buses in multi-terminal dc line I (NCONV $\le$ 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
```

where:

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.

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SETVL — Converter setpoint. When IB is equal to VCONV or VCONVN, SETVL specifies the scheduled dc voltage magnitude, entered in kV, across the converter. 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.

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

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

where:

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, DCCKT, MET, RDC, LDC
```

where:

IDC	Branch from bus dc bus number. No default allowed.
JDC	Branch to bus dc bus number. No default allowed.
DCCKT	One-character uppercase alphanumeric branch circuit identifier. It is recommended that single circuit branches be designated as having the circuit identifier 1. DCCKT = 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.

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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.

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 PSS®E 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 interchange and 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.

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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 5-14. There are 4 convertors, 5 dc buses and 4 dc links.

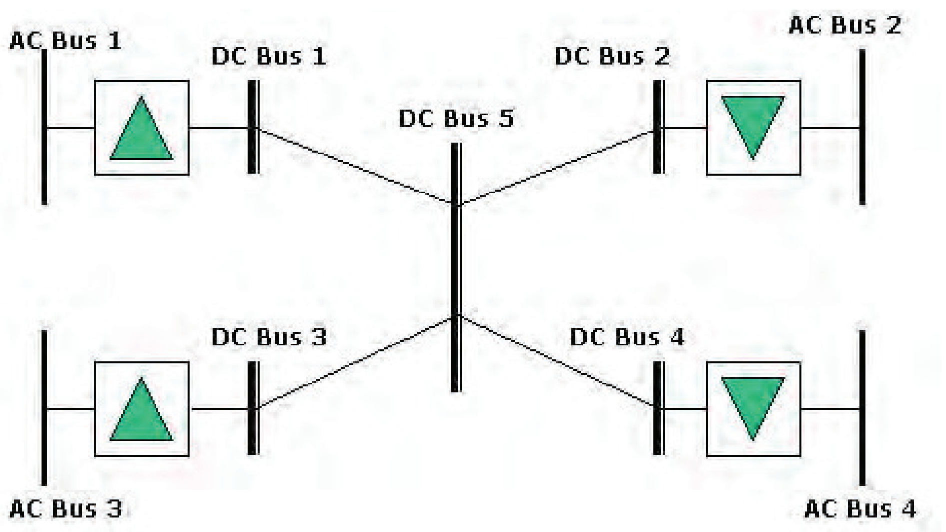
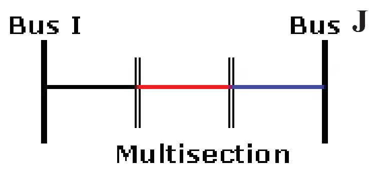


Figure 5-14. Multi-Terminal DC Network

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 PSS®E 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
```

where:

I	From bus number, or extended bus name enclosed in single quotes (refer to Extended Bus Names). No default allowed.

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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.

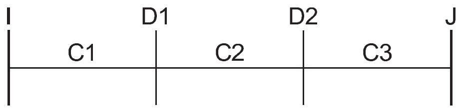
MET = 1 by default.

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.

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:

From	To	Circuit
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
```

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.

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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).

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'
```

where:

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.

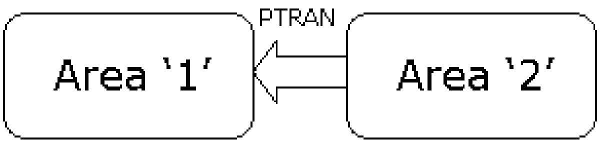
Zone Data Notes

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.

Interarea Transfer Data

The PSS®E 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
```

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where:

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.

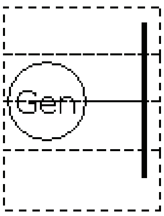
Interarea Transfer Data Notes

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).

Owner Data

PSS®E 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-Terminal DC Transmission Line Data, 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'
```

where:

I	Owner number (1 through 9999). No default allowed.

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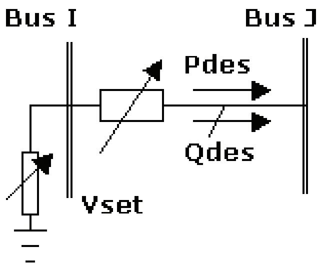
OWNAME	Alphanumeric identifier assigned to owner I. OWNAME may be up to twelve characters and may contain any combination of blanks, uppercase letters, numbers and special characters. OWNAME *must* be enclosed in single or double quotes if it contains any blanks or special characters. OWNAME is twelve blanks by default.

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

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).



PSS®E accepts data for all of these devices through one generic set of data records. Each FACTS device to be represented in PSS®E 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,
                              RMPCT,OWNER,SET1,SET2,VSREF,REMOT,'MNAME'
```

where:

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.

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MODE Control mode:

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.

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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 this shunt element; RMPCT must be positive. RMPCT is needed only if REMOT specifies a valid remote bus and there is more than one local or remote voltage controlling device (plant, switched shunt, FACTS device shunt element, or VSC dc line converter) controlling the voltage at bus REMOT to a setpoint, or REMOT is zero but bus I is the controlled bus, local or remote, of one or more other setpoint mode voltage controlling devices. 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.
REMOT	Bus number, or extended bus name enclosed in single quotes (refer to Extended Bus Names), of a remote Type 1 or 2 bus where voltage is to be regulated by the shunt element of this FACTS device to the value specified by VSET. If bus REMOT 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. REMOT is 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. REMOT = 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.

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

FACTS Device Notes

PSS®E'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).

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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 5-15 shows the PSS®E 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.

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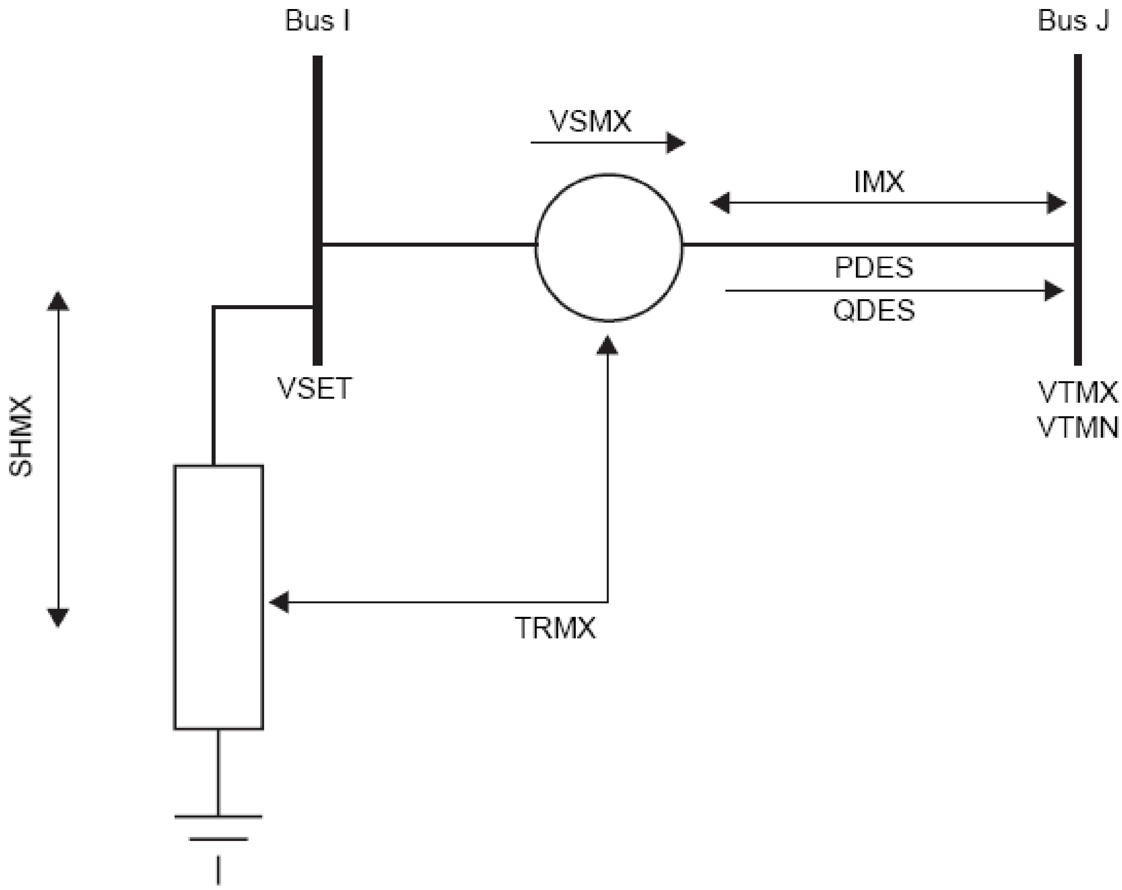
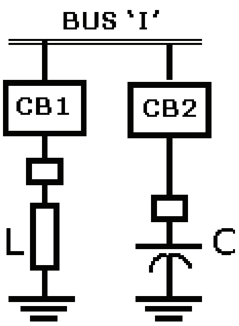


Figure 5-15. FACTS Control Device Setpoints and Limits

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 PSS®E 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, STAT, VSWHI, VSWLO, SWREM, RMPCT, 'RMIDNT',
                                      BINIT, N1, B1, N2, B2, ... N8, B8
```

where:

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 SWREM
- 2 continuous adjustment, controlling voltage locally or at bus SWREM
- 3 discrete adjustment, controlling the reactive power output of the plant at bus SWREM
- 4 discrete adjustment, controlling the reactive power output of the VSC dc line converter at bus SWREM 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 SWREM
- 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 PSS®E-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.

STAT — Initial switched shunt status of one for in-service and zero for out-of-service; STAT = 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.

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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.
SWREM	Bus number, or extended bus name enclosed in single quotes (refer to Extended Bus Names), of the bus where voltage or connected equipment reactive power output is controlled by this switched shunt. When MODSW is 1 or 2, SWREM is entered as 0 if the switched shunt is to regulate its own voltage; otherwise, SWREM specifies the remote Type 1 or 2 bus where voltage is to be regulated by this switched shunt When MODSW is 3, SWREM specifies the Type 2 or 3 bus where plant reactive power output is to be regulated by this switched shunt. Set SWREM to I if the switched shunt and the plant that it controls are connected to the same bus. When MODSW is 4, SWREM specifies the converter bus of a VSC dc line where converter reactive power output is to be regulated by this switched shunt. Set SWREM 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, SWREM specifies the remote bus to which the switched shunt for which the admittance setting is to be regulated by this switched shunt is connected. SWREM is not used when MODSW is 0 or 6. SWREM = 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 SWREM specifies a valid remote bus and there is more than one local or remote voltage controlling device (plant, switched shunt, FACTS device shunt element, or VSC dc line converter) controlling the voltage at bus SWREM to a setpoint, or SWREM is zero but bus I is the controlled bus, local or remote, of one or more other setpoint mode voltage controlling devices. 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 SWREM. 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 ($0 \leq N_i \leq 9$). 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.

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

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, $\Sigma N_i B_i - \Sigma N_j B_j$ when MODSW is 5 where i are those switched shunt blocks for which B_i is positive and j are those for which B_i 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:

$$0.0 \leq VSWLO < VSWHI \leq 1.0$$

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:

$$-50.0 + 0.2*(50.0 - (-50.0)) = -50.0 + 0.2*100.0 = -50.0 + 20.0 = -30.0 \text{ Mvar}$$

through:

$$-50.0 + 0.75*(50.0 - (-50.0)) = -50.0 + 0.75*100.0 = -50.0 + 75.0 = +25.0 \text{ Mvar}$$

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

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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.

Switched Shunt Example

Figure 5-16 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.

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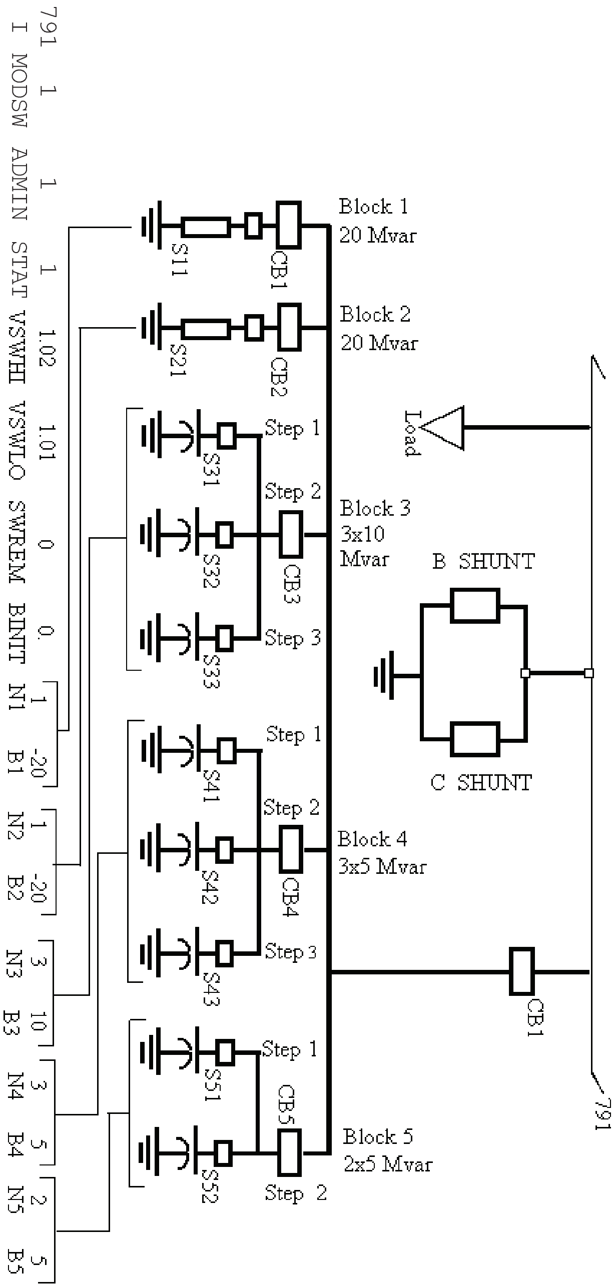

Figure 5-16. Example Data Record for Combination of Switched Shunts

GNE Device Data

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

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```
'NAME','MODEL',NTERM, BUS1, ...,BUSNTERM,NREAL,NINTG,NCHAR,

STATUS, OWNER,NMETR

REAL1, ..., REALmin(10,NREAL)
INTG1, ..., INTGmin(10,NINTG)
CHAR1, ..., CHARmin(10,NCHAR)
```

where:

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" 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.
BUS_i	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" 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" 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" 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 BUS_1 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 = BUS_{NTERM} by default.
$REAL_i$	NREAL floating point data items required by model MODEL. $REAL_i$ = 0.0 by default. 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.
$INTG_i$	NINTG bus numbers or extended bus names required by model MODEL. $INTG_i$ = BUS_1 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.
$CHAR_i$	NCHAR two-character identifiers required by model MODEL. $CHAR_i$ = "1" by default. 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.

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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.

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,STAT,SCODE,DCODE,AREA,ZONE,OWNER,TCODE,BCODE,MBASE,RATEKV,
     PCODE,PSET,H,A,B,D,E,RA,XA,XM,R1,X1,R2,X2,X3,E1,SE1,E2,SE2,IA1,IA2,
     XAMULT
```

where:

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.
STAT	Machine status of 1 for in-service and 0 for out-of-service. STAT = 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).

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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 ($\geq$ 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 ($\geq$ 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.

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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 by default.

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

Machine Electrical Data

The positive sequence steady state equivalent circuit for the induction machine is shown in Figure 5-17.

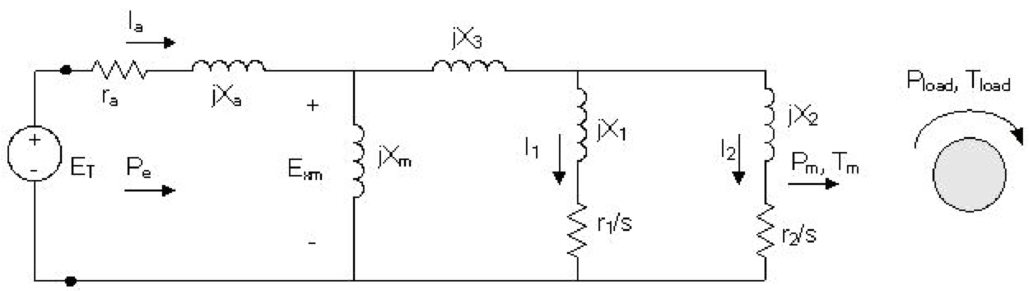

Figure 5-17. Induction Machine Equivalent Circuit

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.

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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).

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:

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

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

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.

5.2.2 Operation of Activity READ

The following API routines are used to implement activity READ. Each of them includes among its input data items the name of the Power Flow Raw Data File to be read and the flag for selecting the bus *names* input option of activity READ (see Section 5.2, Reading Power Flow Raw Data into the Working Case and Extended Bus Names).

Read	Standard READ of a Power Flow Raw Data File in the format of the PSS®E release indicated in the file. No other inputs.
ReadRawVersion	Standard READ of a Power Flow Raw Data File in the format of the current or a prior release of PSS®E. It accepts as input a character string indicating the PSS®E release.
ReadSub	Subsystem READ of a Power Flow Raw Data File in the format of the PSS®E release indicated in the file. It accepts as input several data items defining the subsystem for which the data records are to be read and other processing options.

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ReadSubRawVersion	Subsystem READ of a Power Flow Raw Data File in the format of the current or a prior release of PSS®E. It accepts as input a character string indicating the PSS®E release along with several data items defining the subsystem for which the data records are to be read and other processing options.

As data records are read, a message is displayed at the **Progress** device at the start of each new category of data.

Before it has completed reading its input data, activity READ may be ended by entering the AB interrupt control code (refer to Section 4.3, Interruption of PSS®E by the User). Activity READ checks for an interrupt following processing of each group of data records corresponding to 50 equipment items.

Bus Names Input Option

When the bus *names* input option of activity READ is enabled, data fields designating ac buses on load, fixed shunt, generator, induction machine, non-transformer branch, transformer, area, two-terminal dc line, VSC dc line, multi-terminal dc line, multi-section line, FACTS device, switched shunt, and GNE device data records may be specified as either Extended Bus Names enclosed in single quotes or as bus numbers. Otherwise, bus numbers **must** be used to designate ac buses on these records.

Use of the bus *names* input option of activity READ requires that all buses be assigned unique extended bus names. While reading each bus data record with this option enabled, if a bus with the same extended bus name but a different bus number is present in the working case, an error message is printed, the record is ignored, and processing continues.

Bus Sequence Numbers

As each bus data record is read, activity READ assigns to each new bus (i.e., a bus not previously read) a **bus sequence number,** which defines the location of data for the bus in the various bus data arrays. Bus sequence numbers are assigned sequentially starting with 1 in the order in which bus data records are read.

Plant and Machine Sequence Numbers

Each bus for which a generator data record is read is assigned a **plant sequence number**, which defines the location of its plant-related generator data in the plant data arrays. Data for each plant contains a **machine sequence number** assigned for each machine for which a generator data record is read. This number defines the location of its machine-specific data in the machine data arrays. Plant and machine sequence numbers are assigned sequentially starting with 1 in the order in which generator data records are read. It is permissible to enter a generator data record for a bus that was assigned a type code of 1 or 4 during bus data input. (Refer to Generator Data and activity MCRE.)

Load Sequence Numbers

Each load introduced into PSS®E is assigned a **load sequence number**, which defines the location of its data in the load data arrays. Load sequence numbers are assigned sequentially starting with 1 in the order in which load data records are read.

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