Chapter 3

Managing Power Flow Data

3.1 Overview: Managing Power Flow Data

This chapter describes the data requirements for establishing a power flow data set suitable for use in steady-state analyses. The application of this data for planning and operations studies is treated in detail in Chapters 4 through 10.

In addition to the basic data set describing the network elements, PSS/E requires other data and control element files for specific applications. Those files and their data requirements will be described in the subsections of Chapters 4 through 10, where they are appropriate.

Objectives of this chapter are to describe several aspects of data preparation, including:

- Specific network data required and their format for importation into PSS/E.
- Methods of importing data.
- Means by which data can be listed and examined.
- Methods to check data for errors and conflicts.
- Data editing.
- Data exportation.
- Building a network using the Diagram View.
- Building a network using the Spreadsheet View.

The user should be aware that not all the data described in this chapter are needed for all applications and that some data can be defaulted. The following subsection will indicate which data fall into those categories.

3.2 Power Flow Data Categories

Representation of power networks in PSS/E comprises 16 data categories of network and equipment elements, each of which requires a particular type of data. The data categories and the order in which they are input are shown in Figure 3-1.

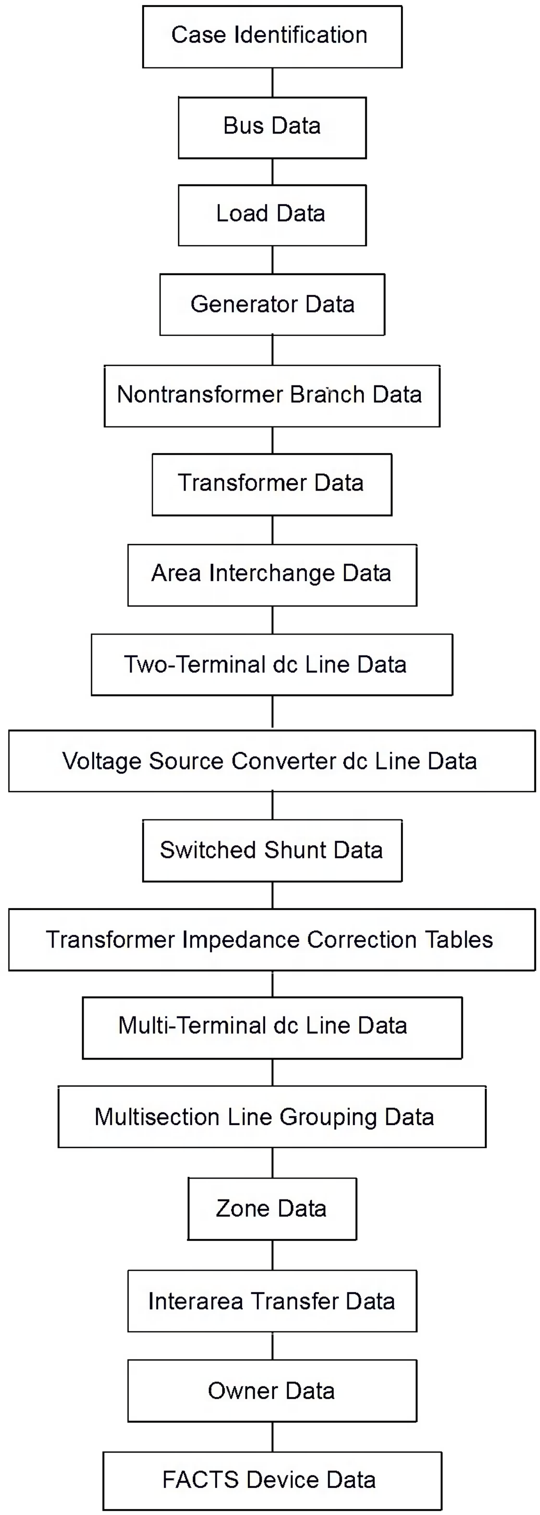


Figure 3-1. Power Flow Data Categories

The bulk power flow data input facility, ***File>Open...*** (Section 2.6.2) imports hand-typed power flow source data from a correctly formatted Power Flow Raw Data File (*.raw*) and enters it into the load flow working case, rearranging it from its original format into a computationally oriented data structure in the process.

All data is read in "free format" with data items separated by a comma or one or more blanks. Tabbed delimited data items are not recommended. The ***File>Open...*** command may also import binary saved case files (*.sav) containing power flow data as well as solution values and related options (see Section 1.8.2).

The following sections identify the power flow data categories in the order of presentation expected in the Power Flow Raw Data File.

3.2.1 Case Identification Data

Case identification data consists of three data records.

The first record contains two items of data as follows:

```
IC, SBASE
```

where:

IC — Change code:

0 - base case (i.e., clear the working case before adding data to it)

1 - add data to the working case

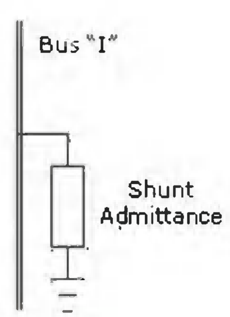
IC = 0 by default.

SBASE — System base MVA. SBASE = 100.0 by default.

The next two records each contain a line of heading to be associated with the case. Each line may contain up to 60 characters.

3.2.2 Bus Data

Each network bus to be represented in PSS/E is introduced through a bus data record. Each bus data record includes not only data for the basic bus properties but also includes information on an optionally connected shunt admittance to ground. That admittance 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, loads, line charging or transformer magnetizing impedance, all of which are entered in other data categories.



Bus data has the following format:

```
I, 'NAME', BASKV, IDE, GL, BL, AREA, ZONE, VM, VA, OWNER
```

where:

I	Bus number (1 to 999997).
NAME	Alphanumeric identifier assigned to bus "I". The name may be up to twelve characters and *must* be enclosed in single quotes. NAME may contain any combination of blanks, uppercase letters, numbers and special characters, but the first character *must not* be a minus sign. NAME is twelve blanks by default.
BASKV	Bus base voltage; entered in kV. BASKV = 0.0 by default.
IDE	Bus type code: 1 - load bus or other bus without any generator boundary condition. 2 - generator or plant bus either regulating voltage or with a fixed reactive power (Mvar). A generator that reaches its reactive power limit will no longer control voltage but rather hold reactive power at its limit. 3 - swing bus or slack bus. It has no power or reactive limits and regulates voltage at a fixed reference angle. 4 - disconnected or isolated bus. IDE = 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 admittance 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; or transformer magnetizing admittance, which is entered as part of transformer data. BL is positive for a capacitor, and negative for a reactor or an inductive load. BL = 0.0 by default.
AREA	Area number. (1 through the maximum number of areas at the current size level; see Table 1-1). AREA = 1 by default.
ZONE	Zone number (1 through the maximum number of zones at the current size level; see Table 1-1). ZONE = 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.
OWNER	Owner number (1 through the maximum number of owners at the current size level; see Table 1-1). OWNER = 1 by default.

VM and VA could be set to values obtained from a previously solved case if they were available. Normally, however, they can be set to default value.

When entering bus data in the Power Flow Raw Data File, bus data input is terminated with a record specifying a bus number of zero.

3.2.2.1 Extended Bus Names

When bus data records are input, each bus is identified by either its number or its name. The name comprises a twelve character alphanumeric in single quotes.

When the "Extended Name" bus input option is enabled in the ***Misc>Change Program Settings (OPTN)...*** dialog, data fields designating buses on load, generator, branch, transformer, area, two-terminal dc line, VSC dc line, switched shunt, multi-terminal dc line, multisection line, and FACTS device data records may be specified as either extended bus names enclosed in single quotes or as bus numbers.

As for data output, reports developed by PSS/E functions can be ordered in ascending bus number or by the buses extended bus name, in alphabetical order. The setting of bus output to either bus number or extended name is made using the ***Misc>Change Program Settings (OPTN)...*** option (see Section 1.7.4).

The requirements to specify an extended bus name are:

1. It must be enclosed in single quotes.
2. The twelve-character bus name, including any trailing blanks, must be the first twelve characters.
3. The bus base voltage in kV must immediately follow the bus name. Up to six characters may be used.
4. For those data fields whose sign is used to indicate a modeling attribute, a minus sign may be specified between the leading single quote and the first character of the twelve-character bus name.

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

As an example, consider a 345 kV bus with the name FRONT-STREET. Its extended bus name would be:

```
'FRONT-STREET   345'
```

3.2.2.2 Using Defaults to Minimize Bus Data

Because there are default values for some of these data, you can include only the specific information you need. For example, if bus # 99 is a 345 kV, Type 1 bus without a shunt admittance, which lies in Zone #3, the data line within the Power Flow Raw Data File could be:

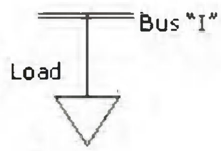
```
99,,345, 1,,,,3
```

If, in addition, you name the bus ERIE BLVD and it has a 200 Mvar shunt reactor, the minimum data line would be:

```
99, 'ERIE BLVD', 345,1,,- 200,,3
```

3.2.3 Load Data

Each network bus at which a load is to be represented must be specified in at least one load data record. If multiple loads are to be represented at a bus, they must be individually identified in a load data record for the bus with a different load identifier. Each load at a bus can be a mixture of loads with different characteristics, (see Section 4.5).



Each load data record has the following format:

```
I, ID, STATUS, AREA, ZONE, PL, QL, IP, IQ, YP, YQ, OWNER
```

where:

I	Bus number, or extended bus name enclosed in single quotes (see Section 3.2.2.1).
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	Initial 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 the maximum number of areas at the current size level, see Table 1-1). By default, AREA is the area to which bus "I" is assigned (see Section 3.2.2).
ZONE	Zone to which the load is assigned (1 through the maximum number of zones at the current size level, see Table 1-1). By default, ZONE is the zone to which bus "I" is assigned (see Section 3.2.2).
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 the maximum number of owners at the current size level, see Table 1-1). By default, OWNER is the owner to which bus "I" is assigned (see Section 3.2.2).

As for buses, it is possible to enter only the data items which apply to the analyses to be undertaken. An example entry in the Power Flow Raw Data File for a constant MVA load of 100 MW and 50 Mvar, at bus 123, with no assigned area, zone or owner, would be:

```
123, '1',,,,100,50
```

Within the Raw Data File, load data input is terminated by a record specifying a bus number of zero.

3.2.3.1 Load Characteristics

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 3-2 depicts this characteristic for PQBRAK values of 0.6, 0.7, and 0.8 pu. The user may modify the value of PQBRAK by selecting ***Power Flow>Solution>Parameters...*** and modifying the ***Constant power characteristic threshold (PQBRAK)*** located on the General tab.

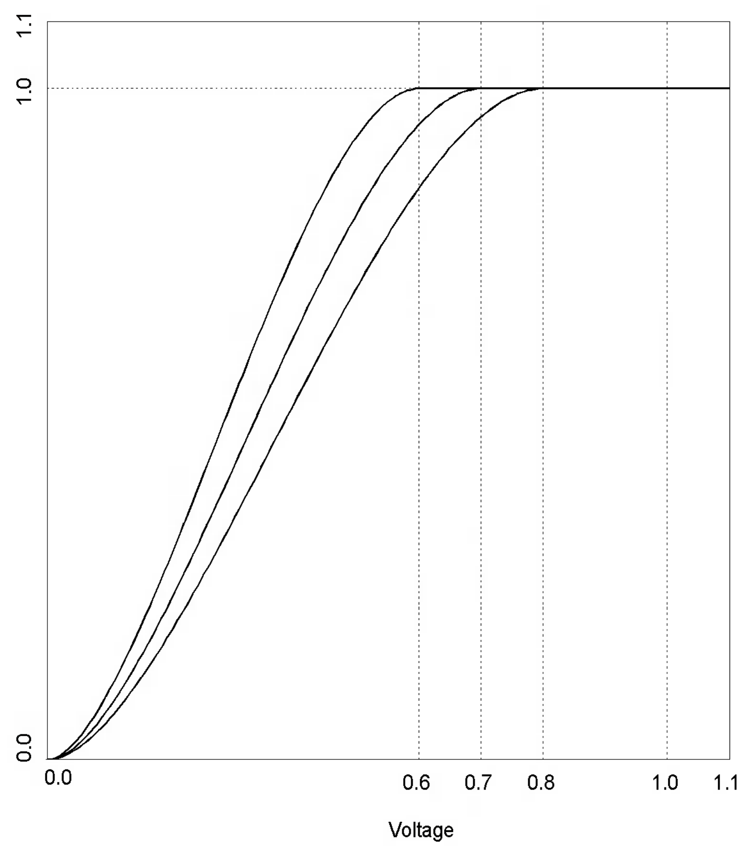


Figure 3-2. Constant Power Load Characteristic

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 3-3 for voltages below 0.5 pu.

Further details on load characteristic and modeling requirements are given in Section 4.5.

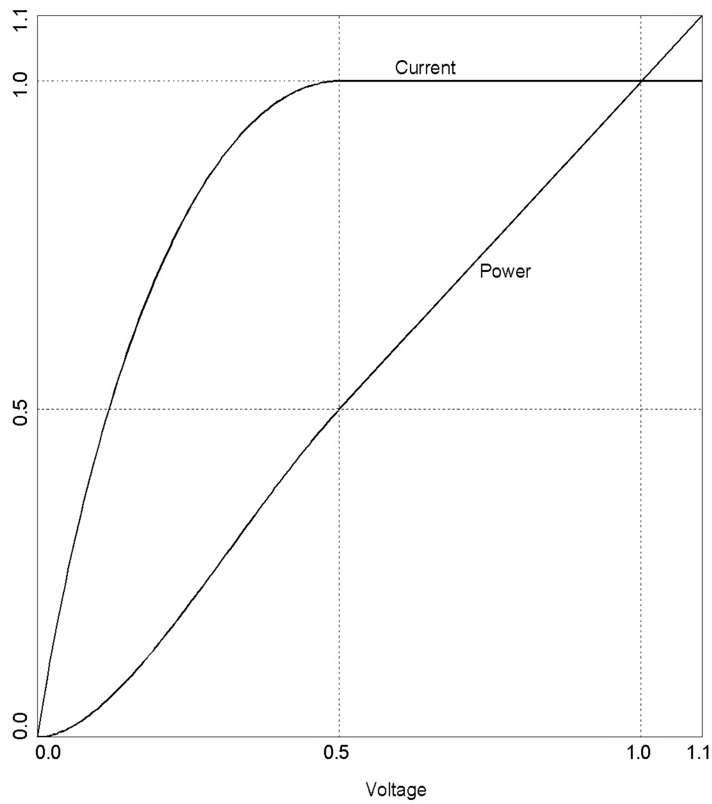
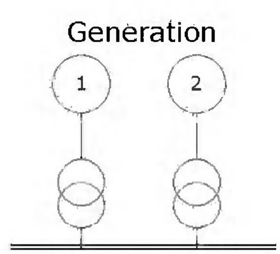


Figure 3-3. Constant Current Load Characteristic

3.2.4 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 two (2) or three (3) *must* have a generator data record entered for it.



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

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

where:

I	Bus number, or extended bus name enclosed in single quotes (see Section 3.2.2.1).
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 (see Section 3.2.2.1), of a remote type 1 or 2 bus whose 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 three (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.
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. GTAP is used only if XTRAN is nonzero. GTAP = 1.0 by default.

STAT Initial 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 this bus "I" that are to be contributed by the generation at bus "I"; RMPCT must be positive. RMPCT is needed 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. RMPCT is needed also if bus "I" itself is being controlled locally or remotely by 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 the maximum number of owners at the current size level: see Table 1-1). Each machine 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 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.

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 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.

3.2.4.1 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 forms part of the generator data list
- The transformer is not represented as a transformer branch

Figure 3-4 shows that Bus K is the Type 2 bus. This is the bus at which the generator will regulate/control voltage unless the user specified otherwise.

As with other data sets, some of the generator data have default values and, further, it is not necessary to specify all the data for basic power flow studies.

If an implicit transformer model is used, the minimum data set needed is:

```
I, 'ID', PG, QG, QT, QB, VS,,,,,RT, XT, GTAP
```

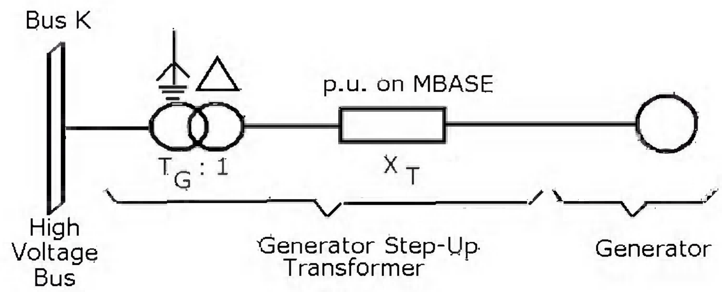


Figure 3-4. Implicit GSU Configuration – Specified as Part of the Generator

The Explicit Method

In this method, the Transformer data does not appear in the generator data. It is entered separately (see Section 3.2.6) in a transformer branch data list.

In Figure 3-5, 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 otherwise.

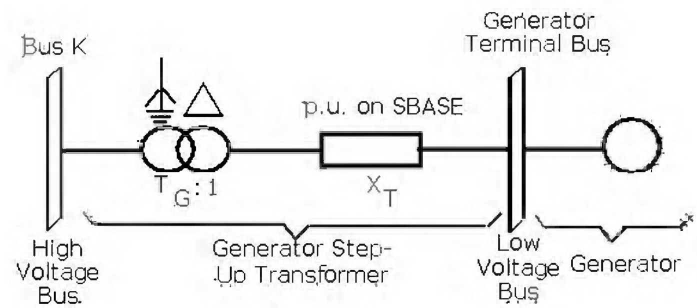


Figure 3-5. Explicit GSU Configuration – Specified Separately from the Generator

Multiple Generators

If a generating plant has several units, they can be represented separately even if they are connected to the same Type 2 bus.

Figure 3-6 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.

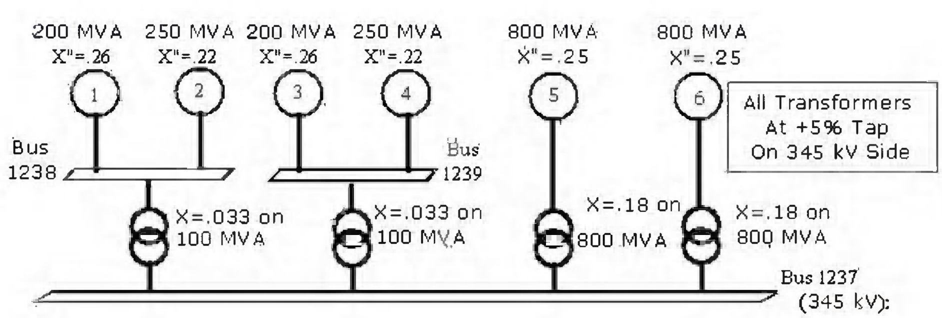


Figure 3-6. Multiple Generators at a Single Plant

To clarify the data requirements, Figure 3-7 shows a properly formatted listing for the generators in Figure 3-6.

The separate transformer branches from Buses 1238 and 1239 to Bus 1237 are not included in this generator list.

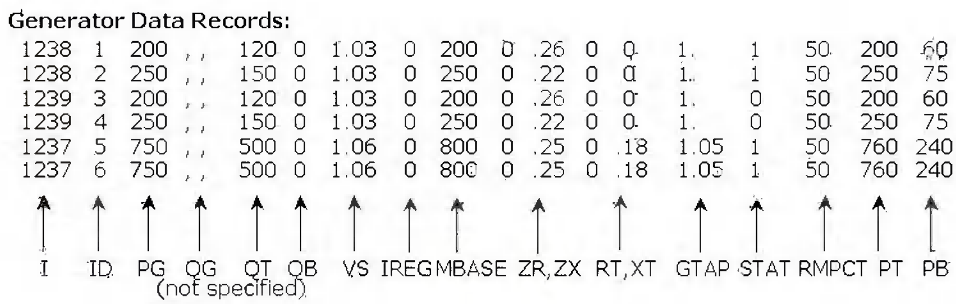


Figure 3-7. Date Set for the Multiple Generators in Figure 3-6

Generator data input from a Power Flow Raw Data File is terminated with a record specifying a bus number of zero.

3.2.5 Nontransformer Branch Data

In PSS/E, the basic transmission line model is an Equivalent Pi connected between network buses. Figure 3-8 shows the required parameter data where the equivalent Pi comprises:

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

Data for shunt equipment units, such as reactors, which are connected to and switched with the line, are entered in the same data record. The figure shows these shunts represented as (G + jB).

To represent shunts connected to buses, that shunt data should be entered in the bus data record.

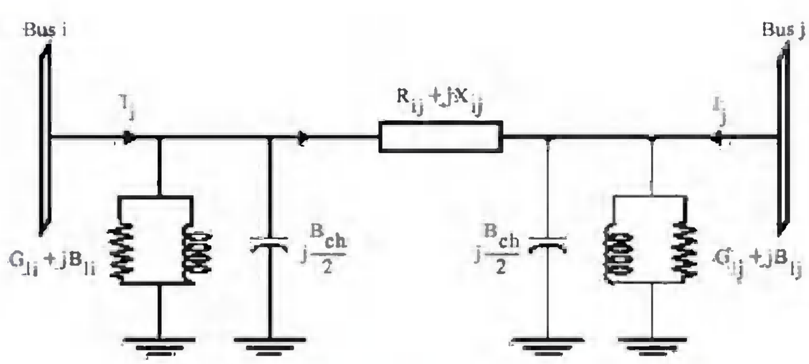


Figure 3-8. Transmission Line Equivalent Pi Model

Each nontransformer branch data record has the following format:

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

where:

I — Branch "*from bus*" number, or extended bus name enclosed in single quotes (see Section 3.2.2.1).

J — Branch "*to bus*" number, or extended bus name enclosed in single quotes (see Section 3.2.2.1). "J" is entered as a negative number, or with a minus sign before the first character of the extended bus name, to designate it as the metered end; otherwise, bus "I" is assumed to be the metered end.

CKT — One- or two-character uppercase nonblank alphanumeric branch circuit identifier; the first character of CKT *must not* be an ampersand "&" (see Section 3.4.4.12 for a discussion on use of the ampersand in designation of multisection transmission lines). 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 nonzero value of X must be entered for each branch. See Section 3.2.5.1 for a discussion of the treatment of branches as zero impedance lines.

B — Total branch charging susceptance; entered in pu. B = 0.0 by default.

RATEA — First loading rating; entered in MVA. If RATEA is set to 0.0, the default value, this branch will not be included in any examination of circuit loading. (See Section 4.4.5.1.1).

RATEB — Second loading rating; entered in MVA. RATEB = 0.0 by default.

RATEC — Third loading rating; entered in MVA. RATEC = 0.0 by default.

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 — Initial branch status where 1 designates in-service and 0 designates out-of-service. ST = 1 by default.

LEN — Line length; entered in user-selected units. LEN = 0.0 by default.

Oi — Owner number; (1 through the maximum number of owners at the current size level: see Table 1-1). Each branch 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 — 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.

When specifying a nontransformer 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).

Branches to be modeled as transformers are not specified in this data category; rather, they are specified in the transformer data category described in the following Section 3.2.6.

Nontransformer branch data input to the Power Flow Raw Data File is terminated with a record specifying a "*from bus*" number of zero.

3.2.5.1 Zero Impedance Lines

PSS/E provides for the treatment of bus ties, jumpers, 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 not be a transformer.

There are points to be noted, and restrictions to be observed, in using zero impedance lines as discussed below.

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

When obtaining power flow solutions, zero impedance line flows, as calculated at the end of the solution, are preserved with the power flow case and are available to the power flow solution procedures. Similarly, in unbalanced fault calculations, the positive, negative, and zero sequence branch currents on zero impedance lines are determined and preserved, and are subsequently available to be reported. In other applications such automatic contingency analysis, short-circuit scanning and in linearized network analyses, zero impedance line results are calculated and reported as needed.

The zero impedance line threshold tolerance, THRSHZ, may be changed by launching the Solution Parameters dialog (see Figure 4-22) from the ***Power Flow>Solution>Parameters*** option under the General tab. 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 nonzero 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.

While more than two buses may be connected together by zero impedance lines, buses may not be connected in a loop arrangement by zero impedance lines. For example, connecting bus 1 to bus 2 and bus 2 to bus 3 by zero impedance lines is allowed; adding a third zero impedance line connecting buses 1 and 3 would form a zero impedance line connected loop and is not allowed.

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 within a zero impedance connected group of buses must have coordinated voltage schedules.

With large databases it is important to have the ability to easily identify which bus voltages are being regulated and which equipment is controlling the regulation. This helps to avoid situations in which there are potential regulation conflicts. Clicking the ***Regulated buses*** tab in the ***Power Flow>Reports>Limit checking reports...*** dialog, will facilitate generation of a report that tabulates those buses whose voltages are controlled by generation, switched shunts, voltage controlling transformers, FACTS devices, and/or VSC dc line converters.

Similarly, if multiple voltage controlling devices are present within 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.

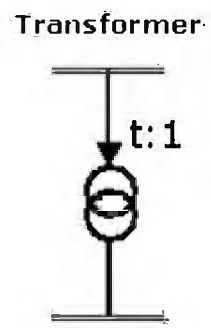
In the fault analysis activities, a branch treated as a zero impedance line in the positive sequence is treated in the same manner in the zero sequence, regardless of its zero sequence branch impedance. Zero sequence mutual couplings involving a zero impedance line are ignored in the fault analysis solution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

3.2.6 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 a set of ancillary data, comprising 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 Section 3.2.12.

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.



The data records for the two-winding transformer are common to the three-winding transformer. Figure 3-9 shows the transformer winding configurations.

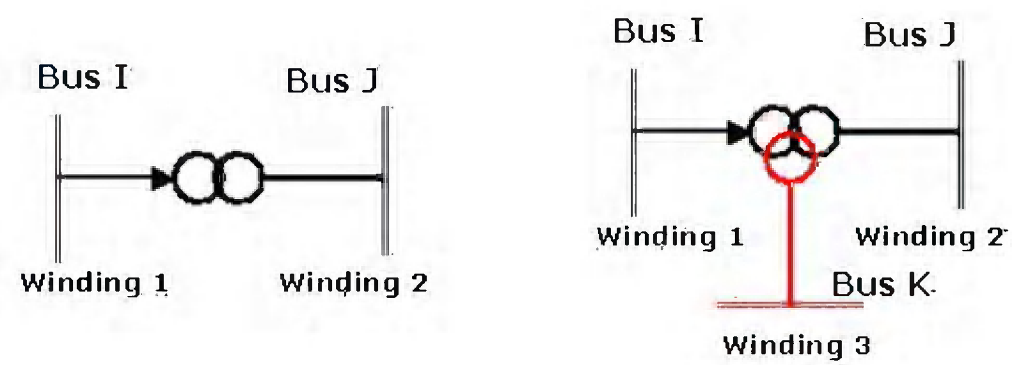


Figure 3-9. Two and Three-winding Transformer Configurations Related to Data Records

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
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
WINDV2,NOMV2,ANG2,RATA2,RATB2,RATC2,COD2,CONT2,RMA2,RMI2,VMA2,VMI2,NTP2,TAB2,CR2,CX2
WINDV3,NOMV3,ANG3,RATA3,RATB3,RATC3,COD3,CONT3,RMA3,RMI3,VMA3,VMI3,NTP3,TAB3,CR3,CX3
```

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
R1-2,X1-2,SBASE1-2
WINDV1,NOMV1,ANG1,RATA1,RATB1,RATC1,COD1,CONT1,RMA1,RMI1,VMA1,VMI1,NTP1,TAB1,CR1,CX1
WINDV2,NOMV2
```

The three-winding transformer model in PSS/E is in fact a grouping of three two-winding transformers models 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.

Record 1

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

I	The bus number, or extended bus name enclosed in single quotes, of the bus to which the first winding is connected. The transformer's magnetizing admittance is modeled on winding one. The first winding is the only winding of a two-winding transformer whose 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 the second winding is connected. This winding may have a fixed, off-nominal tap ratio assigned to it. No default is allowed for "J".
K	The bus number, or extended bus name enclosed in single quotes, of the bus to which the third winding 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). This winding may have a fixed, off-nominal tap ratio assigned to it. K = 0 by default.
CKT	One- or two-character uppercase nonblank alphanumeric transformer circuit identifier; the first character of CKT *must not* be an ampersand ("&"); see Section 3.4.4.12. CKT = '1' by default.
CW	The winding data I/O code which defines the units in which the turns ratios WINDV1, WINDV2 and WINDV3 are specified (the units of RMAi and RMIi are also governed by CW when |CODi| is 1 or 2): 1 for off-nominal turns ratio in pu of winding bus base voltage; 2 for winding voltage in kV. CW = 1 by default.
CZ	The impedance data I/O code that 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 base quantities; 2 for resistance and reactance in pu on a specified base MVA and winding bus base voltage; 3 for transformer load loss in watts and impedance magnitude in pu on a specified base MVA and winding bus base voltage. CZ = 1 by default.
CM	The magnetizing admittance I/O code that defines the units in which MAG1 and MAG2 are specified: 1 for complex admittance in pu on system base quantities; 2 for no load loss in watts and exciting current in pu on winding one to two base MVA and nominal voltage. CM = 1 by default.
MAG1, MAG2	The magnetizing conductance and susceptance, respectively, in pu on system base quantities when CM is 1; MAG1 is the no load loss in watts and MAG2 is the exciting current in pu on winding one to two base MVA (SBASE1-2) and nominal voltage (NOMV1) when CM is 2. MAG1 = 0.0 and MAG2 = 0.0 by default.
NMETR	The nonmetered end code of either 1 (for the winding one bus) or 2 (for the winding two bus). In addition, for a three-winding transformer, 3 (for the winding three bus) is a valid specification of NMETR. NMETR = 2 by default.
NAME	An alphanumeric identifier assigned to the transformer. The name may be up to twelve characters and must be enclosed in single quotes. NAME may contain any combination of blanks, uppercase letters, numbers and special characters. NAME is twelve blanks by default.
STAT	The initial transformer status, where 1 designates in-service and 0 designates out-of-service. In addition, for a three-winding transformer, 2 designates that only

winding two is out-of-service, 3 indicates that only winding three is out-of-service, and 4 indicates that only winding one is out-of-service, with the remaining windings in-service. STAT = 1 by default.

Oi — An owner number; (1 through the maximum number of owners at the current size level: see Table 1-1). 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.

Record 2

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

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

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 base quantities; when CZ is 2, they are the resistance and reactance, respectively, in pu on winding one to two base MVA (SBASE1-2) and winding one bus base voltage; when CZ is 3, R1-2 is the load loss in watts, and X1-2 is the impedance magnitude in pu on winding one to two base MVA (SBASE1-2) and winding one bus base voltage. R1-2 = 0.0 by default, but no default is allowed for X1-2.

SBASE1-2 — The winding one to two 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 base quantities; when CZ is 2, they are the resistance and reactance, respectively, in pu on winding two to three base MVA (SBASE2-3) and winding two bus base voltage; when CZ is 3, R2-3 is the load loss in watts, and X2-3 is the impedance magnitude in pu on winding two to three base MVA (SBASE2-3) and winding two bus base voltage. R2-3 = 0.0 by default, but no default is allowed for X2-3.

SBASE2-3 — The winding two to three 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 base quantities; when CZ is 2, they are the resistance and reactance, respectively, in pu on winding three to one base MVA (SBASE3-1) and winding three bus base voltage; when CZ is 3, R3-1 is the load loss in watts, and X3-1 is the impedance magnitude in pu on winding three to one base MVA (SBASE3-1) and winding three bus base voltage. R3-1 = 0.0 by default, but no default is allowed for X3-1.

SBASE3-1 The winding three to one base MVA of a three-winding transformer; ignored for a two-winding transformer. SBASE3-1 = SBASE (the system base MVA) by default.

VMSTAR The voltage magnitude at the hidden star point bus; entered in pu. VMSTAR = 1.0 by default.

ANSTAR The bus voltage phase angle at the hidden star point bus; entered in degrees. ANSTAR = 0.0 by default.

Record 3

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

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

WINDV1 The winding one off-nominal turns ratio in pu of winding one bus base voltage when CW is 1; WINDV1 = 1.0 by default. WINDV1 is the actual winding one voltage in kV when CW is 2; WINDV1 is equal to the base voltage of bus "I" by default.

NOMV1 The nominal (rated) winding one voltage in kV, or zero to indicate that nominal winding one voltage is to be taken as the base voltage of bus "I". NOMV1 is used only in converting magnetizing data between per unit admittance values and physical units when CM is 2. NOMV1 = 0.0 by default.

ANG1 The winding one phase shift angle in degrees. ANG1 is positive for a positive phase shift from the winding one side to the winding two side (for a two-winding transformer), or from the winding one side to the "T" (or star) point bus (for a three-winding transformer). ANG1 must be greater than -180.0 and less than or equal to +180.0. ANG1 = 0.0 by default.

RATA1, RATB1, RATC1 The first winding's three ratings entered in MVA (*not* current expressed in MVA). RATA1 = 0.0, RATB1 = 0.0 and RATC1 = 0.0 (bypass flow limit check for this transformer winding) by default.

COD1 The transformer control mode for automatic adjustments of the winding one tap or phase shift angle during power flow solutions: 0 for no control (fixed tap and 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 (±4 is valid only for two-winding transformers). If the control mode is entered as a positive number, automatic adjustment of this transformer winding is enabled when the corresponding adjustment is activated during power flow solutions; a negative control mode suppresses the automatic adjustment of this transformer winding. COD1 = 0 by default.

CONT1 The bus number, or extended bus name enclosed in single quotes, of the bus whose 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 nonzero 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 two or winding three 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 one side of the transformer. CONT1 = 0 by default.

RMA1, RMI1 The upper and lower limits, respectively, of either:

- Off-nominal turns ratio in pu of winding one bus base voltage when |COD1| is 1 or 2 and CW is 1; RMA1 = 1.1 and RMI1 = 0.9 by default.
- Actual winding one voltage in kV when |COD1| is 1 or 2 and CW is 2. No default is allowed.
- Phase shift angle in degrees when |COD1| is 3. No default is allowed.
- Not used when |COD1| is 0 or 4; RMA1 = 1.1 and RMI1 = 0.9 by default.

VMA1, VMI1 The upper and lower limits, respectively, of either:

- 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 one bus end in Mvar when |COD1| is 2. No default is allowed.
- Active power flow into the transformer at the winding one bus end in MW when |COD1| is 3. 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 (see Section 3.4.4.7), 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.

Record 4

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

WINDV2 The winding two off-nominal turns ratio in pu of winding two bus base voltage when CW is 1; WINDV2 = 1.0 by default. WINDV2 is the actual winding two voltage in kV when CW is 2; WINDV2 is equal to the base voltage of bus "J" by default.

NOMV2 The nominal (rated) winding two voltage in kV, or zero to indicate that nominal winding two voltage is to be taken as the base voltage of bus "J". NOMV2 is present for information purposes only; it is not used in any of the calculations for modeling the transformer. NOMV2 = 0.0 by default.

ANG2 — The winding two phase shift angle in degrees; ignored for a two-winding transformer. ANG2 is positive for a positive phase shift from the winding two side to the "T" (or star) point bus. ANG2 must be greater than -180.0 and less than or equal to +180.0. ANG2 = 0.0 by default.

RATA2, RATB2, RATC2 — The second winding's three ratings entered in MVA (*not* current expressed in MVA); ignored for a two-winding transformer. RATA2 = 0.0, RATB2 = 0.0 and RATC2 = 0.0 (bypass flow limit check for this transformer winding) by default.

COD2 — The transformer control mode for automatic adjustments of the winding two tap or phase shift angle during power flow solutions: 0 for no control (fixed tap and phase shift); ±1 for voltage control; ±2 for reactive power flow control; ±3 for 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, of the bus whose 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 nonzero 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 one or winding three 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 two side of the transformer. CONT2 = 0 by default.

RMA2, RMI2 — The upper and lower limits, respectively, of either:

- Off-nominal turns ratio in pu of winding two bus base voltage when |COD2| is 1 or 2 and CW is 1; RMA2 = 1.1 and RMI2 = 0.9 by default.
- Actual winding two voltage in kV when |COD2| is 1 or 2 and CW is 2. No default is allowed.
- Phase shift angle in degrees when |COD2| is 3. No default is allowed.
- Not used when |COD2| is 0; RMA2 = 1.1 and RMI2 = 0.9 by default.

VMA2, VMI2 — The upper and lower limits, respectively, of either:

- 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 two bus end in Mvar when |COD2| is 2. No default is allowed.
- Active power flow into the transformer at the winding two bus end in MW when |COD2| is 3. 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 (see Section 3.4.4.7), 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.

Record 5

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

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

WINDV3 — The winding three off-nominal turns ratio in pu of winding three bus base voltage when CW is 1; WINDV3 = 1.0 by default. WINDV3 is the actual winding three voltage in kV when CW is 2; WINDV3 is equal to the base voltage of bus K by default.

NOMV3 — The nominal (rated) winding three voltage in kV, or zero to indicate that nominal winding three voltage is to be taken as the base voltage of bus K. NOMV3 is present for information purposes only; it is not used in any of the calculations for modeling the transformer. NOMV3 = 0.0 by default.

ANG3 — The winding three phase shift angle in degrees. ANG3 is positive for a positive phase shift from the winding three side to the "T" (or star) point bus. ANG3 must be greater than -180.0 and less than or equal to +180.0. ANG3 = 0.0 by default.

RATA3, RATB3, RATC3 — The third winding's three ratings entered in MVA (*not* current expressed in MVA). RATA3 = 0.0, RATB3 = 0.0 and RATC3 = 0.0 (bypass flow limit check for this transformer winding) by default.

COD3 — The transformer control mode for automatic adjustments of the winding three tap or phase shift angle during power flow solutions: 0 for no control (fixed tap and phase shift); ±1 for voltage control; ±2 for reactive power flow control; ±3 for 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, of the bus whose 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 nonzero 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 one or winding two 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 three side of the transformer. CONT3 = 0 by default.

RMA3, RMI3 The upper and lower limits, respectively, of either:

- Off-nominal turns ratio in pu of winding three bus base voltage when |COD3| is 1 or 2 and CW is 1; RMA3 = 1.1 and RMI3 = 0.9 by default.
- Actual winding three voltage in kV when |COD3| is 1 or 2 and CW is 2. No default is allowed.
- Phase shift angle in degrees when |COD3| is 3. No default is allowed.
- Not used when |COD3| is 0; RMA3 = 1.1 and RMI3 = 0.9 by default.

VMA3, VMI3 The upper and lower limits, respectively, of either:

- 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 three bus end in Mvar when |COD3| is 2. No default is allowed.
- Active power flow into the transformer at the winding three bus end in MW when |COD3| is 3. 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 (see Section 3.4.4.7), 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.

Transformer input in Raw Data File format is terminated with a record specifying a winding one bus number of zero.

Notes

- 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).
- In deriving winding impedances, for three-winding transformers, from the measured impedance data input values, one winding with a small or negative impedance may result. It is possible to specify a set of measured impedances which 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 which 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 pu if the zero impedance line threshold tolerance itself is 0.0). Whenever a set of measured impedances results in a winding impedance whose magnitude is less than 0.00001 pu, 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?).

3.2.6.1 Example Transformer Data Records

Figure 3-10 shows the data records for 138/34.5 kV two-winding transformer and sample data for clarification.

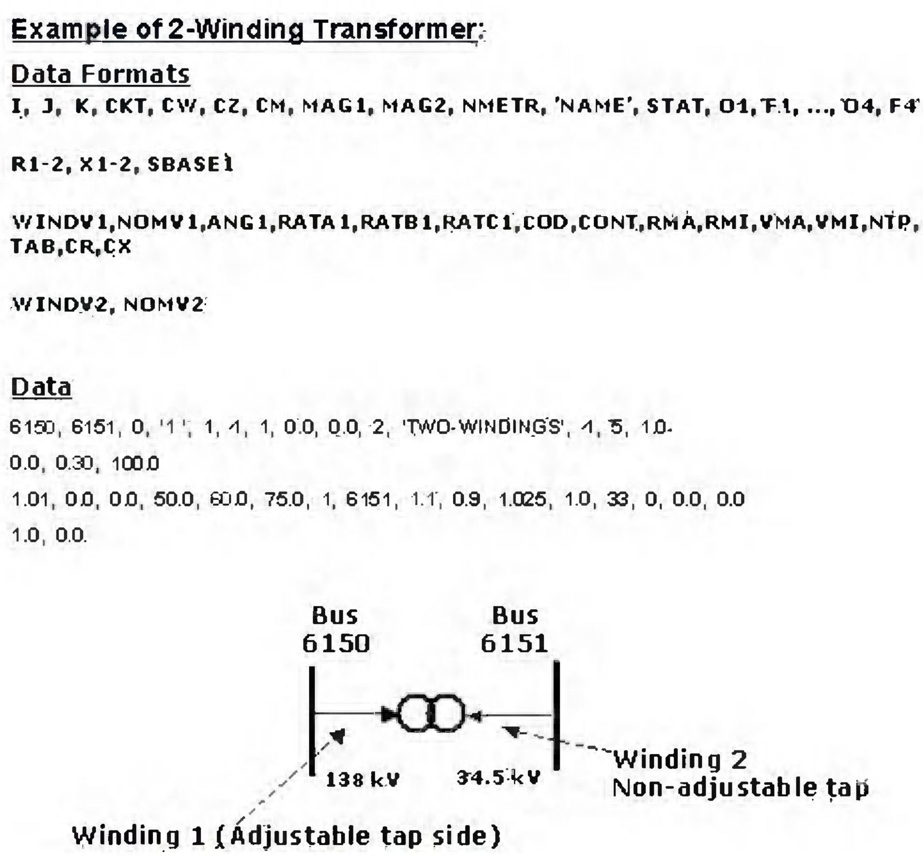


Figure 3-10. Sample Data for Two-Winding Transformer

Figure 3-11 shows the data records for a 345/138/13.8 kV three-winding transformer and sample data.

Example of 3-Winding Transformer:

Data Formats

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

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

WINDV1,NOMV1,ANG1,RATA1,RATB1,RATC1,COD,CONT,RMA,RMI,VMA,VMI,NTP,TAB,CR,CX

WINDV2, NOMV2, ANG2, RATA2,RATB2,RATC2

WINDV3, NOMV3, ANG3, RATA3,RATB3,RATC3

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
1.02, 0.0, 0.0,300, 400, 600
1.00, 0.0, 0.0, 50, 60, 75

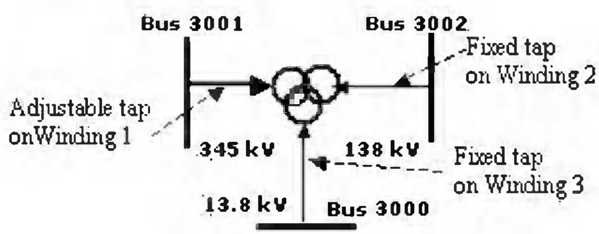


Figure 3-11. Sample Data for Three-Winding Transformer

3.2.7 Areas and Zones

Areas are commonly used to designate sections of the network which represent control areas between which there are scheduled flows. PSS/E facilitates the identification of both areas and schedules. Alternatively, the network can be subdivided between utility companies or other subdivisions useful for specific analyses.

Designating buses to specific zones allows additional subdivision of the network to facilitate analyses and documentation but PSS/E provides no analytical facility to schedule interchange between zones.

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

Figure 3-12 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.

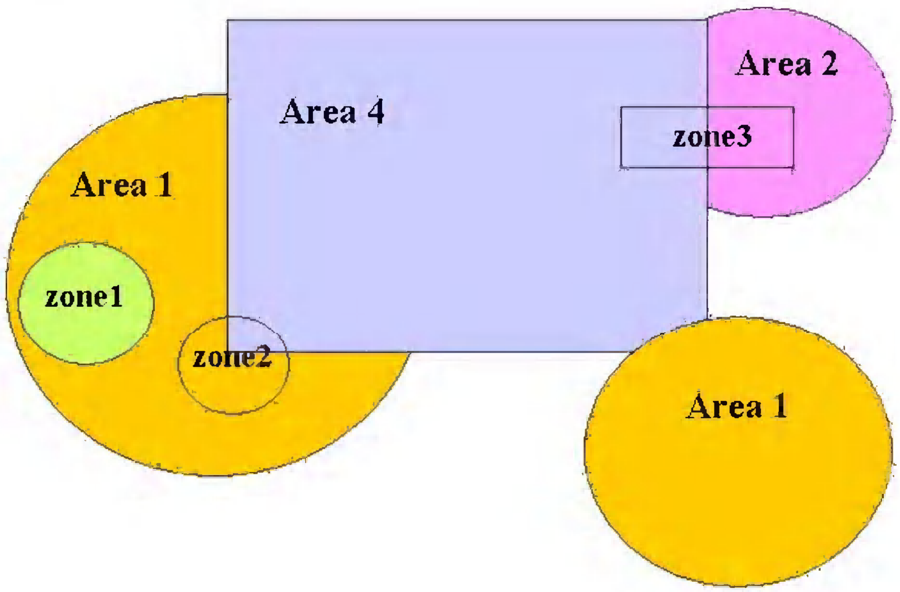
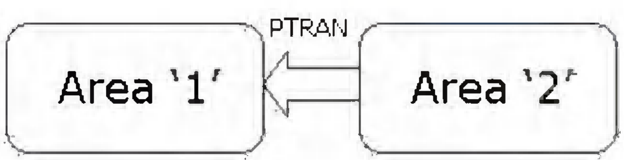


Figure 3-12. Overlapping Areas and Zones

3.2.8 Area Interchange 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 Section 3.2.16.



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.

Area identifiers and interchange control parameters are specified in area interchange data records which have the following format:

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

where:

I — Area number, (1 through the maximum number of areas at the current size level: see Table 1-1).

ISW — Bus number, or extended bus name enclosed in single quotes, of the area slack bus for area interchange control. The bus *must* be a generator (type two) bus in the specified area. Any area containing a system swing bus (type three) *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. In the power flow solution process there are two options for handling the interchange. One assumes that the interchange is exported only on tie lines out of the area. The other assumes that the interchange is a combination of flow on the tie lines plus any loads whose area assignment is different from the bus to which it is connected. Thus the PDES must be specified such that is consistent with these two options either of which will be selected at initiation of the power flow solution. PDES = 0.0 by default.

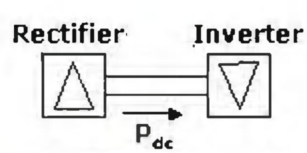
PTOL — Interchange tolerance bandwidth; entered in MW. PTOL = 10.0 by default.

ARNAME — Alphanumeric identifier assigned to area I. The name may contain up to twelve characters and **must** be enclosed in single quotes. ARNAME may be any combination of blanks, uppercase letters, numbers, and special characters. ARNAME is set to twelve blanks by default.

Area interchange data input from the Power Flow Raw Data File is terminated with a record specifying an area number of zero.

3.2.9 Two-terminal dc 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

The steady-state model comprising this data enables not only power flow analysis but also establishes the initial steady-state for dynamic analysis.

Data for each two-terminal dc transmission line are specified on three consecutive data records. The three data records have the following formats.

Record 1

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

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

I	The dc line number.
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 GAMMX = GAMMN) 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.

Record 2

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

```
IPR,NBR,ALFMX,ALFMN,RCR,XCR,EBASR,TRR,TAPR,TMXR,TMNR,STPR,ICR,IFR,
ITR,IDR,XCAPR
```

IPR	Rectifier converter bus number, or extended bus name enclosed in single quotes. No default allowed.
NBR	Number of bridges in series (rectifier). No default allowed.
ALFMX	Nominal maximum rectifier firing angle; entered in degrees. No default allowed.
ALFMN	Minimum steady-state rectifier firing angle; entered in degrees. No default allowed.
RCR	Rectifier commutating transformer resistance per bridge; entered in ohms. No default allowed.
XCR	Rectifier commutating transformer reactance per bridge; entered in ohms. No default allowed.
EBASR	Rectifier primary base ac voltage; entered in kV. No default allowed.
TRR	Rectifier transformer ratio. TRR = 1.0 by default.
TAPR	Rectifier tap setting. TAPR = 1.0 by default.
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. 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 one side "*from bus*" number, or extended bus name enclosed in single quotes, of a two-winding transformer. IFR = 0 by default.
ITR	Winding two 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. If no branch is specified, 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 two side of the transformer. The limits TMXR and TMNR specified here are used; except for the transformer control mode flag (COD of Section 3.2.6), the ac tap adjustment data is ignored.

XCAPR Commutating capacitor reactance magnitude per bridge; entered in ohms. XCAPR = 0.0 by default.

Record 3

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 converter buses, IPR and IPI, may be type one, two, or three buses. Generators, loads, fixed and switched shunt elements, other dc line converters, and FACTS device sending ends are permitted at converter buses.

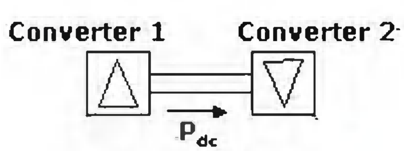
When either XCAPR > 0.0 or XCAPI > 0.0, the two-terminal dc line is treated as capacitor commutated. Capacitor commutated two-terminal dc lines preclude the use of a remote ac transformer as commutation transformer tap and remote commutation angle buses at either converter. Any data provided in these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

Further details on dc line modeling in power flow solutions are given in Section 4.3.5.

The dc line data input from a Power Flow Raw Data File is terminated with a record specifying a dc line number of zero.

3.2.10 Voltage Source Converter dc Line Data

Each voltage source converter (VSC) dc line to be represented in PSS/E is introduced by a set of three consecutive data records.



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

Record 1

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

NAME The non-blank alphanumeric identifier assigned to this VSC dc line. Each VSC dc line *must* have a unique NAME. The name may be up to twelve characters and *must* be enclosed in single quotes. NAME may contain any combination of blanks, uppercase letters, numbers and 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 the maximum number of owners at the current size level: see Table 1-1). 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.

Records 2 and 3

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

```
IBUS,TYPE,MODE,DOCET,ACSET,ALOSS,BLOSS,MINOSS,SMAX,IMAX,PWF,MAXQ,
MINQ,

REMOT,RMPCT
```

IBUS — Converter bus number, or extended bus name enclosed in single quotes. No default allowed.

TYPE — Code for the type of converter dc control: 0 for converter out-of-service, 1 for dc voltage control, or 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 or 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 ≤ PWF ≤ 1.0) used in reducing the active power order and either the reactive power order (when MODE is 2) or the reactive power limits (when MODE is 1) when the converter MVA or current rating is violated. When PWF is 0.0, only the active power is reduced; when PWF is 1.0, only the reactive power is reduced; otherwise, a weighted reduction of both active and reactive power is applied. PWF = 1.0 by default.

MAXQ
Reactive power upper limit; entered in Mvar. A positive value of reactive power indicates reactive power flowing into the ac network from the converter; a negative value of reactive power indicates reactive power withdrawn from the ac network. Not used if MODE = 2. MAXQ = 9999.0 by default.

MINQ
Reactive power lower limit; entered in Mvar. A positive value of reactive power indicates reactive power flowing into the ac network from the converter; a negative value of reactive power indicates reactive power withdrawn from the ac network. Not used if MODE = 2. MINQ = -9999.0 by default.

REMOT
Bus number, or extended bus name enclosed in single quotes, of a remote type 1 or 2 bus whose 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 are 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 within a Power Flow Raw Data File is terminated with a record specifying a blank dc line name (' ') or a dc line name of '0' or zero.

Each VSC dc line converter bus:

- must be a type one or two bus. Generators, loads, fixed and switched shunt elements, other dc line converters, and FACTS device sending ends are permitted at converter buses.
- must not have the terminal end of a FACTS device connected to the same bus.
- must not be connected by a zero impedance line to another bus which violates any of the above restrictions.

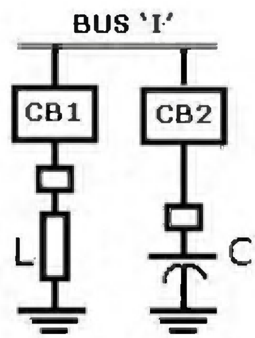
In specifying reactive power limits for converters which control ac voltage (i.e., those with unequal reactive power limits whose MODE is 1), the use of very narrow var limit bands is discouraged. The Newton-Raphson based power flow solutions require that the difference between the controlling equipment's 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.

Further details on dc line modeling in power flow solutions are given in Section 4.3.5.

3.2.11 Switched Shunt Data

It is possible to represent switched shunt devices, in the form of capacitors and/or reactors 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) or entirely of blocks of capacitor banks (each B_i is a positive quantity). Any bus can have both switched capacitors and reactors.

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

where:

I — Bus number, or extended bus name enclosed in single quotes.

MODSW — Control mode:

0 - fixed

1 - discrete adjustment, controlling voltage locally or at bus SWREM

2 - continuous adjustment, controlling voltage locally or at bus SWREM

3 - discrete adjustment, controlling reactive power output of the plant at bus SWREM

4 - discrete adjustment, controlling reactive power output of the VSC dc line converter at bus SWREM of the VSC dc line whose name is specified as RMIDNT

5 - discrete adjustment, controlling admittance setting of the switched shunt at bus SWREM

MODSW = 1 by default.

VSWHI
When MODSW is 1 or 2, the controlled voltage upper limit; entered in pu.

When MODSW is 3, 4 or 5, the controlled reactive power range upper limit; entered in pu of the total reactive power range of the controlled voltage controlling device.

VSWHI is not used when MODSW is 0. VSWHI = 1.0 by default.

VSWLO
When MODSW is 1 or 2, the controlled voltage lower limit; entered in pu.

When MODSW is 3, 4 or 5, 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 (see Section 3.2.2.1), of the bus whose 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 one or two bus whose voltage is to be regulated by this switched shunt.

When MODSW is 3, SWREM specifies the type two or three bus whose plant reactive power output is to be regulated by this switched shunt. Set SWREM to "I" if the switched shunt and the plant which it controls are connected to the same bus.

When MODSW is 4, SWREM specifies the converter bus of a VSC dc line whose 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 which it controls are connected to the same bus.

When MODSW is 5, SWREM specifies the remote bus to which the switched shunt whose admittance setting is to be regulated by this switched shunt is connected.

SWREM is not used when MODSW is 0. 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 whose converter bus is specified in SWREM. 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. 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 from a Power Flow Raw Data File is terminated with a record specifying a bus number of zero.

The following notes apply to switched shunts:

- BINIT needs to be set to its actual solved case value only when the network, as entered into the working case, is to be considered solved as read in, or when the device is to be treated as fixed (i.e., MODSW is set to zero or switched shunts are to be locked 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, the shunt blocks are specified in the order in which they are switched on the bus.
- If the switched shunt devices at a bus are a mixture of reactors and capacitors, 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.
- 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 or 5, 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, and $\Sigma N_i B_i - \Sigma N_j B_j$ when MODSW is 5, where "i" are those switched shunt blocks for which B_i is positive and "j" are those for which B_j is negative). VSWLO must be greater than 0.0 and less than VSWHI, and VSWHI must be less than 1.0. That is, the following relationship must be honored:

  $$0.0 < VSWLO < VSWHI < 1.0$$

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

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

  through:

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

- The switched shunt admittance is kept in the working case and reported in output tabulations separately from the fixed bus shunts, which are input on the bus data record (see Section 3.2.2).

- Details on the handling of switched shunts during power flow solutions are discussed in Section 4.3.3.
- It is recommended that data records for switched shunts whose control mode is 5 (i.e., they control the setting of other switched shunts) be grouped together following all other switched shunt data records. This practice will eliminate any warnings of no switched shunt at the specified remote bus simply because the remote bus' switched shunt record has not as yet been read.

3.2.11.1 Example Combination Switched Shunts

To assist in clarifying the data record, Figure 3-13 shows the data record set up to match the shown combination of switched elements on Bus 791.

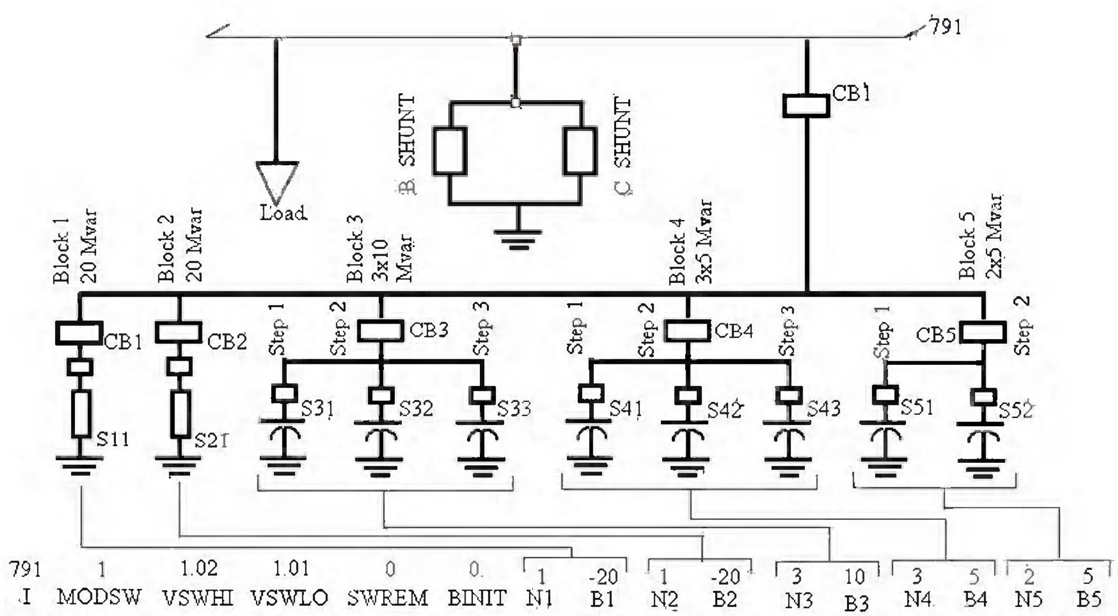


Figure 3-13. Example Data Record for Combination of Switched Shunts

3.2.12 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. Each transformer impedance correction data record has the following format:

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

where:

I	Impedance correction table number.
T_i	Either off-nominal turns ratio in pu 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 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 3-14.

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

Although a transformer winding is assigned to an impedance correction table, 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 by the user 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.

Transformer impedance correction data input from a Power Flow Raw Data File is terminated with a record specifying a table number of zero.

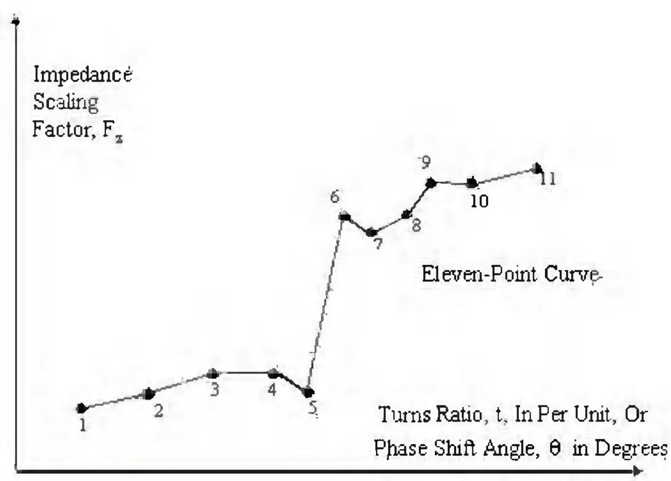
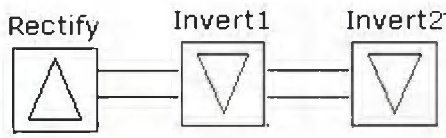


Figure 3-14. Typical Impedance Correction Factor Curve

3.2.13 Multi-Terminal dc Line Data

PSS/E allows the representation of up to 12 converter stations on one multi-terminal dc line. Further, the program allows the modelling of multi-terminal networks of up to 20 buses including the ac convertor buses and the dc network buses.



Each multi-terminal dc transmission line to be represented in PSS/E is introduced through a series of data records. Each set of multi-terminal dc line data records begins with a record which defines the number of converters, number of dc buses and dumber of dc links as well as related bus numbers and control mode.

Following this first record there are subsequent records for:

- each converter
- each dc bus
- each dc link

Data Record 1

```
I, NCONV, NDCBS, NDCLN, MDC, VCONV, VCMOD, VCONVN
```

where:

I	Multi-terminal dc line number.
NCONV	Number of ac converter station buses in multi-terminal dc line "I". No default allowed.
NDCBS	Number of dc buses in multi-terminal dc line "I" (NCONV $\leq$ NDCBS). No default allowed.
NDCLN	Number of dc links in multi-terminal dc line "I". No default allowed.
MDC	Control mode 0 - blocked 1 - power 2 - current MDC = 0 by default.
VCONV	Bus number, or extended bus name enclosed in single quotes, 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.

Data Record 2

Data record 1 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. No default allowed.

N — Number of bridges in series. No default allowed.

ANGMX — Nominal maximum ALPHA or GAMMA angle; entered in degrees. No default allowed.

ANGMN — Minimum steady-state ALPHA or GAMMA angle; entered in degrees. No default allowed.

RC — Commutating resistance per bridge; entered in ohms. No default allowed.

XC — Commutating reactance per bridge; entered in ohms. No default allowed.

EBAS — Primary base ac voltage; entered in kV. No default allowed.

TR — Actual transformer ratio. TR = 1.0 by default.

TAP — Tap setting. TAP = 1.0 by default.

TPMX — Maximum tap setting. TPMX = 1.5 by default.

TPMN — Minimum tap setting. TPMN = 0.51 by default.

TSTP — Tap step; must be a positive number. TSTP = 0.00625 by default.

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

Data Record 3

Following are NDCBS records, one for each dc bus, with the following format:

```
IDC, IB, IA, ZONE, 'NAME', 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, 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.

IA Area number, (1 through the maximum number of areas at the current size level: see Table 1-1). IA = 1 by default.

ZONE Zone number, (1 through the maximum number of zones at the current size level: see Table 1-1). ZONE = 1 by default.

NAME Alphanumeric identifier assigned to dc bus IDC. The name may be up to twelve characters and *must* be enclosed in single quotes. NAME may contain any combination of blanks, uppercase letters, numbers, and special characters. NAME 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 the maximum number of owners at the current size level: see Table 1-1). OWNER = 1 by default.

Data Record 4

Following the above records are NDCLN records, one for each dc link, with the following format:

```
IDC, JDC, DCCKT, RDC, LDC
```

where:

IDC — Branch "*from bus*" dc bus number.

JDC — Branch "*to bus*" dc bus number. JDC is entered as a negative number to designate it as the metered end for area and zone interchange calculations. Otherwise, bus "IDC" is assumed to be the metered end.

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.

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 from a Power Flow Raw Data File is terminated with a record specifying a dc line number of zero.

A multi-terminal layout is shown in Figure 3-15. There are 4 convertors, 5 dc buses and 4 dc links.

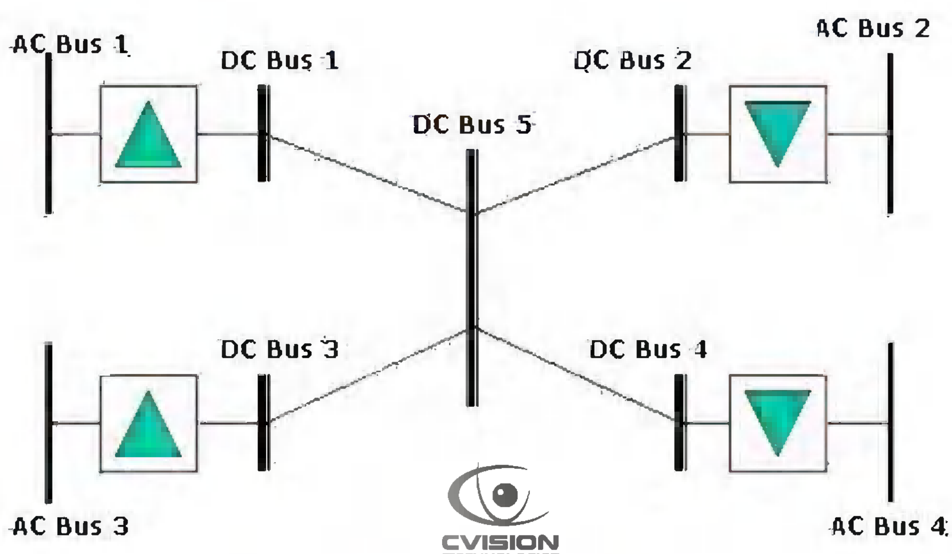


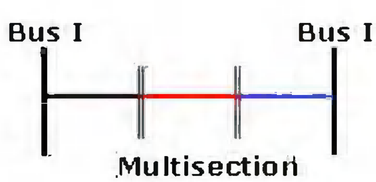
Figure 3-15. Multi-Terminal DC Network

The following are notes on multi-terminal links:

- Conventional two-terminal 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 number 1 along with a multi-terminal line numbered 1.
- Multi-terminal lines should have at least three converter terminals; conventional dc lines consisting of two terminals should be modeled as two-terminal lines (See Section 3.2.9).
- Ac converter buses may be type one, two, or three buses. Generators, loads, fixed and switched shunt elements, other dc line converters, and FACTS device sending ends 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 subnetwork.
- The area number assigned to dc buses and the metered end designation of dc links are used in calculating area interchange and assigning losses as well as in the interchange control option of the power flow solution activities. Similarly, the zone assignment and metered end specification are used in Zonal reporting activities.
- Further details on dc line modeling in power flow solutions are given in Section 4.3.5.

3.2.14 Multisection Line Grouping

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 multisection line grouping to be represented in PSS/E is introduced by reading a multisection line grouping data record. Each multisection line grouping data record has the following format:

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

where:

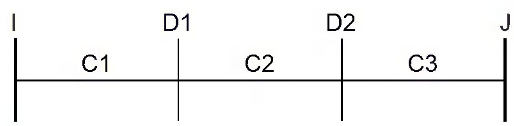
I — "*From bus*" number, or extended bus name enclosed in single quotes.

J — "*To bus*" number, or extended bus name enclosed in single quotes. J is entered as a negative number or with a minus sign before the first character of the extended bus name to designate it as the metered end; otherwise, bus I is assumed to be the metered end.

ID — Two-character upper case alphanumeric multisection line grouping identifier. The first character *must* be an ampersand ("&"). ID = '&1' by default.

DUM_i — Bus numbers, or extended bus names enclosed in single quotes (see Section 3.2.2.1), of the dummy buses connected by the branches that comprise this multisection line grouping. No defaults allowed.

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 multisection 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 multisection line grouping is to be assigned the line identifier "&1", the corresponding multisection line grouping data record is given by:

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

Multisection line grouping data input from a Power Flow Raw Data File is terminated with a record specifying a "*from bus*" number of zero.

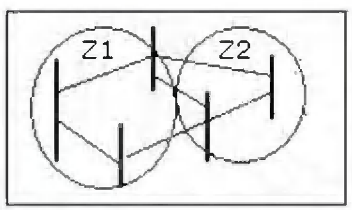
The following notes apply to multisection line groups:

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

- Each dummy bus must have exactly two branches connected to it, both of which must be members of the same multisection line grouping. A multisection line dummy bus may not be a converter bus of a dc transmission line. A FACTS control device may not be connected to a multisection line dummy bus.
- The status of line sections and type codes of dummy buses are set such that the multisection line is treated as a single entity with regards to its service status.
- When the multisection line reporting option is enabled, several power flow reporting activities, specifically bus related reports, do not tabulate conditions at multisection 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).

3.2.15 Zone Data

All buses (ac and dc) and loads can be assigned to reside in a zone of the network. To enable this facility, each zone should be assigned a name and number. Specifically, the zone number is entered as part of the data records for the buses and loads. 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.



Zone identifiers are specified in zone data records with the following format:

```
I, 'ZONAME'
```

where:

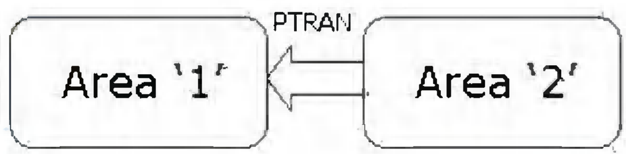
I — Zone number, (1 through the maximum number of zones at the current size level: see Table 1-1).

ZONAME — Alphanumeric identifier assigned to zone I. The name may contain up to twelve characters and *must* be enclosed in single quotes. ZONAME may be any combination of blanks, uppercase letters, numbers, and special characters. ZONAME is set to twelve blanks by default.

Zone data input from a Power Flow Raw Data File is terminated with a record specifying a zone number of zero.

3.2.16 Interarea Transfer Data

Using PSS/E, the user has the capability to identify in which area each bus or load resides (see Sections 3.2.2 and 3.2.3). Further, the user can schedule active power transfers between pairs of areas.



Scheduled active power transfers between pairs of areas are specified in interarea transfer data records each of which has the following format:

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

where:

ARFROM — "*From area*" number (1 through the maximum number of areas at the current size level: see Table 1-1).

ARTO — "*To area*" number (1 through the maximum number of areas at the current size level: see Table 1-1).

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.

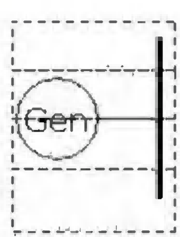
PTRAN — MW comprising this transfer. A positive PTRAN indicates that area ARFROM is selling to area ARTO. PTRAN = 0.0 by default.

Following the completion of interarea transfer data input, PSS/E alarms any area for which at least one interarea transfer is present and whose sum of transfers differs from its desired net interchange, PDES (see Section 3.2.8 for the definition of PDES).

Interarea transfer data input from a Power Flow Raw Data File is terminated with a record specifying a *"from area"* number of zero.

3.2.17 Owner Data

PSS/E allows the user to identify which organization or utility actually owns a facility, a piece of equipment or a load. Major network elements can have up to four different owners. This facilitates interpretation of results and reporting of results on the basis of ownership.



Owner identifiers are specified in owner data records with the following format:

```
I, 'OWNAME'
```

where:

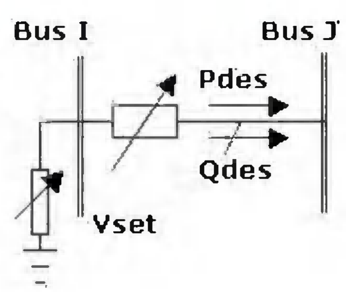
I — Owner number, (1 through the maximum number of owners at the current size level: see Table 1-1).

OWNAME — Alphanumeric identifier assigned to owner I. The name may contain up to twelve characters and must be enclosed in single quotes. OWNAME may be any combination of blanks, uppercase letters, numbers, and special characters. OWNAME is set to twelve blanks by default.

Owner data input from a Power Flow Raw Data File is terminated with a record specifying an owner number of zero.

3.2.18 FACTS Device Data

There is a multiplicity of Flexible AC Transmission System devices currently available comprising 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 the Interline Power Flow Controllers (IPFC), of which the latter are parallel series devices.



PSS/E facilitates these devices with one generic set of data records.

Each FACTS device data record has the following format:

```
N,I,J,MODE,PDES,QDES,VSET,SHMX,TRMX,VTMN,VTMX,VSMX,IMX,LINX,RMPCT,
OWNER,SET1,SET2,VSREF
```

where:

N — FACTS device number.

I — Sending end bus number, or extended bus name enclosed in single quotes. No default allowed.

J — Terminal end bus number, or extended bus name enclosed in single quotes; 0 for a STATCON. J = 0 by default.

MODE	Control mode:
	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; FACTS device N+1 must be 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; FACTS device N-1 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; FACTS device N+1 must be 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; FACTS device N-1 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.
	If J is specified as 0, MODE must be either 0 or 1. MODE = 1 by default.
PDES	Desired active power flow arriving at the terminal end bus; entered in MW. PDES = 0.0 by default.
QDES	Desired reactive power flow arriving at the terminal end bus; entered in MVAR. QDES = 0.0 by default.
VSET	Voltage setpoint at the sending end bus; entered in pu. VSET = 1.0 by default.
SHMX	Maximum shunt current at the sending end bus; entered in MVA at unity voltage. SHMX = 9999.0 by default.
TRMX	Maximum bridge active power transfer; entered in MW. TRMX = 9999.0 by default.
VTMN	Minimum voltage at the terminal end bus; entered in pu. VTMN = 0.9 by default.
VTMX	Maximum voltage at the terminal end bus; entered in pu. VTMX = 1.1 by default.
VSMX	Maximum series voltage; entered in pu. VSMX = 1.0 by default.
IMX	Maximum series current, or zero for no series current limit; entered in MVA at unity voltage. IMX = 0.0 by default.
LINX	Reactance of the dummy series element used during model solution; entered in pu. LINX = 0.05 by default.

RMPCT — Percent of the total Mvar required to hold the voltage at bus I that are to be contributed by the shunt element of this FACTS device; RMPCT must be positive. RMPCT is needed only if 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 I to a setpoint. RMPCT = 100.0 by default.

OWNER — Owner number, (1 through the maximum number of owners at the current size level: see Table 1-1). 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.

FACTS device data input from a Power Flow Raw Data File is terminated with a record specifying a FACTS device number of zero.

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 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 series synchronous condenser (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).

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).

An Interline Power Flow Controller (IPFC) is modeled by using two consecutively numbered series FACTS devices. The first of this pair must be assigned as the IPFC master device by setting its control mode to 5 or 7, and the second must be assigned as its companion IPFC slave device by setting its control mode to 6 or 8. 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.

Figure 3-16 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 4.3.4 for other topological restrictions and for details on the handling of FACTS devices during the power flow solution activities.

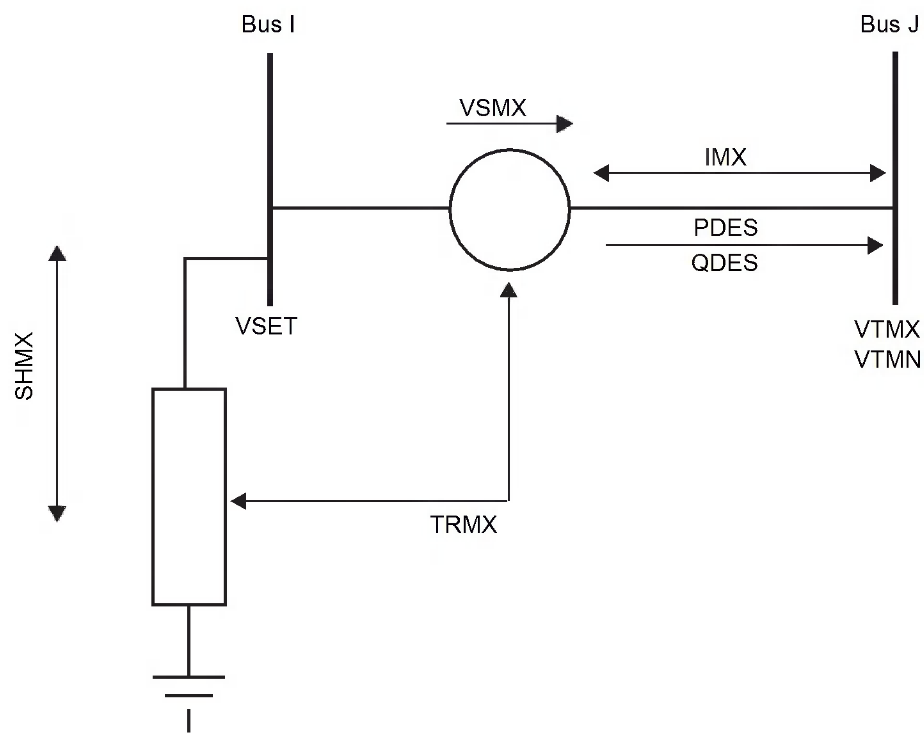


Figure 3-16. Basic FACTS Control Device Model

3.3 Importing Power Flow Data

Importing the Power Flow Raw Data File is facilitated by the ***File>Open*** option shown in Figure 3-17 or more directly by clicking the ***Open*** toolbar button on the File toolbar.

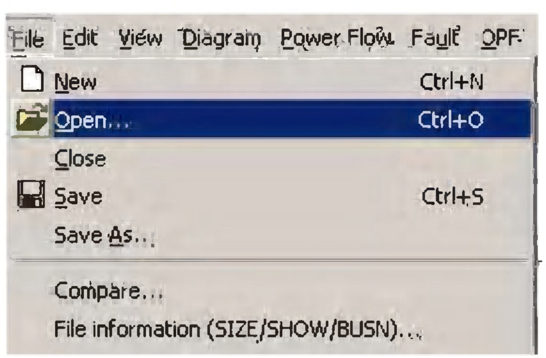


Figure 3-17. File>Open Option

This option will give access to the Open dialog where the available *.raw* files will be listed in the user's directory as shown in Figure 3-18. Clicking the ***Open*** button will initiate data import once the required file has been selected. Prior to data import, the user will be given the option of using the NAMES or NUMBERS option for importing data records. This selection will override the selection made (see Section 1.8.9).