

# **ADVANCED POWER FLOW**



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### Table of Contents

1.	What is New in this Release	1
2.	Program Description and Capabilities	1
3.	Solution Methods	2
4.	Generator Modeling	3
5.	Under Load Tap Changing Transformers (ULTC)	3
	Voltage Controlling ULTC	3
	Phase Shifting/Active Power Controlling ULTC	5
	Reactive Power Controlling ULTC.	5
6.	Area Interchange Control	5
7.	Three Winding Transformers	7
8.	Autotransformers	7
9.	Line Voltage Regulator (LVR)	8
10.	Power Flow Solution Options and Controls	9
11.	Customizing the EAPF Report, Setting Units and Exporting Facilities	11
12.	Violation and Summary Reports	
13.	Important Notes	13
	Selection of Base Power "BASE MVA/KVA"	
	What to do if the Load Flow does not converge	
14.	Tutorial: ULTC using Two-Winding Transformers	14
15.	Tutorial: ULTC using Three-Winding Transformers	25
16.	Tutorial: Voltage Control Using Generators	
17.	Tutorial: Voltage Control Using Static VAR Compensators	
18.	Tutorial: Area Control	
19	Tutorial: Using DC Lines and Verification and Validation	
	DC Line Sample Network 2	

### List of Figures

ULTC Voltage Control Transformer Controlling its Own Terminal or Remote Bus.	5
Schematic of an Autotransformer Circuit	8
Line Voltage Regulator (LVR)	9
Advanced Power Flow Solution Options	.10
Initializing the Power Flow Solution with Preliminary Gauss Seidel Iterations	.10
Setting Report Units in the Advanced Power Flow Program	.11
Selection of Reports, Units, Customizing, and Exporting Power Flow Results	.12
Sample Power System used for DC Line Tutorial	.51
Selecting DC line Symbol	.52
DC Line Data Dialog	.53
DC Line Data Dialog - Rectifier and Inverter	.54
Rectifier and Inverter Data	.55
Power Flows Shown on the Single Line Diagram of the Sample Network	
with DC Line	.57
Example of a Power System using DC Line, "T14bus-dc"	.59
DC Line Data for the Sample Network using DC Line	.60
	ULTC Voltage Control Transformer Controlling its Own Terminal or Remote Bus. Area Interchange Control Schematic of an Autotransformer Circuit Line Voltage Regulator (LVR) Advanced Power Flow Solution Options Initializing the Power Flow Solution with Preliminary Gauss Seidel Iterations Setting Report Units in the Advanced Power Flow Program Selection of Reports, Units, Customizing, and Exporting Power Flow Results Sample Power System used for DC Line Tutorial Selecting DC line Symbol DC Line Data Dialog Power Flows Shown on the Single Line Diagram of the Sample Network with DC Line Example of a Power System using DC Line, "T14bus-dc" DC Line Data for the Sample Network using DC Line



Note: You can view this manual on your CD as an Adobe Acrobat PDF file. The file name is:

Advanced Power Flow

Adv\_Power\_Flow.pdf

You will find the Test/Job files used in this tutorial in the following location:

 Designbase\Samples\ADPF
 =
 Advanced Power Flow

Test Files: 2wxfmrvc, 3wxfmrvc, areacont, genvc, svcvc, T14bus, T9bus, T14bus-DC, T9bus-DC

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#### 1. What is New in this Release



We have added "Governor Response Solution (distribute generation based on equal droop)" choice in the power flow options dialog box as shown in the above. By default this option is disabled (unchecked).

In power flow solution, the active power generation for each generator in the system is given (specified) by the user except for the swing (reference) bus. Selecting "Governor Response Solution" implies that the program should assume that all generators in the system have the same governor droop. This means that any load changes in the system will be distributed among generators in proportion to their KVA rating. The program first solves power flow (finds system voltages and the swing generation) without "Governor Response Solution". Then, the program redistributes the total generations (from all units and swing) to all units including swing in proportion to their KVA rating and solves power flow one more time. For example, if in a system there are five identical generators, when this option is selected, regardless of the user given generation assigned to each unit, the program distribute the total required generation among five equally.

### 2. Program Description and Capabilities

The EDSA Advanced Power Flow (EAPF) program is one of the most powerful, fast, and efficient power flow programs with excellent graphical user interface. EAPF supports advanced plotting, numerous options and modeling features. The EAPF program is based on advanced and robust solution algorithms, which incorporates state-of-the-art solution techniques applicable to large and complex systems. The program is equipped with an easy to use and intelligent graphical interface. The program's modeling capabilities include:

- ✓ Support full models of DC lines
- ✓ Unlimited Number of power sources
- ✓ Real and Reactive Power Losses
- ✓ Power Factor Correction and Automatic Temperature Adjustment
- ✓ Newton Raphson, Fast Decoupled, and Accelerated Gauss Seidel



- ✓ Double Precision Newton Raphson
- ✓ Advanced Solution Techniques for Fast Convergence
- ✓ Load Forecasting
- ✓ Overload and violation warnings for bus and branch equipment
- ✓ Option to select any scenario or loading category
- Global and individual bus diversity factors
- ✓ Phase Shifting Transformer
- ✓ Simulate single-phase networks tapped from 3phase network
- ✓ Voltage Profile
- ✓ Single Phase local and remote voltage control
- ✓ Local and Remote Bus Voltage Control via Static Var Compensation
- ✓ Local and Remote Bus Voltage control 1, 2 and 3 winding Transformers
- ✓ Combined SVC, Generator and Transformer Voltage Control
- ✓ Local and Remote Bus voltage control through Generation Kvar
- Unlimited physical load connections to a bus
- ✓ Area Interchange Control
- ✓ Transformer Impedance Adjustment based on Transformer Taps
- ✓ Hybrid Simulation Method
- ✓ Transformer ULTC simulation and auto voltage control
- ✓ Relaxed Generator limits simulation technique
- ✓ SVC, Shunt and Reactor compensation
- ✓ Variable voltage initialization techniques
- ✓ Simulate Power Flow inside Schedules
- ✓ Load Analysis by Voltage
- ✓ Load Analysis by Category
- ✓ True Analog/Digital Scope with Built-in Triggering Mechanism
- ✓ IEEE Common Format Output
- ✓ Professional Report Writer with intelligent wizard
- ✓ Detailed reporting in Text, HTML, MS Word, graphical and Excel Formats
- ✓ Custom Report Template Designer for Professional Custom Reporting
- ✓ Governor Response solution Distribute Generation based on Equal Droop

The Program output includes:

- ✓ Bus voltage and voltage angle;
- Reactive power, terminal voltage and remotely controlled bus (if any), power factor for generators;
- Current, active power, reactive power flows and flow power factor through branches;
- ✓ Branch losses and system losses in zone, area, or in entire system;
- ✓ Total Generation, Load, Losses, and System Power Mismatch;
- ✓ Voltage Violations report vs. user-defined threshold;
- ✓ Branch Loading Violations vs. user-defined threshold;

In Addition, all of the solution quantities (voltages and flows) are exportable to Excel, and can be used to Customize reports using Professional Report Writer.

### 3. Solution Methods

To cope with the unique features of different power systems, such as transmission, distribution and industrial power systems, or a mix of these systems, EAPF supports a number of solution techniques. The solution methods are **Newton Raphson, Fast Decoupled, Hybrid Solution**, and the **Gauss Seidel**. The latter offers better convergence for the networks having branches with high **R/X**. This situation may arise especially in a power system with predominately cable installations. The users may select the Fast



Decoupled method with limits and controls turned off when experiencing non-convergence. In this solution technique, transformer taps will not be adjusted and the generators are assumed able to deliver/absorb reactive power beyond their reactive power capabilities. This solution technique is particularly useful when the user wishes to determine the reactive power requirements in a new installation, or sometimes with a power system having data errors.

If the Fast Decoupled method does not converge even when you deactivate the constraints, the user should use the Gauss Seidel method. Since this method is inherently slow in convergence, user should allow more iterations.

Hybrid Solution is a very powerful technique suitable when systems with a diverse voltage, load sizes and impedances are modeled. This method utilizes both Newton Raphson and Gauss Seidel techniques. The active power mismatch is solved using Newton Raphson and reactive power mismatch is solved using Gauss Seidel.

### 4. Generator Modeling

The generator can be modeled using any of the following options:

- Fixed generation i.e., the user specifies constant active and reactive power generation;
- Voltage controlled also referred to as P-V, in this case active power and reactive power capability (maximum and minimum reactive power) is specified. In addition, the user specifies a desired controlled voltage for either generator terminal or a remote bus. The EAPF solution will determine how much reactive power is required to maintain the desired controlled voltage;
- Swing generator (sometimes it is also referred to as Utility or Reference generator). In this case, the user only specifies desired controlled voltage and its voltage angle (normally set to zero) at the generator terminal. EAPF will determine the required active and reactive power generation at the swing generator.

The user may connect more than one generator to a bus. The generators do not have to be the same rating and type. The following explains how EAPF divides the power among generators connected at the same bus:

- Fixed generators do not participate in the allocation;
- Swing generators share the required active and reactive generation equally;
- Voltage-controlled generators when each produces its specified active generation. Their share of the reactive power required in the solution is distributed proportionately to their reactive power capability range (without violating their limit).
- Governor response solution If this is selected in power flow options, the active power of a network will be equally shared on the generators in the network.

### **5.** Under Load Tap Changing Transformers (ULTC)

The EAPF program supports three types of ULTC transformers, which are described in the following section:

Voltage Controlling ULTC



This transformer can be used to control the voltage at either side of the transformer, or alternatively, it may control the voltage at the bus remote from the transformer terminals. For the latter case, to be practical, the remote bus should be in close proximity of the transformer. The required input data are:

- Transformer leakage impedance and ratings;
- Available tap range, maximum and minimum tap and number of taps;
- The range of controlled voltage (maximum and minimum voltage);
- The controlled bus identification. This may be either one of the transformer's terminals or a valid remote bus in the network.

For example, in Figure 1, a voltage regulating ULTC is connected between buses: BUSA and BUSB. The transformer tap can be on BUSA or BUSB and the voltage may be controlled at BUSA or BUSB or a remote bus such as BUSC. The power flow program will adjust the transformer tap to maintain the voltage at the controlled bus between the maximum and minimum specified voltage. In cases where the program is unable to control the voltage within the specified range, the transformer tap will be at either minimum or maximum tap position. The position is also user defined and can be either one of the transformer's terminals.





Figure 1: ULTC Voltage Control Transformer Controlling its Own Terminal or Remote Bus

#### Phase Shifting/Active Power Controlling ULTC

This type of transformer can be used to control the flow of active power through the transformer. It is also known as phase shifting transformer. The required input data are:

- Transformer leakage impedance and rating;
- Available phase shift range (maximum and minimum phase shift and number of taps);
- The range of controlled active power through the transformer.

The EAPF program will automatically adjust the transformer phase shift within its controlled range until the desired active power flow through transformer is obtained. If unable to control active power flow to the prescribed value, the phase shift will be set at either maximum or minimum allowable values.

#### Reactive Power Controlling ULTC.

This transformer controls the flow of reactive power flow through the transformer by adjusting its tap. The required input data are:

- Transformer leakage impedance and ratings;
- Available tap range (maximum and minimum tap and number of taps);
- The range of controlled reactive power flow through transformer;

The EAPF program will automatically adjust the transformer tap within its controlled range until the desired reactive power through transformer is obtained. If unable to control reactive power flow to the prescribed values, the transformer tap will be set at either maximum or minimum allowable values.

### 6. Area Interchange Control

This modeling of EAPF program can be used to simulate power transactions between utilities or areas of a power network. To illustrate this modeling concept, consider the following example based on Figure 2:





Figure 2: Area Interchange Control

Let's assume that there are three areas in the network, as shown in the figure. Area 2 is exporting power to areas 1 and 3. Area 1 is only importing power from areas 2 and 3. However, area 3 is both importing and exporting power to areas 1 and 2. The following data are the required for each area:

- Area name;
- Bus identification of the area control generator;
- Net exchange value of Active Power. This number could be positive or negative. If the exchange is positive, then, it is considered to be exporting power.
- Tolerance of MW Exchange;
- Maximum and Minimum active generation of the area control generator;
- "Zones" per "Area" assignment, many zones can be assigned to one area.

Tie lines are branches that link system areas and are entered like any other lines. The metering point for a tie line is the "From bus". Losses on the tie line are accounted for in the area of the "To bus". The power flow program automatically determines (using network connectivity information and zones in areas) the associated area tie lines. For example, in Figure 2, there is one tie line between area 1 and area 2. There are three tie lines between areas 3 and 1 and finally two tie lines between areas 2 and 3. For each of iterations the program will try to adjust the area control active power generation (within its specified maximum and minimum) such that the desired amount of import and export within each area is achieved.

Note that each area should have unique zones assigned to it. For example if there are 10 zones, then:

Area 1 can have zones 3,5,9. Area 2 can have 1,2,7 Area 3 can have 4,6,8 and 10



### 7. Three Winding Transformers

Three winding transformers are modeled as three 2-winding transformers. The required data are as follows:

- Primary, secondary, and tertiary bus identification;
- Transformer rating;
- Primary to secondary impedance;
- Primary to tertiary impedance;
- Secondary to tertiary impedance;
- Primary, secondary, and tertiary overload capabilities;
- Identification of the voltage controlled bus;
- Primary, secondary, tertiary tap information (maximum tap, minimum tap, number of taps, range of voltage control).

The EAPF program will automatically create three two-winding transformers. Then, each of the twowinding transformers will be treated as either a fixed-tap or ULTC depending on the data provided.

#### 8. Autotransformers

The Autotransformer is a special type of power transformer. It consists of a single, continuous winding that is tapped on one side to provide either a step-up or step-down function. This is different from a conventional two-winding transformer, which has the primary and secondary completely insulated from each other, but magnetically linked by a common core. The autotransformer's windings are both electrically and magnetically interconnected.

An autotransformer is initially cheaper than a similarly rated two-winding transformer. It also has better regulation (smaller voltage drops) and greater efficiency. Furthermore, it can be used to obtain the neutral wire of a three-wire system, just like the secondary of a two-winding transformer. It is commonly used to transform between two high-voltage circuits. But, the autotransformer is considered unsafe for use on ordinary distribution circuits. This is because the high-voltage primary circuit is connected directly to the low-voltage secondary circuit. The capacity of the Autotransformer is:

$$S'_1 = (V_1 + V_2) \cdot I_1 = I_1 V_1 (1 + \frac{1}{a}) = S_1 (1 + \frac{1}{a})$$

The transformation ratio of the Autotransformer is:

$$a' = \frac{(V_1 + V_2)}{V_2} = a + 1$$





Figure 3: Schematic of an Autotransformer Circuit

For example, if a=1, the capacity has been doubled! The advantages of autotransformers include:

- □ No "galvanic" isolation between primary and secondary windings;
- □ More power transformation capacity with the same size of the transformer;
- Possibilities to control voltage and reactive power flow;
- Widespread applications in power systems.

The mathematical model of an autotransformer is similar to a two-winding transformer and the EAPF treats an autotransformer the same as a voltage-controlled transformer but with simplified data requirements.

### 9. Line Voltage Regulator (LVR)

The line voltage regulator normally uses several-tap autotransformer to control the voltage to a precise set point. The Voltage Regulator circuitry monitors the incoming line voltage and compares it to a voltage reference set point. If a voltage fluctuation requires that a different tap be selected, the new tap is electronically switched (normally at the zero-crossing, to avoid distorting the AC waveform). In some design, if necessary, it can switch taps as often as once each cycle. Most commercial voltage regulators using multiple-tapped transformers switch taps at uncontrolled times, thereby creating voltage spikes.





Figure 4: Line Voltage Regulator (LVR)

Again, the LVR is modeled similarly to voltage controlled ULTC, but with simplified data entry. The function of LVR can be either boost or buck of the secondary voltage.

### **10.** Power Flow Solution Options and Controls

The EAPF program solution options and control parameters are shown in Figure 5. With these options user can select:

- □ Solution Method (Newton, Gauss, etc.);
- □ Convergence tolerance;
- □ Select Automatic Adjustments (ULTC's, Generator, and SVC);
- Limits & Controls On/Off;
- Governor Response Solution (default is unchecked);
- Auto Text Report;

The solution options were described in the previous sections. EAPF also allows the user to initialize the power flow solution by Gauss Seidel method. This is shown in Figure 6 where the number of initial iteration is specified as 20.

The Governor Response Solution (distribute generation based on equal droop) is unchecked in default. If this selection is checked, the power flow calculation will equally distribute the total active power of a network to all the generators. It's convenient for this type of application.





Figure 5: Advanced Power Flow Solution Options



Figure 6: Initializing the Power Flow Solution with Preliminary Gauss Seidel Iterations



### 11. Customizing the EAPF Report, Setting Units and Exporting Facilities

The EAPF supports a number of standard reports that are commonly accepted by the power industry load flow report formats. In addition to these reports, the result of power flow solution, i.e., voltages and power flows can be exported to Excel program. The reports can also be customized by advance "Professional Report Writer Wizard".

The units for reporting voltages and flows can be selected as shown in Figure 7. The voltages can be reported in p.u, volts, or kV. The unit of current report can be p.u., Amps, or kA. Finally, the active and reactive powers are reported in p.u., KW/KVAR, or MW/MVAR.

Power Flov	v Report Manager		×
Profession	Export Results to Excel Professional Report Writer Wizard	Short Text Reports Violatio Summary Report Bus Input Data	ns Checking Bus Voltage Violation Busbar Current Violation
- Digital Gau	Unit Setting Units for Report Format 1 an Uni	A Short Text Reports  Precision 3  Precision 3  Precision 2	iurrent Violation
	Full Pc IEEE C IEEE Co IEEE Co	ges Branch identification Volts © Branch Name © From/To Bus Names © Both OK Cancel	ange Report
Unit Settin	g and Calculation Log Information	Schedule Report           Schedule Voltage Report           Schedule Voltage Violation	Exit

Figure 7: Setting Report Units in the Advanced Power Flow Program

Figure 8 shows how different report options can be accessed in the Advanced Power Flow Program. The "Area Interchange Report" button will be active if area power interchange is selected in the master file editor.



ofessio	onal Reports	Short Text Reports	Violations Checking
X	Export Results to Excel	Summary Report	Bus Voltage Violation
S	Professional Report Writer Wizard	Bus Input Data	Busbar Current Violation
gital G	auges	Branch Input Data	Line Current Violation
	Output Results to Digital Meters	Bus Voltage Report	Transformer Violation
ull Text	Reports	Bus Flow Report	
Ż	Full Power Flow Report Format 1		
	Full Power Flow Report Format 2	Branch Current Report	Area Power Interchange Report
	IEEE Common Format Bus Report	Branch Power Flow	Area Interchange Report
	IEEE Common Format Branch Report	Transformer Loading	
3	IEEE Common Format Exchange File	Transformer Sizing	
nit Sett	ing and Calculation Log Information	Schedule Report	
	Unit Setting	Schedule Voltage Repo	t
	Lastetanakan	Cohodulo ) (altaga ) (altaga	Exit

Figure 8: Selection of Reports, Units, Customizing, and Exporting Power Flow Results

### 12. Violation and Summary Reports

The violation report identifies undesirable conditions in the network (overloaded equipment and unacceptably high or low voltages). It contains <u>only</u> those transformers, lines and cables that are loaded beyond the limits specified by the user. It also lists <u>only</u> those buses whose voltages fall outside the user-defined acceptable range. The program allows the user to adjust these limits before or even after the load flow calculation.

The summary report provides totals of generation, load, losses and mismatches<sup>1</sup> in the network. (Losses are the difference between generation and load.) Active and reactive quantities are listed separately. Motor load and static load are identified by separate totals. The solution method, base power, calculation tolerance and mismatches are also listed.

It is possible to show the power flows and the bus voltages directly on the one-line diagram.

<sup>&</sup>lt;sup>1</sup> If reported mismatches are not small as compared to the other quantities reported (for example a few percent of the total system load), consider running the load flow again with a smaller tolerance.



### **13. Important Notes**

#### Selection of Base Power "BASE MVA/KVA"

This is the common power base to which all impedances will be referred (per unitized). Choose a value midway between the largest and smallest power rating of the equipment in the network. Convenient values are 0.1, 1, 10 or 100 MVA.

#### What to do if the Load Flow does not converge

EAPF generates a file named "ErrorLog", where all the warnings and error messages are logged. The power flow iterations are also reported in this file. Log file gives the user the information about the convergence of the power flow solution process. Also, if the power system component data are in error, the program will issue messages related to the erroneous data.

If the ErrorLog shows that the calculation does not converge, inspect to see what buses have high power mismatches. If from iteration to iteration, the mismatches increase steadily, check the input data for components connected to the indicated buses. Look for very high or very low line/cable/transformer impedances. Make sure line and cable lengths are consistent with the length unit used for defining the impedance. If the mismatches increase and decrease and devices are being adjusted on every iteration, try solving without constraints. If that calculation converges, you may be able to see from the results what is wrong. Perhaps two devices have been asked to control the voltage at the same bus. If the convergence seems to be going up and down, this is an indication that some transformers/generators devices are continually being adjusted. If so, you may also try changing the settings of one or more of these devices before re-attempting another run. If the mismatches steadily decrease but remain higher than the specified tolerance as the permitted number of iterations is exhausted, try increasing the number of iterations before solving again.



### 14. Tutorial: ULTC using Two-Winding Transformers

1. Invoke the EDSA Graphical Interface, and proceed to open the file called "**2WXFMRVC**" as indicated in the following screen captures.







2. Next, proceed to designate the desired transformer, or transformers, that will be used as ULTC Control Transformers. Follow the instructions shown in the next screen capture.





Analysis: Adv. Power Flow 🔽 🚫 📶 🔤 📓 📓 🚟
Area Power Control Options
Analysis: Adv. Power Flow 💌 🐼 🌠 📾 📓 🖾 🌌
Options
Analysis: Adv. Power Flow 🔽 🤡 📶 🛄 🔛
Analyze
🛛 Analysis: 🗚dv. Power Flow 🔄 📀 🇞 📾 🧾 🗺 📟
Report Manager
Analysis: Adv. Power Flow 👤 📀 💋 🧱 🧱
Back Annotation
Analysis: Adv. Power Flow 🖃 🐼 🏂 🔤 📕 🜌
Scenario Voltage Profile

Overview – EDSA Toolbar



3. Proceed to enter the transformer data as well as the Auto Tap Adjustment Control options for this unit. In this example, the type of control will be defined as follows:

Control Variable:VoltageControlled Bus:FFF69 (69kV Primary Bus)

Follow the instructions shown in the following screen capture. Repeat this procedure for as many transformers as necessary. In this example, only one transformer will be equipped with adjustable taps.

Note: There is no limit in Voltage Control Transformers.

2 EDSA JobFile [2WXFMRVC] - Device [FFF69 ->FFF138] - ID [100062]				
Branch Name FFF69 →FFF138 Transformer Library 1000-3-D ▼ Kva Rating 100000.00 Kva System Voltages	Mation Dat	ta Entry Format Actual Values Per Unit		
Frequency       60       Hertz       From KV       63.000       Di         To KV       138.000       Di         Description       Short Circuit       Load Flow       PDC       Reliability       Installation	stribute [53.000 138.000	Step1: Ente transforme	er the data for r as indicated here	
Transformer Impedance         Powe           R % [0.00000         X % [12.00000         Dpen, SC Tests           G % [0.00000         B % [0.00000         Dpen, SC Tests           Transformer Cooling         Type [01 · AA · Dry-Type Self-Cooled] Factor [1.000	r System Optimization I-1 Security	Step2: Select adjustment" a as indicated h indicated here	"Automatic tap nd enter the tap limits ere. transformer as	
Tap Settings         Primary Tap:         1.00         Secondary Tap:         1.00         Z Adjusting Factor:         1.00         Adj Profile         Controlle         Winding types and Phase Shift data on Short Circuit tab are also used by Load Flow pro         Save to Library       Normalize	Automatic Tap Adjustment imum Adi (0.900 P.U. Adjustable imum Adi (1.100 P.U. Secon # Steps 60 ad Bus grams and are common to both.	Tap y vdary		
Step3: Select "Controlled bus". Complete the "Auto Tap Adjustment Control" dialog box as indicated here	Auto Tap Adjus Controlled Vari Voltage C Reactive Acceptable Vo Min Controlled Bus	stment Con able ontrol Power Control oltage (pu) 0.99 Max FFF69	trol 🔀	



4. Next, proceed to invoke the Advanced Power Flow Program, as indicated in the following screen capture. You will then see the Advanced Power Flow Options screen appear.







Please review and examine all the options. In this interface you can select Solution Algorithm and select/unselect the Automatic Voltage Control. You may also turn the Limits and Controls **On** or **Off**.

There are four Power Flow Methods: **Fast Decoupled**, **Newton Raphson**, **Hybrid Solution** (half Newton Raphson and half Gauss Seidel) and **Gauss Seidel**. Each of the method employed, can be used with or without applying generator reactive power limits. Turning off the generator reactive power limits (Limits& Controls switch) is particularly useful when the user wishes to determine reactive power requirements in new installation or sometimes with power system having data errors. The Gauss Seidel or Hybrid Solution methods are recommended for the networks that have branches with high R/X (cables) that both the Fast Decoupled and Newton Raphson methods do not converge. This situation may arise especially in a power system with predominately cable installations.

The following guidelines are offered as an aid to determine which technique may be the most appropriate for a particular system condition:

- The Gauss Seidel method is generally tolerant of power system operating conditions involving poor voltage distribution and difficulties with generator reactive power allocation, but does not converge well in situations where real power transfers are close to the limits of the system;
- The **Gauss Seidel** method is quite tolerant of poor starting voltages estimates but converges slowly as the voltage estimate gets close to the true solution;
- The **Gauss Seidel** method will not converge if negative reactance branches are present in the network, such as due to series capacitors or three-winding transformer models;
- The **Newton Raphson** method is generally tolerant of power system situations in which there are difficulties in transferring real power, but is prone to failure if there are difficulties in the allocation of generator reactive power output or if the solution has a particularly low voltage magnitude profile; in this situation, it is recommended to turn off "Limits &Controls" option;
- The **Newton Raphson** method is prone to failure if given a poor starting voltage estimate, but is usually superior to the Seidel-Gauss method once the voltage solution has been brought close to the true solution;
- The **Fast Decoupled** method will not converge when the network contains lines with resistance close to, or greater than, the reactance (cables). This is often the case in low-voltage systems.

Some experimentation is recommended to determine the best combination of methods for each particular model. The followings are recommended:

- Start with Gauss Seidel (20 iterations);
- Switch to Newton Raphson method until either the problem is converged or turning off Limits & Controls;
- Switch back to **Gauss Seidel** method if the **Newton Raphson** method does not settle down to a smooth convergence within 8 to 10 iterations.
- The **Hybrid Solution** technique can be used for systems that have diverse voltages, e.g., 400kV to 120v, very high or low impedance mixes and diverse loads, such as, 50HP and 5000HP. This is a very exact, fast technique for large power distribution and transmission systems.
  - 5. Once you have selected the Power Flow options, you may click the "Analyze" icon as shown in the screen capture below.





You will then see an information window that shows convergence of the calculation and the calculation iterations. The window will be automatically closed in 2 seconds. A test result report will be open if the "Auto Text Report" is checked in the options dialog box. The results will also be shown on the drawing depends on the selected data in the annotation dialog box. Close the text report now.



6. You may then proceed to open the Report Manager as shown in the next screen:

	Analysis: Adv. Power Flor	w 💌	📀 💋 🖬 📕	
				Report Manager
Power Flow Rep	ort Manager			X
- Professional Repo	orts	Short Te	xt Reports	Violations Checking
	Export Results to Excel		Summary Report	Bus Voltage Violation
Prol	fessional Report Writer Wizard	2	Bus Input Data	Busbar Current Violation
Digital Gauges		2	Branch Input Data	Line Current Violation
0u	Itput Results to Digital Meters	2	Bus Voltage Report	Transformer Violation
Full Text Reports			Bus Flow Report	
Ful	I Power Flow Report Format 1	4	Branch Current Report	Area Power Interchange Report
Ful	I Power Flow Report Format 2		Branch Power Flow	Area Interchange Report
	E Common Format Bus Report		Transformer Loading	
	Common Format Branch Report			
IEEE	Common Format Exchange File	<mark></mark>	Transformer Sizing	
Unit Setting and 0	Calculation Log Information	Schedule	e Report	]
	Unit Setting	P	Schedule Voltage Report	
	Log Information		Schedule Voltage Violation	Exit

Advanced Power Flow Report Manager has all the above options. This very powerful Report Manager includes: Professional Reports generator, Digital Gauges, Full Text Report, Unit Setting, Calculation Log Information, Short Report, Schedule Report and Area Power Interchange Report. Selecting the "Professional Report Writer Wizard" will take you through the appropriate steps for building your report.



© EDSA Power Flow Report Designer	
Image: Contract of the second cont         Sum and the second cont         Success 11440         West Bernardo Court         Success 11440         Success 11440         Vest Bernardo Court         Success 11440         Success 11440         Vest Bernardo Court         Success 11440         Success 11440         Success 11440         Vest Bernardo Court         Success 11440         Vest Bernardo Court	
Power Flow Report	
Detailed EDSA Power Flow Analysis of the Electric Power System	
Date: May 19, 2003	
	-

The user can view Digital Gauges by selecting "Output Results to Digital Meters". Please try all the options and view the outputs.

Buses and Brane         Select 'Buses'           Buses         Branches	View 'All' or select "Buses with Violations" and specify limits.
Powe	r Flow Calculated Values
Bus Voltage	Al C Buses with Violations     JJJJ138     Swing
Bus Voltage Per Unit	AAA138 Gen DDD138 Gen DDD69 Gen FFF138 Gen
Bus Voltage	BBB138 P_Load CCC138 P_Load FEE69 P_Load
V Voltage	File Information - A 14-bus network shown in Fig.E.3 in Paul M. Anderson's Faulted Power Systems 2-Winding Xfmr Voltage Control Voltage Control at Bus FFF69
-50 Voltage Degrees -100. 100	grees
	Close

Sample Bus Digital Meters





Sample Branches Digital Meters



Select the "Full Power Flow Report Format 1" button, you will see the following dialog box that you can choose the report sections desired. Try all the buttons to get familiar with the reports and settings.

🖸 Power Flow Output Options 🛛 🔀			
Output Unit Voltage KV Current KA Power MVA	Precision 3 Precision 3 Precision 2	Per Unit: 🗖	
<ul><li>Bus Input Data</li><li>Bus Voltage</li><li>Branch Current</li></ul>	<ul> <li>Branch Input Dat</li> <li>Branch Power Flo</li> <li>Transformer Load</li> </ul>	a Select All ow Clean All	
Voltage Violation	Over Limit 125	Under Limit 120 (%)	
🔽 Busbar Current Violation	Over Limit 105	Under Limit 95 (%)	
Line Current Violation	Over Limit 100	Under Limit 50 (%)	
Transformer Violation	Over Limit 100	Under Limit 50 (%)	
	Cancel		



## **15.** Tutorial: ULTC using Three-Winding Transformers

1. Invoke the EDSA interface. Proceed to open the file named "**3WXFMRVC**" as indicated in the following screen capture.

	ls Data <u>b</u> ase <u>A</u> nalysis <u>S</u> election	<u>D</u> raw <u>M</u> odify <u>W</u> indow <u>H</u> elp		
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	Open		?⊠	
	Look in: 🗀 AdvPF	▼ ← €	≝	
	2WXFMRVC1.axd	ACTEST.axd		
	2WXFMRVC.axd	♥ACTEST_15SCEN.axd ♥ACTEST_PF.axd	EX2.axd	
	SWXFMRVC.axd	ACTEST_SCHEDULE.axd	SENVC1.	
	ACTEST5_S1.axd	ADVLFV_V.axd	EEE399	
	<		>	
	File name: 3WXFMRVC.axd		Open	
	Files of type: Actrix Drawing (*.a	axd)	Cancel	



2. Next, proceed to designate the desired three-winding transformer or transformers that will be used as ULTC Control Transformers. Follow the instructions shown in the following screen capture.





3. Proceed to enter the transformer data as well as the Auto Tap Adjustment Control options for this unit. In this example, the type of control will be defined as follows:

Control Variable: Winding with Taps: Controlled Busses: Voltage Primary and Tertiary By Primary > Bus 07 By Tertiary > Bus 10

Follow the instructions shown in the following screen capture. Repeat this procedure for as many transformers as necessary. In this example, only one transformer will be equipped with adjustable taps.

anch Name 02 ->07	3-winding Transform	Auto Tap Adjustment Control
Library 1000-3-D Kva Rating (K Prim 200000 Sec 200000 Tert 200000	Primary Bus     02       (VA)     Secondary Bus     07       100     Tertiary Bus     10       100     Circuit     1	Primary ✓ Primary Auto Tap Adj Controlled Bus 07 Acceptable Voltage (pu) Min 1.020 Max 1.050 Tap Position Limit Nin 000 Max 1.050 00 00 00 00 00 00 00
escription         Short Circuit         Load How         PDC           Primary to Secondary Winding	Base: Primary Base: Primary Base: Primary Coadi	P Note for # Steps, 3 dial positions = 2 steps
R+ %  .10000 ×+ %  5.69000	Base: Primary 💌 Emer	genu Controlled Bus 10
Primary Tap:     .97931       Secondary Tap:     1.00000       Tertiary Tap:     1.00000       Z Adjusting Factor:     1.000	Add Delete Coolin Add Delete Add Delete Add Delete Add Profile Add Profile	ng T. Acceptable Voltage (pu) Min 1.020 Max 1.050 Tap Position Limit Min .900 Max 1.100 Steps 30 Note for # Steps 2 dial positions = 2 steps
Winding types and Phase Shift data on Sho	t Circuit tab :o used by Loa	d FicCancel



4. Next, proceed to invoke the Advanced Power Flow Options, as indicated in the following screen capture.

💱 File Edit View Insert Format Iools Database Analysis Selection Draw Modify Window Help 🔯 Package Li	mit: 30000 Active Buses: 10
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Analysis: Adv. Power Flow 💽 📀 🚾 🗺	
EDSA Advanced Dever Elevy Options	
Select Solution Algorithm Limits & Controls Conver	gence Settings OK
Correct Topo - D     Fast Decoupled     On Off     Maxim	um Iterations
G A Newton Raphson	
Gauss Seidel	
Advance 6.12kv Auto Report Selection Automatic Voltage Control	ed Options
Transformer Tap	alize Voltage with Gauss Seidel
Auto Text Report	
Gov	ernor Response Solution ribute generation based on
equ	al droop)



5. Run the analysis by following the instructions shown in the following screen capture.





6. Next proceed to view the text output results by following the steps in the above screen capture.

💱 Eile Edit View Insert Format Iools Database Ana	alysis <u>S</u> election <u>D</u> raw <u>M</u> odify <u>W</u> indow <u>H</u> elp	Package Limit: 30000 Active Buses: 10
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Analysis: Adv. Power Flow 💽 📀 💋 🧱		
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Power Flow Report Manager		
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Export Results to Excel	Summary Report	Bus Voltage Violation
Professional Report Writer Wizard	Bus Input Data	Busbar Current Violation
Digital Gauges	Branch Input Data	Line Current Violation
Output Results to Digital Meters	Bus Voltage Report	Transformer Violation
Full Text Reports	Bus Flow Report	
Full Power Flow Report Format 1	Branch Current Report	Area Power Interchange Report
Full Power Flow Report Format 2	Branch Power Flow	Area Interchange Report
IEEE Common Format Bus Report	Transformer Loading	
IEEE Common Format Exchange File	Transformer Sizing	
Unit Setting and Calculation Log Information	Schedule Report	
Unit Setting	Schedule Voltage Report	
Log Information	Schedule Voltage Violation	Exit



### **16.** Tutorial: Voltage Control Using Generators

1. Invoke the EDSA interface. Proceed to open the file named "GENVC" as indicated in the following screen capture.





2. Next, proceed to designate Generators 2 & 3 as **Voltage Control** units. Follow the instructions shown in the following screen capture.





3. Proceed to enter the required data for Generator 2 as indicated in the following screen capture.

EDSA JobFile [GENVC] - Device [02]	- ID [100075]	
Connection Information Name 02 Library	Generator Voltage System K Gen Actual K	V 18.0000 V 18.0000
Optional Location Information Zone Area	Operating Status	Frequency Temperature
Description Short Circuit Load Flow PDC	Reliability Installation Optimization	1
Type of Generator         PQ Bus         PV Bus         Units         Kw Kvar         Mw Mvar         Per Unit         Generator Voltage Control Settings         Controlled Bus       08         Desired Voltage       1.000         (PU)	Generation Characteristic Generator Swing Bus PG 163000. Kw Volt 18.000 KV QG 80000.0 Min QG 80000.0 Max Load Connected to Bus PL 0.00000 Kwar Constant Impedance	Operating Mode Doubly Fed Induction Generator Synchronous Generator
Save to Library		OK Cancel
J		



4. Proceed to enter the required data for Generator 3 as indicated in the following screen capture. In those two examples, the type of control will be defined as follows:

Generator 2:	Controlled Bus: Desired Voltage:	08 1.00 PU
Generator 3:	Controlled Bus: Desired Voltage:	03 1.025 PU

Repeat this procedure for as many generators as necessary. In this example, only two generators will be used for voltage control.

O EDSA JobFile [GENVC] - Device [03] -	ID [100076]	
Connection Information Name 03 Library	Generator V	/oltage System KV 13.8000 Gen Actual KV 13.8000
Optional Location Information Zone Area		Dperating Status Frequency Temperature
Description   Short Circuit   Load Flow   PDC   F	Reliability   Installation   Optimization	
PQ Bus	Generatio Generator C Swing Bus	on Characteristic Departing Mode Doubly Fed Induction Generator Schedule Schedule
Units -	Limits-	Generation
Mw Mvar	PG 85000.0 Kw QG	-40000.0 Min
Per Unit	Volt 13.800 KV QG	40000.0 Max
Generator Voltage Control Settings Controlled Bus 03 Desired Voltage 1.025 (PU)	Load Co PL 0.00000 Kw QL 0.00000 Kvar I Const	onnected to Bus-
Save to Library		OK Cancel



5. Next, proceed to invoke the Advanced Power Flow Options, as indicated in the following screen capture.

File Edit View Insert For	mat <u>T</u> ools Data <u>b</u> ase <u>A</u> nalysis	<u>Selection Draw M</u> odify <u>W</u> ind	ow Help 🔯 Package Limit: 30000 Active Buses: 9
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Analysis: Adv. Power Flow	- 🐼 📶 🖬 🖪		
	EDSA Advanced Power F	low Options	
©} 02 Vs: 18 kV	Select Solution Algorithm  Fast Decoupled  Newton Raphson Hybrid Solution Gauss Seidel	Limits & Controls	Convergence Settings Maximum Iterations 100 Tolerance 1 Mva 1 %
	Auto Report Selection	Automatic Voltage Control	Advanced Options Initialize Voltage with Gauss Seidel Governor Response Solution (distribute generation based on equal droop)



6. Run the analysis by following the instructions shown in the following screen capture, make sure power flow program converges.

File Edit View Insert Format Tools Dat	a <u>b</u> ase <u>A</u> nalysis <u>S</u> election (	Draw Modify <u>W</u> indow <u>H</u> elp	🔯 🛛 Package L	imit: 30000 Active Buses: 9
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Analysis: Adv. Power Flow 💽 🚫 💋	R 🛛 🖉			
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¥			s: 230	- 03
		08 Vs: 230 KV		Vs: 13.8 KV
			14 14	<u>, ()</u>
02 Vs: 18 kV				



7. Once the calculations have been completed, proceed to select output reports as indicated in the following screen capture.

Analysis: Adv. Power Flo	• 💽 🐼 💋 📼 📕	
		Report Manager
Power Flow Report Manager		
Professional Reports	Short Text Reports	Violations Checking
Export Results to Excel	Summary Report	Bus Voltage Violation
Professional Report Writer Wizard	Bus Input Data	Busbar Current Violation
Digital Gauges	Branch Input Data	Line Current Violation
Output Results to Digital Meters	Bus Voltage Report	Transformer Violation
Full Text Reports	Bus Flow Report	
Full Power Flow Report Format 1	Branch Current Report	Area Power Interchange Report
IEEE Common Format Bus Report	Branch Power Flow	Area Interchange Report
IEEE Common Format Branch Report	Transformer Loading	
IEEE Common Format Exchange File	Transformer Sizing	
Unit Setting and Calculation Log Information	Schedule Report	
Unit Setting	Schedule Voltage Report	
	Schedule Voltage Violation	E xit



## 17. Tutorial: Voltage Control Using Static VAR Compensators

<u>File Edit View Insert Format Tools Database Analysis Selection Draw</u>	Modify Window Help	
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	t9bus.axd Rad_n.axd	Line_VR
	Svcvc.axd MultI-SCEN.AXD	LFIS3.a:
	File name: Sycyc axd	Onen
	Files of type: Actrix Drawing (* axd)	Cancel

1. Invoke the EDSA interface. Proceed to open the file named "**SVCVC**" as indicated in the above screen capture.



Eile Edit V	<u>(</u> iew <u>I</u> nsert	F <u>o</u> rmat <u>T</u> oo	ols Data <u>b</u> as	e <u>A</u> nalysis	<u>S</u> election	Draw M	<u>1</u> odify <u>W</u> i	indow <u>H</u> e	p 🗵	Packa	ge Limit:	30000 Acti	ve Buses	: 14
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											_			

2. Next, proceed to designate Bus ZZZ69 as a Static VAR Compensation Bus. Follow the instructions shown in the above screen capture.



O EDSA Job File: SVCVC Bus ZZZ69	(14 of 14)	
Connection Information Name	Capacitor	Voltage System KV 69.0000 Rated KV 69.0000 Operating Status On Temperature Con
Type - Kvar - Per Unit	Reactive KVAF - Automatic Voltage Control - Static V	Power Compensation
	On Minimum K Controlled Bus Maximum K ZZZ69 Desired Volta	var -1000.00 var 10000.00 age 1.020 per unit
	Enter Bus Name	

3. Proceed to enter the required data for the SVC Bus, as indicated in the above screen capture. Repeat this procedure for as many SVC's as necessary. In this example, only one SVC will be used for voltage control.



🕎 Eile Edit View Insert Format Iools Database Analysis Selection Draw Modify Window Help 🔯 Package Limit: 30000 Active Buses: 14	
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Analysis: Adv. Power Flow 🔽 🐼 📶 🖾 🗮	
EDSA Advanced Power Flow Options	ecbus D 🗳 🗑 🖆
Select Solution Algorithm       Limits & Controls         • Fast Decoupled       Maximum Iterations         • Newton Raphson       Mybrid Solution         • Gauss Seidel       Tolerance         • Auto Report Selection       Automatic Voltage Control	Power Grid/Utility 1 Power Grid/Utility 3 Power Grid/Utility 3
Image: Construction of the second	Power Grid/Utility 7
	GEN IEC Generator 1

4. Next, proceed to invoke the Advanced Power Flow Program and then the program option, as indicated in the above screen capture.





5. Run the analysis by following the instructions shown in the above screen capture. Make sure the powerflow program converges.



Profession	nal Reports	Short Te	ext Reports	Violation	s Checking
X	Export Results to Excel	2	Summary Report		Bus Voltage Violation
X)	Professional Report Writer Wizard		Bus Input Data		Busbar Current Violation
)igital Ga	uges	3	Branch Input Data		Line Current Violation
	Output Results to Digital Meters	3	Bus Voltage Report		Transformer Violation
full Text F	Reports		Bus Flow Report		
4	Full Power Flow Report Format 1				
	Full Power Flow Report Format 2		Branch Current Report	Area Por	wer Interchange Report
	IEEE Common Format Bus Report		Branch Power Flow		Area Interchange Report
	IEEE Common Format Branch Report		Transformer Loading		
2	IEEE Common Format Exchange File		Transformer Sizing		
Unit Setting and Calculation Log Information Schedule Report					
	Unit Setting		Schedule Voltage Report		
	Log Information		Schedule Voltage Violation		Exit

# 6. Once the calculations have been completed, proceed to view the output report as indicated in the above screen capture.

Power Flow Outp	ut Format 1											
Exit Print Printer Font	Screen Font	Clipboard	d Save As	DONE								
	Sum ===	mary o	f Total	Genera	tion	and Deman	d =					
		P(	MW)	Q(M	VAR)	S	(MVA)	PF(%)				
Swing Bus(e Generators Shunt	s): : :	-62. 600. 0.	328 000 000	40 169 54	.497 .536 .979	7 62 5	4.329 3.492 4.979	83.85 96.23 0.00				
Static Load Motor Load Total Loss		525. 0. 12.	000 000 673	270 0 -4	.000 .000 .996	59	0.360 0.000	88.93 0.00				
Mismatch	:		001	0	.008							
G =	enerator 	& Capa =====	citor/I:	nductor	(SVC	) Voltage	Control					
Bus Nam	e 		Control	led Bus		DesiredV (kV)	AchieveV (kV)	Gen∛ (k∛)	₽ (MW)	Qmin (MVAR)	Q (MVAR)	Qmax (MVAR)
AAA138 DDD69 FFF138 ZZZ69		AAA13 DDD69 FFF13 ZZZ69	8			138.000 69.000 138.000 70.380	138.000 69.000 138.000 69.555	$ \overset{138.000}{_{69.000}} \\ \overset{138.000}{_{138.555}} $	200.00 0.00 200.00 0.00	0.00 0.00 0.00 -1.00	32.18 12.93 68.23 9.99	100.00 100.00 100.00 10.00



### 18. Tutorial: Area Control



**Area Controlled Network Under Study** 

This tutorial will be based on the network shown above. This power system has been subdivided into two Areas (212 & 213) as indicated above. In turn, each node within these areas belongs to its own Zone, also as indicated in the figure. The intent here is to export 70 MW from Area 213 into Area 212. Each area has the following operational characteristics:

#### a. <u>AREA 212</u>

Zones:	B3, A1, B1, B2, A3			
Area Control Generator ID:	AAA138			
Maximum Active Generation =	200.000 MW			
Minimum Active Generation =	10.000 MW			
Desired Net Import Active Power =	70.000 MW			
Power Exchange Tolerance=	5.000 MW			
b. <u>AREA 213</u>				
Zones:	C2, C1, C3			
Area Control Generator ID:	DDD138			
Maximum Active Generation =	200.000 MW			
Minimum Active Generation =	6.000 MW			
Desired Net Export Active Power =	70.000 MW			
Power Exchange Tolerance =	5.000 MW			





1. Invoke the EDSA, and proceed to load the pre-arranged file called "**Areacont.axd**". The network should look as indicated in the above screen capture.



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Ite   Company   Drawing Number   Bevision Number   Engineer   Revision History     DK   Cancel     EDSA Edit JobFile [AREACONT] Master File     Bus Defaults   AC Branch Defaults   Set All   Company   Defaults   Company   Defaults   AC Branch Defaults   Set All     The Visibility		Project N <u>a</u> me	•				
Company   Drawing Number   Bevision Number   Engineer   Revision History     OK   Cancel     EDSA Edit JobFile [AREACONT] Master File     Bus Defaults   AC Branch Defaults   3P Branch Defaults   DE Defaults   Concel     Bus Defaults   AC Branch Defaults   3P Branch Defaults   DE Defaults   Seneral   Network Settings   AC Visibility   Visw Phase Dependent Load Flow Fields   View Voltage Profile Fields   View Notor SC 2 Running   View Voltage Profile Fields   View IEC 363 fields for Short Circuit Analysis   View Notor SC 2 Running   View Voltage Profile Fields   View IEC 363 fields for Short Circuit Analysis   View Voltage Profile Fields   View IEC 363 fields for Short Circuit Analysis   View Voltage Profile Fields   View IEC 363 fields for Short Circuit Analysis   View Voltage Profile Fields   View IEC 363 fields for Short Circuit Analysis   View Voltage Profile Fields   View Voltage Profile Fields   Et None		<u>T</u> itle					
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Engineer         Revision History         DK       Cancel         EDSA Edit JobFile [AREACONT] Master File         Bus Defaults       AC Branch Defaults       3P Branch Defaults         IP Branch Defaults       DC Defaults       3P Branch Defaults         General       Network Settings       Time Periods       File Locations         General       Network Settings       View Phase Dependent Load Flow Fields       View Hase Dependent Load Flow Fields         View Voltage Profile Fields       View Voltage Profile Fields       View Voltage Profile Sields       View Voltage Profile Sields         Set All       Set None       Load Value Precision (decimal places: 0 - 6)       Loid Visibility		<u>R</u> evision Nur	mber				
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DK Cancel         EDSA Edit JobFile [AREACONT] Master File         Bus Defaults       AC Branch Defaults       3P Branch Defaults         1P Branch Defaults       DC Defaults       Scenarics         General       Network Settings       AC Visibility       Visibility         Immediate       Network Settings       Interface Visibility Settings         View Phase Dependent Load Flow Fields       View Motor SC % Running         View Voltage Profile Fields       View Area Interchange Controls         Set All       2       Load Value Precision (decimal places: 0 - 6)			Revision <u>H</u> isto	<u>n</u>			
EDSA Edit JobFile [AREACONT] Master File         Bus Defaults       AC Branch Defaults       3P Branch Defaults         1P Branch Defaults       DC Defaults       Scenarios       Time Periods       File Locations         General       Network Settings       AC Visibility       Visibility       Name Management         Immediate       View Phase Dependent Load Flow Fields       View Notor SC 2 Running       View Motor SC 2 Running         View Voltage Profile Fields       Area Interchange Controls       2       Load Value Precision (decimal places: 0 - 6)			ОК	Cancel			
EDSA Edit JobFile [AREACONT] Master File         Bus Defaults       AC Branch Defaults       3P Branch Defaults         IP Branch Defaults       DC Defaults       Scenarios       Time Periods       File Locations         General       Network Settings       AC Visibility       Visibility       Name Management         Image: Set All       Image: Set All       Image: View Phase Dependent Load Flow Fields       View Voltage Profile Fields         Image: View Voltage Profile Fields       Image: View Voltage Profile Fields       Image: View Precision (decimal places: 0 - 6)         Units Visibility       Units Visibility       Units Visibility	L				_		
Bus Defaults       AC Branch Defaults       3P Branch Defaults         1P Branch Defaults       DC Defaults       Scenarios       Time Periods       File Locations         General       Network Settings       AC Visibility       Visibility       Name Management         Immediate       Interface Visibility       Visibility       Settings         View Phase Dependent Load Flow Fields       View Motor SC & Running         View Motor SC & Running       View Voltage Profile Fields         View Ander Precision (decimal places: 0 - 6)       2         Load Value Precision (decimal places: 0 - 6)       0		EDSA Edit JobFile [AREACON	T] Master File				
Interface Visibility Settings         View Phase Dependent Load Flow Fields         View IEC 363 fields for Short Circuit Analysis         View Motor SC & Running         View Voltage Profile Fields         View Area Interchange Controls         Set All         Set None         Units Visibility		Bus Defaults AC Bra 1P Branch Defaults DC Default General Network Settings	anch Defaults   s   Scenarios   Time F AC Visibility   Visibility	3P Branch Defaults Periods   File Location   Name Managemen	ns nt		
Set All       ✓       Yew Voltage Profile Fields         Set All       ✓       Area Interchange Controls         Set None       2       Load Value Precision (decimal places: 0 - 6)         Units Visibility       Units Visibility		View Pha	Inter ase Dependent Load Flo 363 fields for Short Circ tor SC % Running	race Visibility Settings- w Fields uit Analysis			
Units Visibility		Set <u>All</u> Set <u>None</u> View Vol	tage Profile Fields rchange Controls Load Value Precision (d	ecimal places: 0 - 6)			
Units Visibility							
Power Units KVA  Voltage Units KV Length Units Feet			Power Un Voltage U Length Ur	Units Visibility its KVA • nits KV •			

2. Enable the Area Interchange Control command, as indicated in the above screen capture.

ΟK

Cancel



😵 Elle Edit View Insert Format Tools Database Analysis Selection Dra	w Modify Window Help 😰 Package Limit: 30000 Active Buses: 20
Page 1 💽 🖸 🔂 🖾 🕮 🕄	2 🐰 🗙 🖻 🖀 💁 🗠 🗟 🕲 ८ ८ ८ 🤮 🖓 🖉 🔛 🖉
🔛 🖄 🔁 🥌 🥵 4 📽 📓 🗹 💋 🎋 🐁 🏍 🏍	O EDSA Job File: AREACONT Bus AAA138 (1 of 20)
Analysis: Adv. Power Row   Adv. Power Row  Adv	Connection Information       Generator       Voltage         Name       System KV       138.0000         Ubray       1000       Image: Status       Description         Optional Location Information       Image: Status       Image: Status       Freque         Description       Short Circuit       Load Flow       Dynamic Data       PDC       Reliability       Installation       Optimization         Optional Description       Short Circuit       Load Flow       Dynamic Data       PDC       Reliability       Installation       Optimization         Optional Description       Short Circuit       Load Flow       Dynamic Data       PDC       Reliability       Installation       Optimization         Von-Essential       Essential       Critical       Stand-By       Maintenance Schedule       Image: Status       No Arc Heal         Notes:       Image: Status       Image: Sta
	Save to Library Enter Bus Name

3. Proceed to assign the Area and Zone information to every bus in the network, according to the information provided previously. Follow the instructions shown in the above screen capture, and repeat these instructions for every single bus in the network.



File Edit View Insert Format Tools Database Ana	ysis <u>S</u> election <u>D</u> raw <u>M</u> odify	Window Help	000 Active Buses: 20
🗋 D 🖻 🖬 🎒 🕼 🟙 🕼 👗 🗙 陆 🖻 🖉	N C C 陆 🖉 🖸 🖓	4 4 8 8 8 6 6 6	) 🚺 🛃 C E
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Analysis: Adv. Power Flow 💽 🚫 📶 🔤			
© EDSA Advanced Power Flo	w Options	<pre></pre>	ן ן ן
Select Solution Algorithm Fast Decoupled Newton Raphson Hybrid Solution Gauss Seidel	Limits & Controls	Convergence Settings OK Maximum Iterations Cancel	
Auto Report Selection	Automatic Voltage Control Transformer Tap Generator Voltage Static Var Compensation	Advanced Options Initialize Voltage with Gauss Seidel Number of Iterations: 20 Governor Response Solution (distribute generation based on equal droop)	
			-

4. Proceed to invoke the Advanced Power Flow program, as indicated in the above screen capture.



🔀 🔀 🔁 🥌 🥩 🜆 🖬 📓 🗹 ダ 🖉 🎭 縃 👒 🖧 🕂 🖾 🏂 👫 🖼 🧏 🦉 📟 🖉 👘 🚺 CA Scenario: )
Analysis: Adv. Power Flow 🔄 🐼 🔤 🗺
Area Power Interchange Dialog
Area Name Zone Name
Area Power Interchange Information:
Area Control Generator Name: JJJJ138
Maximum Generating Power (MW): 200
Minimum Generating Power (MW): 10
C Export C Import Net Power (MW): 70 Tolerance (MW): 5

5. Specify the Area Control parameters and run the Load Flow analysis, as indicated in the above screen capture.



Professio	nal Reports	Short Text Reports	Violations Checking
X	Export Results to Excel	Summary Report	Bus Voltage Violation
X	Professional Report Writer Wizard	Bus Input Data	Busbar Current Violation
Digital Ga	uges	Branch Input Data	Line Current Violation
	Output Results to Digital Meters	Bus Voltage Report	Transformer Violation
Full Text	Reports	Bus Flow Report	
4	Full Power Flow Report Format 1		
·····	Full Power Flow Report Format 2	Branch Current Report	Area Power Interchange Report
	IEEE Common Format Bus Report	Branch Power Flow	Area Interchange Report
	IEEE Common Format Branch Report	Transformer Loading	
2	IEEE Common Format Exchange File	Transformer Sizing	
Unit Setti	ng and Calculation Log Information	Schedule Report	
	Unit Setting	Schedule Voltage Repo	ort
	Log Information	Schedule Voltage Violati	on

```
Area ID : 212
                                            _____
Zone:
B3, A1, B1, A3, B2
                                                                                    : AAA138
Area Control Generator Name

      Maximum Active Generation
      = 200.000 MW

      Minimum Active Generation
      = 10.000 MW

      Desired Net Export Active Power
      = 70.000 MW

      Desired Net Export Active Power
      = 5.000 MW

Power Exchange Tolerance
                                                                                            = 5.000 MW
Actual Net Export Active Power= 70.100 MWTotal Area Active Generation= 310.880 MWTotal Area Reactive Generation= 73.740 MVARTotal Area Shunt Capacitor= 44.410 MWARTotal Area Shunt Inductor= 0.000 MVAR
Total Area Shunt Inductor
                                                                                  = 225.000 MW
= 120.000 MVAR
= 15.780 MW
Total Area Active Load
 Total Area Reactive Load
Total Area Active Loss
Total Area Reactive Loss
                                                                                            = 30.150 MVAR
                                           Area ID : 213
                                           _____
Zone:
C2, C1, C3

      Area Control Generator Name
      : DDD138

      Maximum Active Generation
      = 200.000 MW

      Minimum Active Generation
      = 6.000 MW

      Desired Net Export Active Power
      = -70.000 MW

      Power Exchange Tolerance
      = 5.000 MW

Power Exchange Tolerance
Actual Net Export Active Power= -70.100 MWTotal Area Active Generation= 261.840 MWTotal Area Reactive Generation= 130.500 MVARTotal Area Shunt Capacitor= 8.620 MWARTotal Area Shunt Inductor= 0.000 MVARTotal Area Active Load= 325.000 MWTotal Area Reactive Load= 170.000 MVARTotal Area Active Loss= 6.930 MWTotal Area Reactive Loss= -6.690 MVAR
```

6. Once the calculations are completed, the results are shown in the *Advanced Power Flow Output* screen for "Area Power Interchange".



### **19.** Tutorial: Using DC Lines and Verification and Validation

In this section we will show how to use DC lines in a power system. The sample power system is defined in the jobfile named "T9bus-dc". The single line diagram of this system is shown below:



Figure 9: Sample Power System used for DC Line Tutorial

A DC line has several components that are required for its proper operation. These are:

- 1. Rectifier Transformer
- 2. Rectifier
- 3. DC Line
- 4. Inverter
- 5. Invert Transformer

To be able to use a DC line in a power system, the user should make sure that the above components are modeled. Items 1 and 5 should be modeled similar to a normal "voltage regulating/control" transformer. In the sample network we have modeled two voltage regulation transformers one for the rectifier (between buses "7" and "RECTIFIER") and the other for the inverter (between buses "INVERTER" and "05") as shown in Figure 9. Items 2 through 4 above are addressed in the DC line dialog. To insert a DC line, select its symbol from the branch catalog as shown in Figure 10:





After selecting the DC line symbol drag it into single line diagram area and connect it to the buses "RECTIFIER" and "INVERTER" as seen in Figure 9.



To enter the D<u>C</u> line data, double left mouse click on its symbol. The data dialog is shown below:

EDSA JobFile [T9BUS-DC] - Device [DCLINE] - ID [100107]								
Branch Name DCLINE DC Line  Connection Information  Library 250  DC Line Length 1000 Feet Cables per Phase 1  Connection Status  Cables per Phase 1  DC Line Length 1000  Cables per Phase 1  Cables per Phase 1  DC Line Length 1000  Cables per Phase 1  DC Line Length 1000  Cables per Phase 1  Ca	Data Entry Format C Actual Values Per Unit							
Description Data Converter Reliability Installation								
Cable Resistance and Reactance at 40.0 C     Rated Temperature     Size       R + Ohms/1000 ft     10.00000     Cable Ampacity Rating       224.40								
Load Flow Analysis Temperature 40.0 C = 150 - 100 - 50 - 0 - Aluminum								
Save to Library	OK Cancel							

Figure 11: DC Line Data Dialog

DC line identification (branch name), resistance, and ampacity are specified in this section of data dialog. Next select "Converter" tab to enter data for the rectifier and inverter:



🖸 EDSA JobFile [T9BUS-DC] - Device [DCLINE] - ID [100107]							
Branch Name DCLINE DC Lie Library 250  From RECTIFIEF DC Line Length 1000 Feet Cables per Phase 1  Copen	To INVERTER ion Status Normal Connection Status Normally Closed Normally Open						
Description Data Converter Reliability Installation	Temperature Insensitive						
Rectifier Data (at From side)       Invertance         Number of Bridge       1         Desired DC Power       86.00000       MW         Delay Angle       15.00000       Degrees       M	r Data (at To side) Number of Bridge 1 Desired DC Voltage 442.95458 kV Estimate1 nimum Marginal Angle 18.00000 Degrees						
Save to Library	OK Cancel						
J							

#### Figure 12: DC Line Data Dialog - Rectifier and Inverter

It is important to notice that the rectifier is always on the "From" side and inverter is on the "To" side as shown in the upper right part of the Figure 12. For both rectifier and inverter the user should specify number of bridges. For rectifier, the desired delay (also known as firing) angle as well as desired active power flow through DC line should be entered. For inverter, the minimum marginal angle (also known as extinction) angle as well as desired DC line voltage needs to be specified. The proper selection of the DC line voltage is crucial to DC line operation and solution convergence. To assist the user, the program can suggest an approximate value of the DC line voltage. Press "Estimate" button shown next to the field for "Desired DC Voltage". For case at hand the program has calculated a value of 442.95 kV as shown in the above figure. For this example, let's enter 450 kV as shown in Figure 13.



🛛 EDSA JobFile [T9BUS-DC] - Device [DCLINE] - ID [100107]							
Branch Name DCLINE	DC Line Connection Information	Data Entry Format					
DC Line Length 1000 Cables per Phase 1	From HECHFIER TO INVERTER  Feet  From HECHFIER  For Closed  Copen  Normally Closed  Normally Closed  Normally Open	C Per Unit					
	Temperature Insensitive						
Description Data Converter R	eliability   Installation	1					
Rectifier Data (at From side) Number of Bridge	Inverter Data (at To side) I Number of Bridge 1 B6 00000 MW/ Desired DC Voltage 450 00000 kW	/ Estimate					
Delay Angle	15.00000 Degrees Minimum Marginal Angle 18.00000 De	egrees					
Sa	ave to Library	OK Cancel					

Figure 13: Rectifier and Inverter Data

After completing DC line data we solve the power flow. The iteration report for the above sample network is shown below:



	Mismatch	Report		
Iteration No.	kW	Bus	kvar	Bus
1	95169.2	INVERTER	77804.8	09
2	9410.5	05	12424.8	RECTIFIER
3	1129.3	05	2102.7	05
4	128.5	05	305.5	05
5	5117.3	07	29846.8	07
Ctrl Adjustments	made for:	V Ctrl		
б	309.7	05	2204.5	RECTIFIER
7	66.7	05	199.5	RECTIFIER
8	5358.3	07	31696.4	07
Ctrl Adjustments	made for:	V Ctrl		
9	199.8	INVERTER	2241.7	RECTIFIER
10	45.7	INVERTER	246.8	RECTIFIER
11	1830.3	07	30589.4	05
Ctrl Adjustments	made for:	V Ctrl		
12	137.2	INVERTER	1398.5	INVERTER
13	29.1	INVERTER	311.0	INVERTER
14	1785.6	05	32605.3	05
Ctrl Adjustments	made for:	V Ctrl		
15	70.7	INVERTER	1674.5	05
16	50.3	05	442.6	INVERTER
17	1309.2	05	22855.0	05
Ctrl Adjustments	made for:	V Ctrl		
18	97.5	05	1527.7	05
19	51.0	05	385.9	INVERTER
20	12.9	05	76.8	INVERTER
21	3.0	05	17.8	INVERTER
Ctrl Adjustments	made for:	DC		
22	0.7	05	4.0	INVERTER
Ctrl Adjustments	made for:	DC		
23	0.2	05	0.9	INVERTER
Ctrl Adjustments	made for:	DC		
*** Solution conv	verged in	23 iterations		

The above iteration report shows that the solution was achieved in 23 iterations. Also note that control adjustments were made for both voltage control transformers as well as DC line. The results of power flow for the sample system is shown Figure 14.





Figure 14: Power Flows Shown on the Single Line Diagram of the Sample Network with DC Line

The summary as well as branch reports are also shown below. It is important to note that in the branch report for DC line, the MVAR flow is not the reactive power flow on the DC line but it is the reactive power consumed in the rectifier and inverter.



80.00 40.00

			System Inform	mation ======							
	5 1013										
	Base MVA Erequency	=	100.000 (MVA) 60 (HZ)								
	Unit System	=	U.S. Stan	dard							
	MaxIterations	=	1000								
	Error Tolerance	= =	0.00100 (MVA),	0.000010	(PU), O.	0010 (%)					
	# of total Buse	es =	11								
	# of Active Bus	ses =	11								
	# of Generators		2								
	# of Loads	=	3								
	# of Shunts	=	0								
	# of Branches	=	12								
	# of Reactors/d	capacitors =	0								
	# of Circuit B	reakers =	0								
			Abbreviati	ons							
	2-W xfmr =	2-winding tran	sformer	3-W xfmr =	3-winding	transfor	mer				
	Autoximr = F Load =	Autotransforme	r . 4	DReactor = FeederM =	Duplex Re Feeder in	actor Magnetic	Conduit				
	Gen =	Generator		I Load =	Constant	current l	oad				
	None =	None contribut	ing	P_Load =	Constant	power loa	d				
	PhS xfmr =	Phase-Shift Tr	ansformer ,	SeriesC =	Series Ca	pacitor					
	ShuntC =	Shunt Capacito	r i	ShuntR =	Shunt Rea	ctor					
	Z_Load = Ref °C =	Constant imped Reference Temp	ance load i erature	UPS_L =	UPS load						
		Power Flow	By Fast Decoupl	od CONVERG	ED						
			Iteration: 23								
		Summary	of Total Gener	ation and i	Demand =====						
		P(MW)	Q(MVAR)	S	(MVA)	PF(%)					
	Swing Bus(es):	70.904	25.330	7.	5.292	94.17					
	Generators :	248.000	65.375	250	6.472	96.70					
	Shunt :	0.000	0.000		0.000	0.00					
	Static Load ·	315 000	115 000	33	5 3 3 6	93 94					
	Motor Load :	0.000	0.000		0.000	0.00					
	Total Loss :	3.904	-24.296								
	Mismatch :	-0.000	0.002	-							
			1. ( <del>.</del>	( 77 77 ) 17		1					
		Generator & Caj	pacitor/inducto	r (SVC) Vo. ======	ltage Cont =======	ro1 ===					
	Bus Name	Con	trolled Bus	DesiredV (kV)	AchieveV (kV)	GenV (kV)	Р (MW)	Qmin (MVAR)	Q ( MV.	( AR) (1	Qmax MVAR)
02 03		02 03		18.450 14.145	18.450 14.145	18.450 14.145	163.00 85.00	-80.0 -40.0	0 1	4.05 1.33	40.00
		Transformer Vo	ltage Control &	Line Volta	age Regula	tor					
	Branch Name	Туре	Controlled B	us Name	MinV (kV)	CalcuV (kV)	MaxV ( kV )	MinTap (PU)	Tap (PU)	MaxTap (PU)	
INV	-TRSFO	2-W xfmr	INVERTER		327.750	355.124	362.250	0.900	0.907	1.100	
REC	-TRSFO	2-W xfmr	RECTIFIER		327.750	351.442	362.250	0.900	0.953	1.100	
			DC Line Re.	sult ====							
	Branch Name	Type	Library CodeNa	me From k	V To kV	Current	Firing	Exti	nction		
						(KA)	Ang (Deg	9.) Ang 	( <i>Deg.</i> )		
DCL	INE	DC Line	250	451.91	1 450.000	0.191	15	.30	18.44		



#### DC Line Sample Network 2

A second example for the DC line is provided below. This example (jobfile named "T14bus-dc") is similar to the sample power system used in the jobfile named "T14bus". We have added rectifier and inverter transformer as shown below:



Figure 15: Example of a Power System using DC Line, "T14bus-dc"

The data for the rectifier and inverter for this system is shown below:



O EDSA JobFile [T14BUS-D	C] - Device [0003] - ID	[100072]		
Branch Name 0003	I From J Existin	DC Line Connection Information RECTIFIER To INVEI ng Connection Status Normal C - Closed - Open - N	RTER onnection Status ormally Closed ormally Open	Data Entry Format C Actual Values Per Unit
Description Data Converter	Reliability Installation	n Tempe	rature Insensitive	
Rectifier Data (at From side) Number of Bridge Desired DC Power Delay Angle	1         50.00000       MW         15.00000       Degrees	Inverter Data (at To side) Number of Bridge Desired DC Voltage Minimum Marginal Angle	1 300.00000 kV 18.00000 Degr	Estimate ees
	Save to Library			OK Cancel

Figure 16: DC Line Data for the Sample Network using DC Line

The solution is shown in Figure 15 and the text result report is shown below:

System Information							
		======					
Base MVA	=	100.000	(MVA)				
Frequency	=	60	(HZ)				
Unit System	=	U.S. Standard					
MaxIterations	=	100					
Error Tolerance	=	0.01000	(MVA),	0.000100	(PU),	0.0100	(
# of total Buses	=	16					
# of Active Buses	=	16					
# of Swing Buses	=	1					
# of Generators	=	4					
# of Loads	=	9					
# of Shunts	=	4					
# of Branches	=	19					
# of Transformers	=	6					
# of Reactors/capacitors	=	0					
# of Circuit Breakers	=	0					



### Abbreviations

2-W xfmr	= 2-winding transformer	3-W xfmr = 3-winding transformer
Autoxfmr	= Autotransformer	DReactor = Duplex Reactor
F_Load	= Functional load	FeederM = Feeder in Magnetic Conduit
Gen	= Generator	I_Load = Constant current load
None	= None contributing	P_Load = Constant power load
PhS xfmr	= Phase-Shift Transformer	SeriesC = Series Capacitor
ShuntC	= Shunt Capacitor	ShuntR = Shunt Reactor
Z_Load	= Constant impedance load	UPS_L = UPS load
Ref °C	= Reference Temperature	

Power Flow By Newton Raphson CONVERGED Iteration: 11

Summary of Total Generation and Demand

		P(MW)	Q(MVAR)	S(MVA)	PF(%)
Swing Bus(es Generators Shunt	): : :	-33.449 600.000 0.000	29.115 251.850 54.155	44.345 650.714 54.155	75.43 92.21 0.00
Static Load Motor Load Total Loss	: : :	550.000 0.000 16.552	290.000 0.000 45.124	621.772 0.000	88.46 0.00
Mismatch	:	-0.001	-0.004	-	

### Generator & Capacitor/Inductor (SVC) Voltage Control

Bı	is Name	Controlled Bus	DesiredV (kV)	AchieveV (kV)	GenV (kV)	P (MW)	Qmin (MVAR)	Q (MVAR)	Qmax (MVAR)
AAA138		AAA138	140.760	140.760	140.760	200.00	0.00	98.98	100.00
DDD69		DDD69	69.000	69.000	69.000	0.00	0.00	5.81	100.00
FFF138		FFF138	140.760	140.760	140.760	200.00	0.00	90.87	100.00

#### Transformer Voltage Control & Line Voltage Regulator

Branch Name	Туре	Controlled Bus Name	MinV (kV)	CalcuV (kV)	MaxV (kV)	MinTap (PU)	Tap (PU)	MaxTap (PU)
INVERTER-TRSFO RECTFIER-TRSFO	2-W xfmr 2-W xfmr	INVERTER RECTIFIER	218.500 218.500	235.050 231.085	241.500 241.500	0.900 0.900	0.967 0.973	1.100 1.100
		DC Line Result						

=======================================								
	Branch Name	Туре	Library CodeName	From kV	To kV	Current (kA)	Firing Ang (Deg.)	Extinction Ang (Deg.)
0003		DC Line	250	300.167	300.000	0.167	14.30	18.03