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Simulation of Power Losses improvement at 5 Bus System with Unified Power Flow Controller (UPFC) Using the NEPLAN Software

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Abstract

This paper represents a simulation of power losses improvement at 5 bus system with Unified Power Flow Controller (UPFC) using the Software NEPLAN . In electric power system the power flow on transmission lines is a function of the parameter line (ie: line impedance, voltage magnitude of sending end and receiving end, phase angle between voltage of sending end and receiving end. UPFC as one of the Flexible AC Transmission System Devices (FACTS-device) can control the third line parameters, either separately or simultaneously. By adjusting the power magnitude in UPFC, voltage magnitude in series and shunt converter (VSE and Vsh), simulation result of placement of UPFC in the system 5 bus using the Software Neplan, indicating that the voltage on the bus increases, losses in transmission lines has decreased significantly and certainly Loadability and Available Transfer Capability network (ATC) to be increased.

Key word: Unified power flow controller, Power losses, Availability of transfer capability, NEPLAN

Introduction

Development of electric power system can not be separated from the construction / addition of a plant and the development of new transmission lines. However, the development of the transmission line in a rapidly growing area is a complex and complicated. To increase the capacity of the power supplied to the load, the simple solution is to increase the loadability of transmission network by minimizing the power losses through control of line transmission parameters (line impedance, Voltgae of sending end and receiving end, phase angle). Unified power flow controller (UPFC) as power electronics-based controller, can control the active and reactive power flow on line transmission through controlling of parameters [1]. As a versatile and modern controller today, UPFC are the shunt and series reactive compensator and phase shifter, which can operate simultaneously or separately [3]. Operation UPFC can be changed from one state to another without having to reschedule of generation or change of line topologi[2].

The basic structure of UPFC

The basic structure of the UPFC, consists of two sourced Voltage Converters (VSC), which are connected with a common DC link through a DC Capacitor Storage. Each Converter is connected to the system through a coupling transformer. First Converter is connected in parallel with the transmission line through a shunt transformer (Boosting Transformer) and is known as Static Synchronous Compensator (STATCOM), while the second converter connected in series with the transmission line through a series transformer (Exciting Transformer) and is known as a Static Synchronous Series Compensator (SSSC) [3]. More details see figure 1 below.

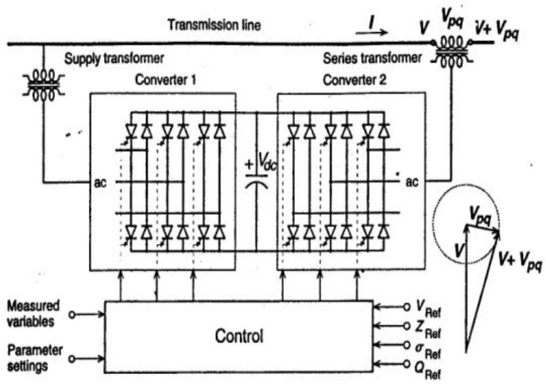

Figure 1. Diagram Block of UPFC

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Function of UPFC

Figure 1. Showed that the two converters are operated from a common dc link through the dc storage capacitor, the series converter function injects the voltage magnitude Vpq and phase angle which controllable, while the shunt converter that supply of reactive current via shunt transformer supplying active power required by the converter series through common dc link, this situation caused the serial converter to exchange active and reactive power with the transmission line.
Each of converter can generate or absorb reactive power on each of its ac terminal. Shunt converter must be able to maintain a constant dc voltage by controlling voltage phase through exchange of active power, as well as control the ac voltage at the transformer terminal shunt through reactive power exchange with the line. While the series converter with voltage injection can control the active and reactive power with the transmission line.

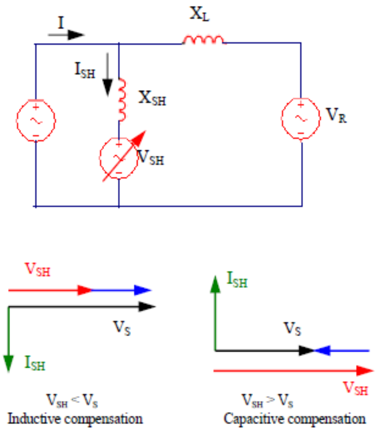
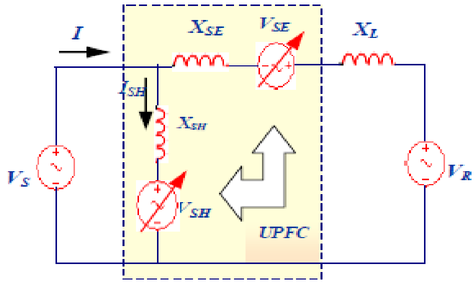


Figure 2. Eqivalen network of UPFC

Illustration of shunt converter operation
In figure 2. Showing the eqivalen Network of UPFC, with series injection voltage source V_{SE} and shunt voltage source V_{SH}, and each has a series reactance X_{SE} and shunt X_{SH}, X_L is the reactance of the transmission line. The illustration of the operation of the shunt converter is shown in figure 3.

In Figure 3. by changing the magnitude of V_{SH} and the phase angle difference between voltage V_{SH} and VS is maintained at zero value, the reactive power flow direction can be changed (V_{SH} function is generate or consume of reactive power). This operation is identical with installation of shunt capacitors on the transmission line, generating or absorbing reactive power by changing its impedance shunt reactive. its condition shows that the function of the shunt compensator duplicated by shunt voltage source (V_{SH}).
If the phase angle of shunt voltage souce Vsh leading to V_S, and the magnitude $V_{SH} > V_S$, V_{SH} generate active and reactive power, whereas if the

phase angle V_S leading to V_{SH}, and $V_S > V_{SH}$, V_{SH} consume the active and reactive power. Its indicate that by controlling the amplitude and phase angle of shunt voltage source Vsh. the direction of the flow of real and reactive power can be controlled, so that the shunt voltage source Vsh can to become load or generator on the power system.



Figur 3. Eqivalen Network for part of shunt UPFC

Illustration of seri converter operation
Part of series gives the main function of the UPFC by controlling the three parameters (voltage, impedance and phase angle), that will affects the power flow in the transmission line simultaneously and independently. In this case represented by a variable series AC Voltage Source with magnitude V_{SE} that controlabled and phase angle α is measured from the reference voltage V_R, connected to the sending end by reactance X_{SE} as illustrated in Fig. 4

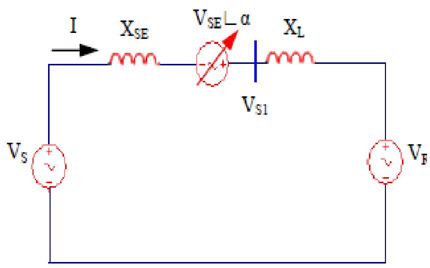


Figure 4. Eqivalen netwok for part of seri UPFC

Neplan Software
NEPLAN Software is a software program made from Swiss that is widely used for the purposes of planning and information systems on the network of electrical, gas and water. This software provides all the menus and calculation modules, making it very easy to operate by the user.
In Neplan Software, provided a wide range of sample applications, which include practical tutorial that shows how to start a new project and how to build a small power system, so the user will learn how to incorporate graphic elements, how to enter data, use the library, perform calculations and present the results in a customized manner for the purpose of analysis.

a. Drawing a simple system
Drawing any system made in Workspace. In the Workspace, different diagrams can be opened, the same diagram can be used to enter the network and build control circuits or drawing sketches. The Workspace form shown in Figure 5.

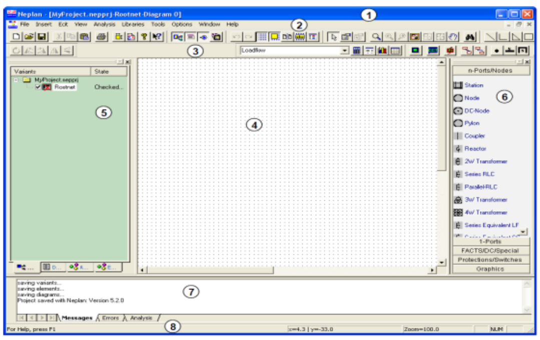


Figure 5. Workspace area

1. Titlebar
2. Menu option bar
3. Toolbar
4. Workspace with diagrams and data tables
5. Variant Manager
6. Symbol Window
7. Message Window
8. Status bar

The results of the image in the workspace shown in figure 6

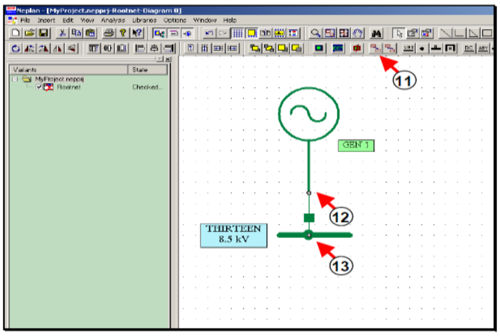


Figure 6. Figure example of parts of system in workspace

b. Input Data

Each drawing the parts of system, facilitated by the input data space, for example in Figure 7, ie: generator, busbar, transmission line and etc.

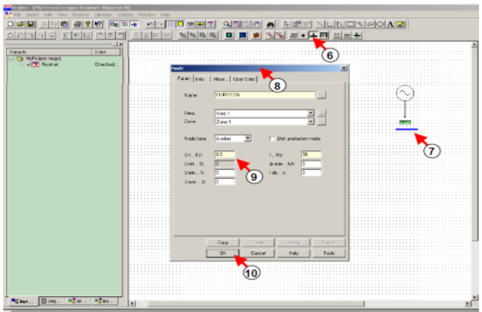


Figure 7. Dialog box example for data input of generator

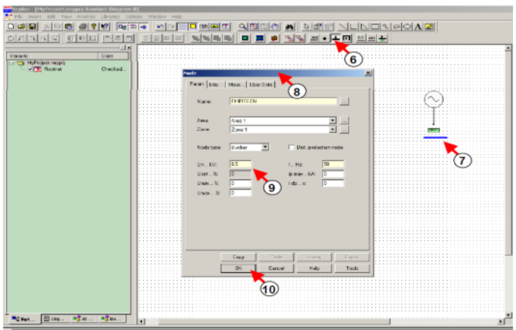


Figure 8. Dialog box example for data input of generator

c. Simulation Program

After all the images have been poured in the workspace, the input data has been completed for each of the elements of the picture, we then performed running the program in accordance with the objectives to be achieved. In the menu bar option available all the options

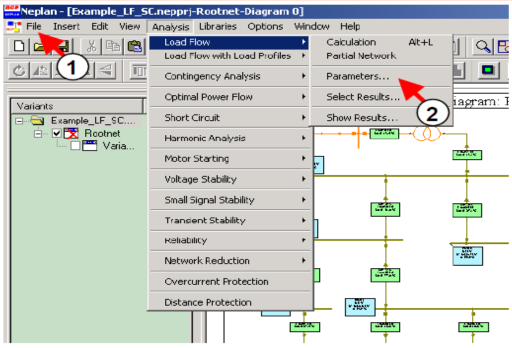
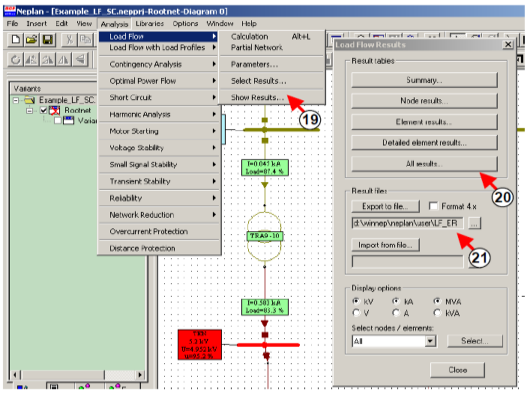


Figure 9. Menu bar option for simulation

d. Simulation Results

The simulation results (analysis), can be selected in accordance with the wishes, for example: The yield on the bus alone, results in a particular element, or the overall results, including conclusions from the results obtained



Gambar 10. Selection of simulation results

e. Other facilities

From the pictures shown, ranging from starting a program, create an image, fill in the data and simulation program, only a small part of the facilities provided by NEPLAN. For more details can be found in Tutorial on Software NEPLAN manual, which can be accessed and downloaded on the internet.

System of 5 bus

Figure 11, is a 5 bus system image using NEPLAN, figure 12. Contain of data 5 bus system and figure 13 is 5 bus System with UPFC using NEPLAN

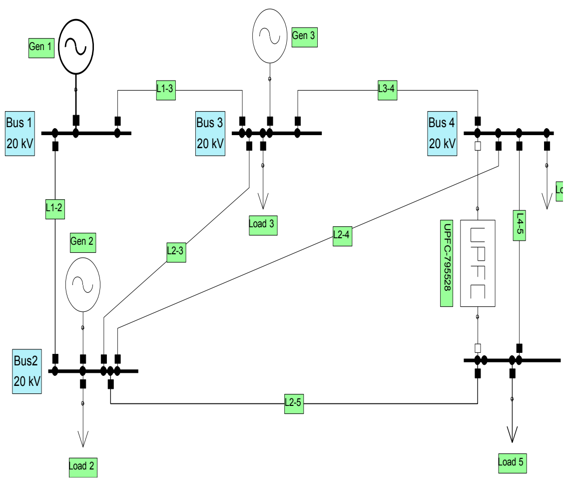


Figure 11. 5 bus system bus without UPFC by NEPLAN

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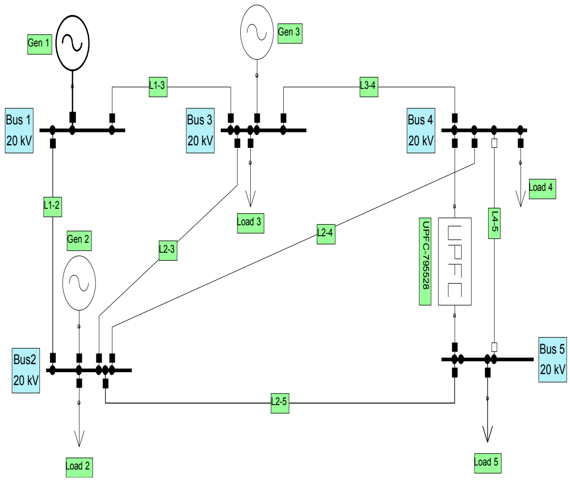
Tabel 1, Data bus

No. Bus	Teg. Nominal (%)	Load (MW, Mvar)	Generator (MW, Mvar)	Generator (Qmin, Qmax)	Injected Mvar
1.	106	0,0	0,0	10,5010,50	0
2.	104,5	20,10	40,30	10,40	0
3.	100	20,15	30,10	0,0	0
4.	100	50,30	0,0	0,0	0
5.	100	60,40	0,0		0

Tabel 2. Data line

Sending Bus	Receiving bus	R (Ohm)	X (Ohn)	Sucep tance
1	2	3.794	11.385	0.06
1	3	15.997	48.005	0.05
2	3	12.014	48.005	0.04
2	4	12.014	48.005	0.04
2	5	7.967	23.908	0.03
3	4	1.998	5.996	0.02
4	5	15.997	48.005	0.05



Gambar 12. 5 bus system with UPFC (Line 4-5 is removed)

Simulation results of using NEPLAN

Tabel 3. Tegangan di setiap bus

Bus No.	Tegangan bus Tanpa UPFC		Tegangan bus Dengan UPFC	
	V (kV)	***Sudut (^{o})***	***V (kV)***	***Sudut (^{o})***
1	106	106	106	106
2	104.478	104.3	104.5	104.4
3	103.244	103.24	103.33	102.8
4	101.891	101.89	102.014	102
5	98.693	101.7	98.665	103.3

Tabel 4. Aliran daya pada line tanpa UPFC

Bus No.	Tanpa UPFTC			
	P (MW)	*Q(MVar)*	*PLoss*	*QLoss*
1 – 2	60.403	9.030	0.6298	1.8238
1 – 3	22.728	5.055	0.3861	1.1039
2 – 3	11.061	3.320	0.0751	0.1821
2 – 4	18.118	8.406	0.2306	0.6495
2 – 5	50.288	34.649	1.3616	4.0545
3 – 4	43.402	32.271	0.2742	0.8019
4 – 5	11.246	9.875	0.1730	0.4688
Jmlh	**217.246**	**102.606**	**3.1304**	**9.0845**

Tabel 5. Aliran daya pada line dengan UPFC

Bus No.	Dengan UPFC			
	P (MW)	*Q(MVar)*	*PLoss*	*QLoss*
1 – 2	56.104	9.917	0.5481	1.5785
1 – 3	26.859	3.537	0.5226	1.5135
2 – 3	17.828	1.077	0.1755	0.4834
2 – 4	26.769	5.986	0.414	1.1998
2 – 5	30.959	40.846	0.9588	2.8460
3 – 4	53.989	27.617	0.3441	1.0117
4 – 5	30.000	2.000	0	-0.6083
Jmlh	**242.508**	**90.98**	**2.9631**	**8.0426**

UPFC is installed in bus 4-5

From table 3 dan 4 and 5 showed that, by regulating the flow of power flowing through the UPFC (30MW, 2MVar) installed on buses 4-5, result its that the voltage on the bus increases, the losses on the network experienced a significant decline and certainly loadability network and available transfer capability increases.

Conclusion

Unified power flow controller (UPFC) is a modern control equipment to control the real and reactive power flow on transmission lines either simultaneously or separately, in addition to its operation can be changed from one state to another without having to reschedule of generation or change of network topologi. This situation shows that UPFC can be a solution for increasing the generation capacity of a power system without having to add power.

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