

Capacitive and Inductive Line Reactance for Network Reconfiguration

Aiman Suhailah Saifuddin*, Karmila Kamil, Halimatun Hashim, Ruthraganapathy Radhakrishnan

Electrical Power Engineering Department, Universiti Tenaga Nasional,
43000 Kajang, Malaysia.

Corresponding author, *e-mail: Aiman_Suhailah@uniten.edu.my

Abstract

Solar PV may cause power congestion to occur in a transmission line when there is high solar irradiance that causing solar PV to generate more power flow than demanded power flow. Transmission line congestion that can be made worst by adding extra power generating farm such as centralized PV farm of renewable energy which helps to deliver customers with the demand or load required. The power generated coming from solar PV is depending on the weather and can definitely worsen the flow in transmission line due to the power captured. In this case, the high solar irradiance can affect the power generated from solar PV and will cause power congestion when power generated is higher than the load demanded. In this paper, the proposed method used to overcome the power congestion in a transmission line is by rerouting the excess power from the overloaded line to underloaded line by changing the line reactance of the line. An IEEE 30 bus test system is developed in PSS/E software as the test system. The output monitored is the line stability index of the affected line before and after rerouting process.

Keywords: power congestion; network reconfiguration; line stability

Copyright © 2017 Institute of Advanced Engineering and Science. All rights reserved.

1. Introduction

Distributed generation is an upcoming renewable energy which is widely used in this modernized world and it is defined as generation of power from a few kilowatts up to 100MW by International Council on Large Electricity System [1]. For a higher load requirement which the generation is more than 100MW, the power will be injected directly to the transmission system. A scenario when power system generated is more than the demanded power system is a concern in power system analysis study for future power generation. Power congestion is a situation when the power generated is more than power demanded by the loads and it will cause overburdened to the power system. Power congestion can cause the voltage collapse to occur in a power system and the system will be interrupted. Besides that, in deregulated systems, line congestion apart from causing stability problems can increase the cost of electricity [2-7]. To overcome power congestion in a power system network, rerouting of power flow from the overloaded transmission line to the underloaded transmission line is proposed. This paper will focus on rerouting the excess power flow by changing the line reactance of the affected line. Network reconfiguration method is employed for loss minimization and exhaustive technique is also applied to achieve the minimal loss switching scheme [8-10].

In the real application, the equipment that might be used to change the line reactance is Distributed Series Reactor that provide control of one or more AC Transmission System parameters to enhance controllability and increase capability in transmitting power supply by IEEE. Mainly there are three types of Distributed Series FACTS Devices. Distributed Series Reactor (DSR) is known to be the most flexible device since it can be implemented either in meshes or interconnected power system configuration. The flexibility of a DSR is determined when it only works with the conjunction of an inductor. Whereas, DSI or other distributed FACTS requires both capacitor and inductor to provide the function. Besides just being flexible, DSR does not need communication system in its topology to direct power flow in cables since it is able to automatically alter each module of DSR in a system or specifically on transmission lines.

The mechanism or function of DSR is simple as it will inject inductance to lines which faces over current or exceed the current carrying capability [11-15].

Power flow of a system can be altered and controlled by changing impedance of each transmission lines. Power flow will be distributed equally with the decrement and increment of impedance values in the transmission lines. Therefore, in order to take charge of power flow between buses, capacitive or inductive injection in the networks can be implemented to change impedance. Main reason to take such action is to avoid the breakdown of the system due to imbalance power flow. Imbalance of power flow causes transmission lines to be worse in a long period of time as it will be carrying current exceeding its capability. Faulted lines will be switched out whenever there is occurrence of breakdown so that there would not be any disturbance to the supply and that has been a reliability issue. Although disturbance can be avoided, it is always better to completely cure the system rather than avoiding. Therefore, lines which faces high imbalance power can be corrected by diverting the excessive power to other neighbouring lines which has extra capacity to handle more power. When current is excessive in a transmission line, there will also be higher losses according to the power loss equation,

$$P_{loss} = I^2 R \quad (1)$$

The discussion about the line impedance theory earlier is a technique used by changing the line reactance using Distributed Series Reactor to control the real power. Besides that, DSR also helps to reconfigure and reroute power flow if there is breakdown occurrence [7].

$$X_L = j(2\pi f)L \quad (2)$$

Where,

X_L	–	Impedance of inductor
L	–	Inductance

All lines should only accept current according to its limit or predetermined value for safety purposes. By increasing the impedance, excessive current from that transmission line will be diverted to under-utilized line so that line burdening can be reduced. The line congestion occurs at few different occasion of the day depending on the load demand needed by users. Therefore, by sharing loads almost equally between lines, transmission capacity and reliability can be enhanced. Besides that, the condition of lines can be kept safe and also increase the life span of each transmission lines.

2. Research Method

Test system used for the simulation is IEEE 30 bus test system. Fig. 1 shows the IEEE 30 Bus Test System in PSS@E. The test system including of 6 synchronous generators at bus 1, 2, 13, 23, 22 and 27. Power System Simulator for Engineering (PSS@E) is being used to simulate the test system and parameters of line voltage, sending real power and receiving reactive power are monitored to check the voltage stability of the line. These parameters are then used to check the voltage stability of the line using the formula of Line Stability Index, LQP. For a stable system, the value of LQP must be in between 0 to 1. However, for this paper, the rerouting process will be done once the value of LQP is more than 0.5.

$$LQP = 4 \left[\frac{X_L}{V_i^2} \right] \left[\frac{X_L}{V_i^2} P_i^2 + Q_j \right] \quad (3)$$

Solar PV is connected randomly at bus 2, 8 and 12. The real power from the Solar PV is increased to a certain level which is more than the maximim power set for the busses and until the line stability index of the affected line exceed 0.5. Once it exceeds 0.5, the line reactance is changed, the power flow is monitored and the line stability index is calculated. The comparison of the line stability index of the lines between with and without rerouting is done from the simulation result.

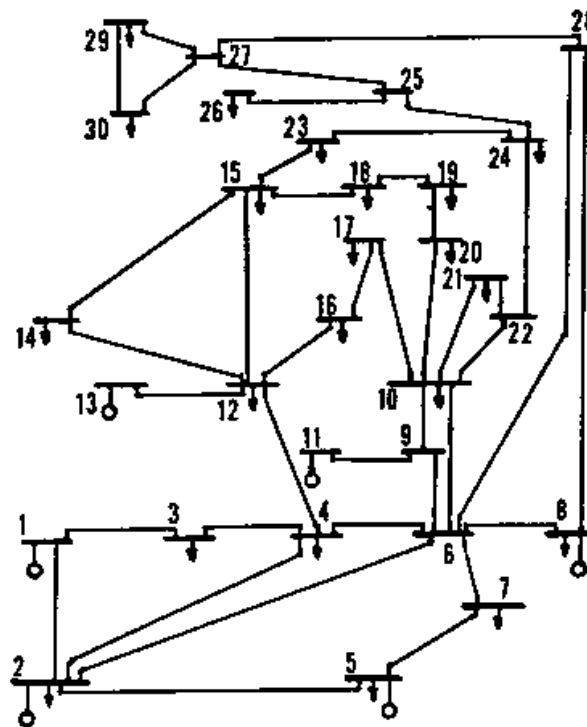


Figure 1. IEEE 30 Bus Test System

3. Results and Analysis

The comparison of the line stability index before and after rerouting is done for each line that connected to the bus injected with excess real power in order to monitor the effect of changing the line reactance for rerouting purpose.

Table 1 shows the changes after rerouting the power. As it can be seen the line stability index from bus 2 to 1 is exceed 0.5. The inductive line reactance of this line is increased which causes the power to divert the direction to flow from bus 2 to 4 which increased the index of bus 2 to 4 and reduce the index of line from bus 2 to 1. However, there is no changes in the index for the line for the connection of bus 2 to 6 and 2 to 5. It means that the power is not divert to these 2 lines.

Table 1. Result between Bus Connections at Bus 2

Bus connection	LQP value before rerouting	LQP value after rerouting	Changes
2 to 1	0.51	0.48	Decrease
2 to 4	0.05	0.13	Increase
2 to 6	0.02	0.02	No changes
2 to 5	0.1	0.1	No changes

Table 2 shows the power flow between lines connected to bus 8. In this case, there are only 2 lines connected to bus 8. Before rerouting the index is exceeded 0.5 on the line from bus 8 to 6 and after rerouting the index is reduced to lower value. The index for the line from bus 8 to bus 28 is increased from lower value to higher value which show the excess power flow to this line.

Table 2. Result between Bus Connections at Bus 8

Bus connection	LQP value before rerouting	LQP value after rerouting	Changes
8 to 6	0.53	0.46	Decrease
8 to 28	0.04	0.38	Increase

Table 3 shows the result for the lines connected to bus number 12. There are 5 busses connected to bus 12. The index for line that connects bus 12 to 13 is exceeded 0.5 before rerouting and others are below 0.5. After increasing the inductive line reactance of the line, the index is reduced while the index of the lines that connect bus 12 to 4 and 12 to 15 increased but still within the limit of less than 0.5.

Table 3. Result between Bus Connections at Bus 12

Bus connection	LQP value before rerouting	LQP value after rerouting	Changes
12 to 4	0.08	0.15	Increase
12 to 13	0.52	0.25	Decrease
12 to 14	0.01	0.01	No changes
12 to 15	0.02	0.04	Increase
12 to 16	0.06	0.06	No changes

4. Conclusion and Recommendation

Power congestion between lines can be solved with the idea of rerouting the excess power to the nearest line(s). It is important to maintain the allowed capacity to flow in the lines in order to maintain the life span of transmission lines and to prevent power losses in the system by mechanism of diverting power from over utilized to under-utilized lines. Finally, power supplies by solar photovoltaic will be a very big plus point to Malaysia as it is placed near to the equator and sun energy can be captured at high rating. The only important factors to be controlled are losses and the life span of lines. This is due to the high-power conversion of solar from sun energy which can cause tremendous of power to flow in lines but at the same time cause losses and reduce the life span of lines.

In the future works, author would like recommend other researchers to studying the numerical value of line reactance should the system has in order to reroute. The author also recommends other researchers to monitor the best line to receive the excess power by studying the impact of changing both the inductive and capacitive line reactance in the system in details.

Acknowledgement

The authors would like to thank the Ministry of Education, Malaysia for funding this project under the Fundamental Research Grant Scheme (20140135FRGS) and Universiti Tenaga Nasional for their full support in publishing this paper.

References

- [1] T. Ackermann, G. Andersson, L. Soder. Distributed Generation: A Definition. *Electrical Power System Research*. 2001; 57: 195-204.
- [2] *Large-Scale Solar Technology and Policy Forum*, April 8-9, 2010.
- [3] Hua Wan, James D. McCalley, Vijay Vittal. Increasing Thermal Rating by Risk Analysis. *Transaction on Power Systems*. 1999; 4(3): 815-828.
- [4] Mulukutla S.Sarma, Thomas J. Overbye, J. Duncan Glover. *Power System Analysis and Design Engage Learning*, Stamford, 2012.
- [5] C. Hitaj. *Renewable Power Effects on Electricity Transmission Congestion and Emissions*. College Park, Maryland, 2012.
- [6] CEC, "Transmission Congestion and Renewable Generation," Clean Energy Council, Victoria, 2010.
- [7] Anthony F. Sleva, *Protective Relay Principles*, FL: CRC Press, 2009.
- [8] A. Mohamed Imran, M. K. (2014). A New Power System Reconfiguration Scheme for Power Loss Minimization and Voltage Profile Enhancement Using Fireworks Algorithm. *Electrical Power and Energy Systems*, 62, pg. 312-322.

- [9] Chanda, S., & De, A. Congestion Relief of Contingent Power Network with Evolutionary Optimization Algorithm. *TELKOMNIKA (Telecommunication, Computing, Electronics and Control)*. 2012; 10(1). doi:10.12928/telkomnika.v10i1.142
- [10] Myint, S. M., & Naing, S. W. Network Reconfiguration for Loss Reduction and Voltage Profile Improvement of 110-Bus Radial Distribution System Using Exhaustive Search Techniques. *International Journal of Electrical and Computer Engineering*. 2015; 5(4): 788-797
- [11] Deepak Divan, Harjeet Johal. Distributed FACTS - A New Concept for Realizing Grid Power Flow Control. *Transaction on Power Electronics*. 2007; 22(6): 2253-2259.
- [12] H. Johal. *Distributed Series Reactance: A New Approach to Realize Grid Power Flow Control*. Ph. D Thesis. Georgia Institute of Technology. 2008.
- [13] Sandeep R. Gaigowal, M. M. Renge. *Some Studies of Distributed Series FACTS Controller to control active Power Flow through Transmission Line*. International Conference on Power, Energy and Control. 2012.
- [14] Er. Qasim Kamil Mohsin, Jyoti Shrivastava. *AC Power Flow Control of Grid by Series D-Fact*. 2013; 2 (4); 245-250.
- [15] L.E. College, Morbi, "D-FACTS - Distributed Static Series Compensator (DSSC) and Distributed Series Reactor (DSR)," *International Journal for Scientific Research and Development*. 2014; 2(3); 838-840.