SHUNT CAPACITOR INJECTION TO IMPROVE VOLTAGE STABILITY IN POWER SYSTEM

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ABSTRACT. Voltage stability is an important factor to be considered in power system operation and planning since voltage instability would lead to system collapse. Furthermore a stable system contributes to reliability and reduction in system loss. Therefore voltage stability analysis is important in order to identify critical buses to enable certain measures to be taken to avoid any incidence of voltage collapse. This project focused on shunt capacitor injection that is used to prevent voltage collapse or instable. To validate the feasibility of the shunt capacitor injection method, 14-bus and 30-bus IEEE test system will be consider as a case study. All simulation was done by MATALB 7.5.

Keyword: voltage stability, shunt capacitor injection,

1.0 INTRODUCTION

The purpose of an electrical power system is to generate and supply electrical energy to consumers. An electric power system consists of three principal basic sub-systems namely generating stations, transmission lines and distribution sub-systems. In daily operation of electrical power system, a stable system is important. Stable operation of a power system depends on the ability to continuously match the electrical outputs of generating units to the electrical load on the system.

Voltage stability is the ability of a power system to maintain steady acceptable voltages at all buses in the system under normal operating conditions after being subjected to disturbance. A system enters a state of voltage instability when disturbance, increase in load demand or change in the system condition causes a progressive and uncontrollable drop in voltage.

The main factor causing instability is the inability of the power system to meet the demand for reactive power. The heart of the problem is usually the voltage drop that occurs when active power and reactive power flow through inductive reactance associated with the transmission network [1-3]. The principal causes of voltage instability:

- The load on the transmission lines is too high
- The voltage sources are too far from the load centre.
- The source voltages are to low
- There is insufficient load reactive compensation.

Voltage collapse is the process by which the sequence of events accompanying voltage instability leads to a low unacceptable voltage profile in a significant part of the power system. Certain measures have to be taken to avoid any incidence of voltage collapse. When the system collapses, the system will be blackout.

Shunt capacitor banks are used to reduce the reactive power required by reactive loads and to aid in the regulation and control of power system voltages [4]. Capacitor banks applied to power systems have several advantages. First, they can contribute toward improving the system power factor, reducing system losses, and thereby improving the electrical efficiency. Second, supporting system voltages with the capacitors aids power transfer to some loads, such as induction motors. Finally, system capacity may be also increase due to the supply of reactive power from the capacitor banks, allowing the power system to supply only real power.

The objective of the project is to stabilize the voltage by injecting shunt capacitor in the sensitive bus. The simulations were carried out in 14-bus and 30-bus IEEE test system.

2.0 THE THEORITICAL BACKGROUND

QV curves are one of the simplest methods to assess voltage stability. Therefore in this paper, using a QV curve is proposed for analyzing voltage stability. This curve shows magnitude of voltage bus versus injection reactive power to the load. At a given operating condition for every bus in the system, the bus voltage magnitude increases as the reactive power injection at the same bus is increase. Figure 2.0 shows a typical QV curve. This curve shows the limit of voltage stability in the places where derivative dQ/dV is zero. If the operating point system is on the right of the QV curve, the system stable and if the operating point is on the left side of the curve, the system will be instable. [5]

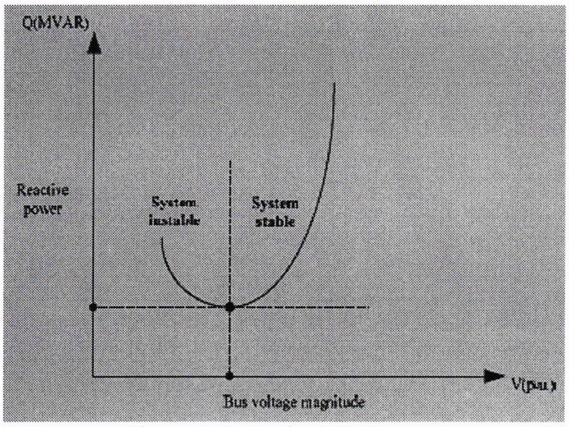

Figure 2.0: Typical Q-V curve

2.1 The Power Load Flow

Power flow studies, commonly referred to as load flow, are the backbone of power system analysis and design. They are necessary for planning, operation, economic scheduling and exchange of power system between utilities. In addition, power flow analysis is required for many other analyses such as voltage stability and contingency studies. The most common technique used for iterative solutions of non-linear algebraic equations is:

1. Gauss-Seidel method
2. Newton Raphson method
3. Fast Decoupled method

The most general and reliable algorithm to solve the power flow program is the Newton-Raphson method. For large power systems, the Newton-Raphson method is found to be more efficient and practical. The equation of the bus admittance matrix as

$$I_i = \sum_{j=1}^{n} Y_{ij} V_j$$

The real and imaginary parts,

$$P_i = \sum_{j=1}^{n} |V_i||Y_{ij}| \cos(\theta_{ij} - \delta_i + \delta_j)$$

$$Q_i = \sum_{j=1}^{n} |V_i||V_j||Y_{ij}| \sin(\theta_{ij} - \delta_i + \delta_j)$$

The new estimates for bus voltages are

$$\delta_i^{(k+1)} = \delta_i^{(k)} + \Delta\delta_i^{(k)}$$

$$\left|V_i^{(k+1)}\right| = \left|V_i^{(k)}\right| + \Delta\left|V_i^{(k)}\right|$$

3.0 METHODOLOGY

The maximum loadability at the sensitive bus was determined. Shunt capacitor was injected in load bus system. Then, simulation of load flow is repeated until power flow is converged. Figure 3.0 shows the flowchart for identify the weakest bus and injection shunt capacitor.

The basic steps for the implementation of voltage stability is as follows

1. Run load flow for IEEE test system until it converges.
2. If converge, the weakest load bus in test system was identified. If no, it will return back until converges.
3. After that, the shunt capacitor was injected in weakest bus, to improve voltage stability.
4. After shunt capacitor was injected, the voltage stability was identified. If the system not stable, it will return back until the system stable.
5. If the system stable, display the result
6. Plot the graph.

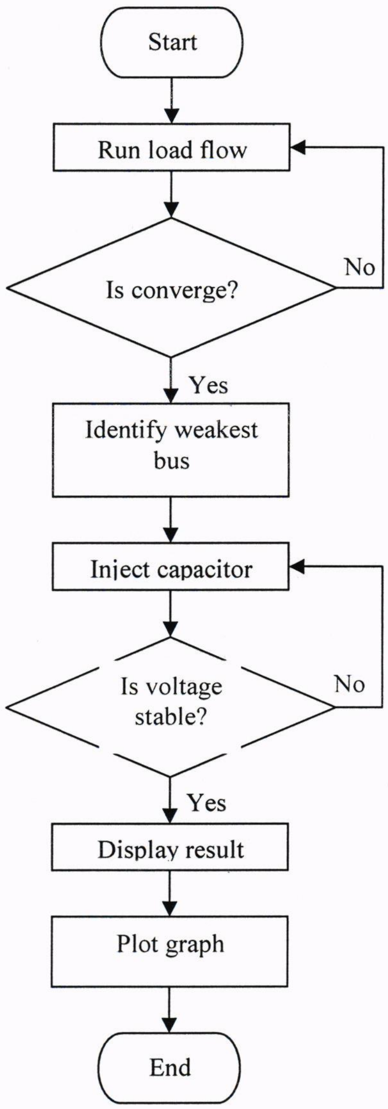

Figure 3.0: Flow chart for identify the weakest bus and injection of shunt capacitor

4.0 RESULTS & DISCUSSION

Simulation results were tested on 14-bus and 30-bus IEEE test system to validate the performance of the voltage stability. Figure 4.1 shows the single line diagram for 14-bus IEEE test system and Figure 4.2 shows the single line diagram for 30-bus IEEE test system.

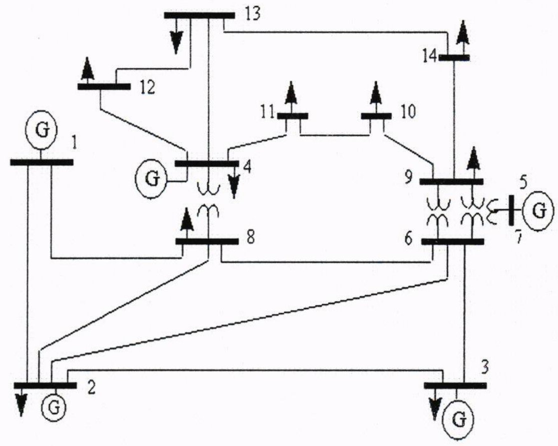

Figure 4.1: Single line diagram for 14-bus system

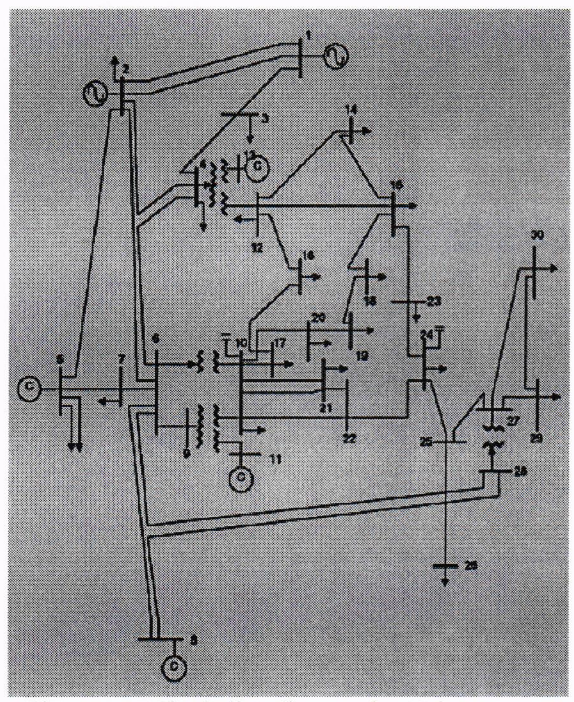

Figure 4.2 : Single line diagram for 30-bus system

4.1 14-Bus IEEE Test System

Table 4.3 tabulates the maximum loadability. From the table, it can be seen that the maximum loadability the three most sensitive buses can withstand before it collapse is 42 MVar for bus-12, 43 MVar for bus-14 and 50 MVar for bus-11.

Bus	Max Loadability (MVar)	Voltage mag. (p.u)
12	42	0.5080
14	43	0.5194
11	50	0.5156

Table 4.3: Maximum loadability

Table 4.4 tabulates the voltage magnitude before and after injection capacitor. For the load bus-12 the voltage magnitude increases to 0.9161 p.u after 50 MVar shunt capacitor injected. For load bus-14, the voltage magnitude increases to 0.9042 p.u after 50 MVar capacitor injected. For load bus-11, the voltage magnitude increases to 0.9021 p.u after 55 MVar capacitor injected.

Bus	Voltage mag. Before (p.u)	Shunt capacitor value (MVar)	Voltage mag. After (p.u)
12	0.5080	50	0.9161
14	0.5194	50	0.9042
11	0.5156	55	0.9021

Table 4.4: Injection of shunt capacitor

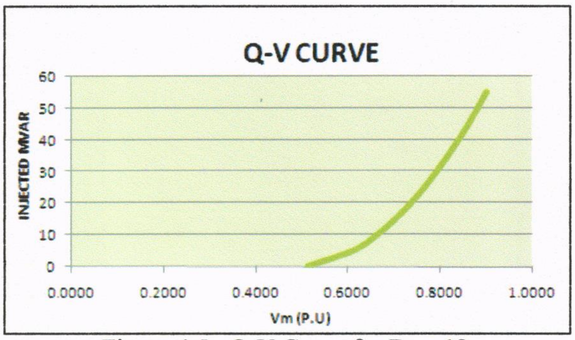

Figure 4.5 : Q-V Curve for Bus_12

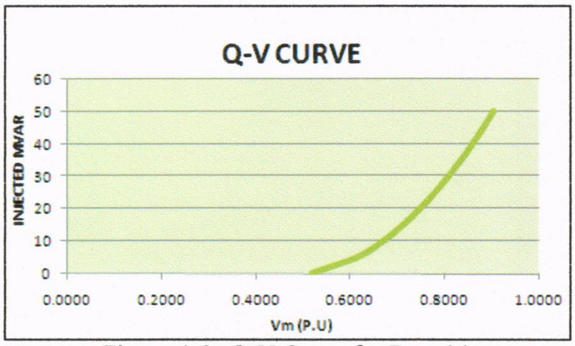

Figure 4.6 : Q-V Curve for Bus_14

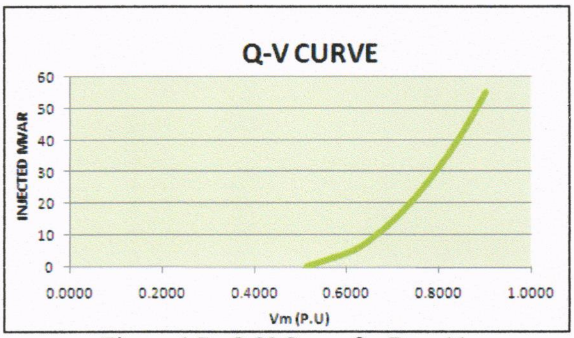

Figure 4.7 : Q-V Curve for Bus_11

Figure 4.5 to 4.7 shows the Q-V curve for load bus-12, bus-14 and bus-11. As the injected capacitor increased, the voltage magnitude also increased.

4.2 30-Bus IEEE Test System

Table 4.8 tabulates the maximum loadability. From the table, it can be seen that the maximum loadability the three most sensitive buses can withstand before it collapse is 33 MVar for bus-26, 35 MVar for bus-30 and 38 MVar for bus-29.

Bus	Max. Loadability (MVar)	Voltage Mag. (p.u)
26	33	0.6020
30	35	0.5270
29	38	0.5310

Table 4.8: Maximum loadability

Table 4.9 tabulates the voltage magnitude before and after injection capacitor. For the load bus-26 the voltage magnitude increases to 0.9136 p.u after 20 MVar capacitor injected. For load bus-30, the voltage magnitude increases to 0.9326 p.u after 25 MVar capacitor injected. For load bus-29, the voltage magnitude increases to 0.9217 p.u after 25 MVar capacitor injected.

Bus	Voltage mag. Before (p.u)	Shunt capacitor value (MVar)	Voltage mag. After (p.u)
26	0.6020	20	0.9136
30	0.5270	25	0.9326
29	0.5310	25	0.9217

Table 4.9: Injection of shunt capacitor

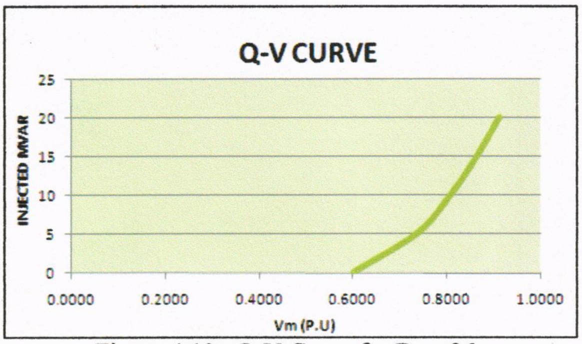

Figure 4.10 : Q-V Curve for Bus_26

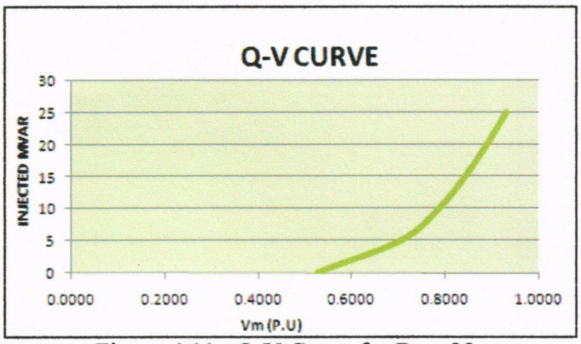

Figure 4.11 : Q-V Curve for Bus_29

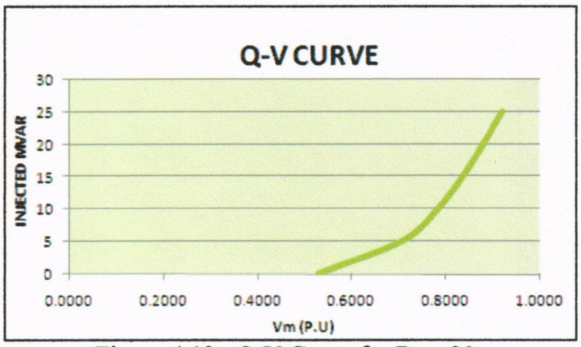

Figure 4.12 : Q-V Curve for Bus_30

Figure 4.10 to 4.12 shows the Q-V curve for load bus-26, bus-29 and bus-30. As the injected capacitor increased, the voltage magnitude also increased.

From simulation result it can be seen it chooses the maximum loadability of the three most sensitive buses for 14-bus system. From that we know the critical bus for 14-bus system is bus-12 which is 42 Mvar reactive power. The voltage magnitude before injected shunt capacitor is 0.5080 p.u. After injection 50 Mvar shunt capacitor, voltage magnitude increase to 0.9161 p.u. It makes the system stable because the voltage at each load bus is within a specified limit ($0.9 \leq V \leq 1.1$).

Simulation result shown it chooses the maximum loadability of the three most sensitive buses for 30-bus system. From that we know the critical bus for 30-bus system is bus-26 which is 33 Mvar reactive power. The voltage magnitude before capacitor injected is 0.6020 p.u. After injection 20 Mvar capacitor, voltage magnitude increase to 0.9136 p.u. The system becomes stable because the voltage at each load bus is within a specified limit ($0.9 \leq V \leq 1.1$).

A criterion for voltage stability is that, at a given operating condition for every bus in the system, the bus voltage magnitude (V) increases as the reactive power injection (Q) at the same bus is increase. It shows in Figure 4.5 to Figure 4.7 for 14-bus system and Figure 4.10 to Figure 4.12 for 30-bus system. This graph shows voltage stability of the power system. It also determines the minimum reactive power required for consistent performance. So, if the operating point of the system is on the right side of the Q-V curve, the system will be stable and if the operating point of the system is on the left side of the curve, the system will be instable [5]. Both 14-bus system and 30-bus system are stable.

5.0 CONCLUSION

This project demonstrated the injection of shunt capacitor could increase the voltage stability in the power system. Through the experiment, it has been observed that shunt capacitor injection approach has successfully determined the optimal value of reactive power that should be placed in the system to improve voltage magnitude to become the system stable.

6.0 FUTURE DEVELOPMENT

For future development, it is suggested to solve the shunt capacitor together with controlling of tap setting transformer in the system. The reason of controlling tap setting transformer is to control the flow of reactive power. Hence, the voltage magnitude can be improved in the system.

7.0 ACKNOWLEDGEMENT

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SUBMISSION OF FINAL PROJECT REPORT FOR FINAL YEAR PROJECT 2 (EEE690)

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This is to certify that the above student has submitted the final project report to the project supervisor and all the necessary amendments has been made according to the recommendations.

PROJECT SUPERVISOR'S NAME : PM. WAN NORAININ WAN ABDULLAH

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