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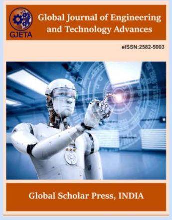

(Review Article)

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Reactive power (VAR) compensation techniques in high voltage transmission lines

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Abstract

Management of reactive power and voltage control constitute part of the major challenges in a power system. Appropriate reactive power management and control solves power quality problems, reduce losses, improve power factor, maintained a balanced voltage profile at all power transmission levels, improved system efficiency and stability. This paper examined the brief idea about the mode of operations, design characteristics of various types of reactive power compensation techniques. These techniques are used to improve the performance of AC transmission & distribution systems. They enhance the stability of the AC transmission system by increasing the active power that can be transmitted thereby enhancing the overall working of the electric power system.

Keywords: Reactive power; HVAC transmission; Distribution; Shunt compensation; Series compensation

1. Introduction

Reactive power compensation is the management and control of reactive power to enhance the performance of AC system. It is the supply of reactive power in a transmission system to improve the transmittable power, thereby making it compatible with the predominant load demand. The need for reactive power management and voltage control in ac transmission lines is very essential as it contribute its own quota in solving one of the major problems and challenges in power system engineering [1]. Generally, the problem of reactive power compensation can be viewed from two viewpoints; Load compensation and Voltage support. Load compensation aimed at boosting the power factor of the system, to support the real power drawn from the a.c supply, to compensate voltage regulation and remove current harmonic components produced by large and fluctuating nonlinear industrial loads while voltage support aimed at reducing the voltage variations at a given terminal of transmission line. [2] Reactive power compensation in transmission line increases transmission efficiency, improves the stability of AC system by increasing the maximum active power that can be transmitted. It also helps to maintain a substantially flat voltage profile at all levels of power transmission and distribution, controls steady-state dynamics and temporary over voltage. The portion of power flow that is temporarily stored in the form of magnetic or electric fields, due to inductive or capacitive network element and then returned to source is known as reactive power. Reactive power can best be described as the quantity of "unused" power that is stored in reactive components, such as inductors or capacitors. In other words, the reactive circuit returns as much power to the supply as it consumes.

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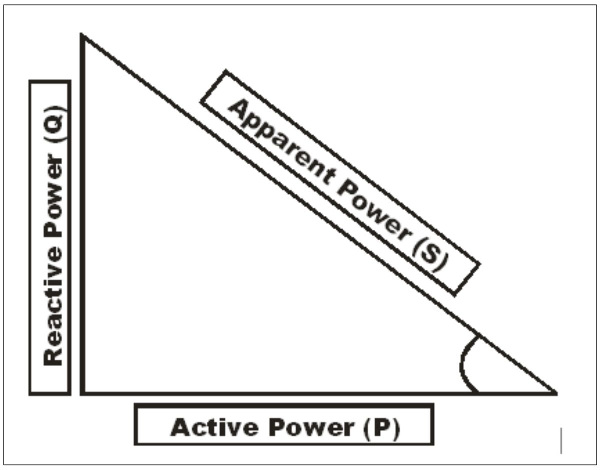

Figure 1 Power triangle

- **Active Power (P):** It is the power that actually powers the equipment and performs useful work .Its units is Watt (W) .
- **Reactive Power (Q):** It is the power that magnetic equipment (transformer, motor etc.) needs to produce the magnetizing flux . Its units is (VAr)
- **Apparent Power (S):** It is the " vectorial summation " of active power (P) and reactive power (Q). Unit of it (VA)

1.1. The aim of this Research Work

This work is focused on reactive power compensation techniques in high voltage transmission lines for improvement of system power factor and reduces losses.

1.2. Objective of this Research Work

The following are the objectives for carrying out this research

- Improvement of the quality of the power.
- Improvement of system power factor.
- To maintain the voltage profile within ±5% of the rated value.
- Reduction of the losses in the network.
- Increase the power availability.

2. Reactive power compensation devices

There are various reactive power (RP) compensation devices, but the most commonly used in power systems to improve the power factor, increase line loadability, and regulate voltages in high voltage transmission lines are discussed below;

2.1. Shunt Reactor Compensation

Inductors, also called reactors, are used to absorb reactive power and reduce over voltages on long transmission lines at no-load or light load conditions. They can also reduce transient over voltages due to switching and lightning surges. The amount of reactor compensation required on a line to maintain the receiving end voltage at a specified value can be calculated as follows:

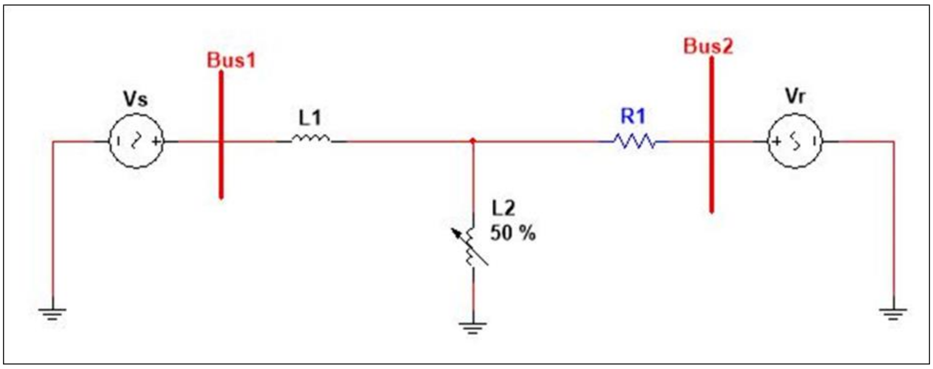

Figure 2 Transmission line with shunt reactors compensation

$$X_{Lsh} = \frac{Sin\ \beta\ell}{\frac{V_1}{V_2} - Cos\ \beta\ell} Z_c \ldots\ldots\ldots\ldots 1$$

For **Vs=V$_R$**, i.e ($V_1 = V_2$)

The required inductor reactance is:

$$X_{Lsh} = \frac{Sin\ \beta\ell}{1 - Cos\ \beta\ell} Z_c \ldots\ldots\ldots\ldots 2$$

2.2. Shunt Capacitor Compensation

Shunt capacitors compensation is used to compensate reactive power and increase transmission voltages at heavy load conditions. The introduction of shunt capacitors to a power system has the effect of improving the power factor, reducing the reactive power required from generators, and maintaining the receiving end voltage at a satisfactory level. A shunt compensator is always connected in the middle of the transmission line [3] along with either a current source, voltage source or a capacitor. The reactive power generated from the capacitor can be obtained as follows:

$$Q_c(3\emptyset) = \left|\frac{|V_{R(L-L)}|}{X_c}\right|^2 \ldots\ldots\ldots\ldots\ldots 3$$

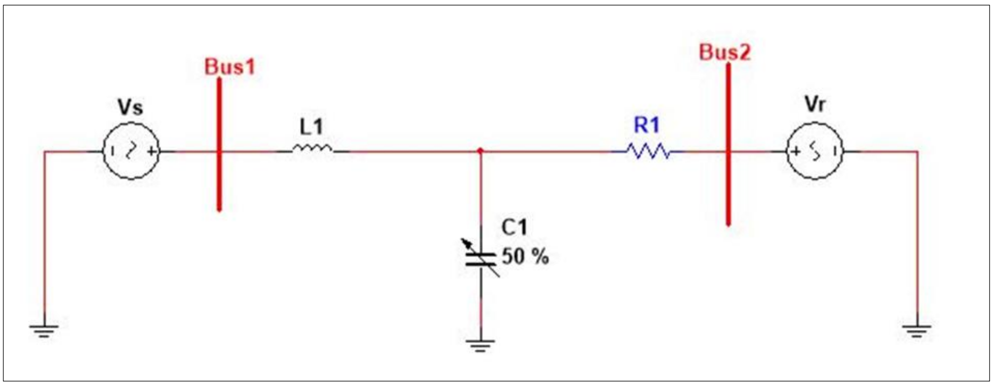

Figure 3 Transmission line with shunt capacitor compensation

2.3. Series Capacitor Compensation

Series capacitors can be used to increase the power transfer capability and improve voltage and angular stability in transmission system. They are installed in series with each phase conductor at strategic locations along the line [4] as shown in figure 4. They reduce the line-voltage drops and increase the steady-state stability limit by reducing the net series impedance of the line.

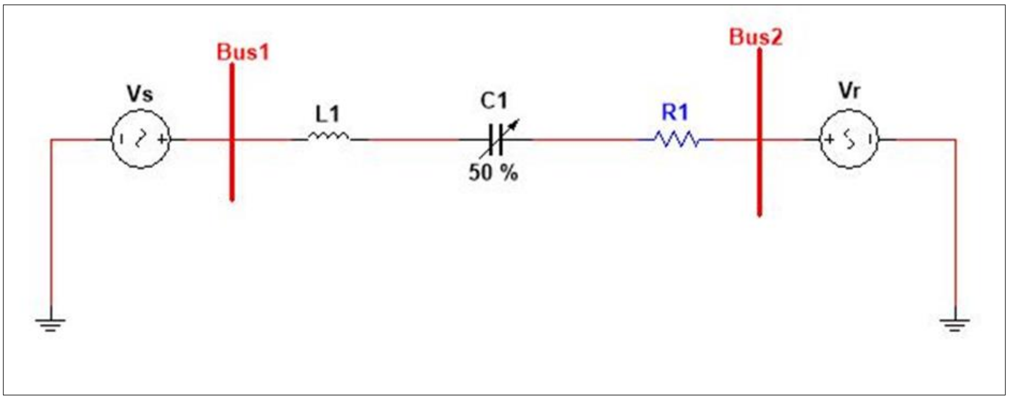

Figure 4 Transmission line with series capacitor compensation

With the series capacitor switched on. The power transfer over the line for a lossless line becomes:

$$P = \frac{V_1 V_2}{X_L - X_C} Sin\ \delta = \frac{V_1 V_2}{X_L\,(1-K)}\ Sin\ \delta \ \ldots\ldots 4$$

The ratio of the series capacitor reactance (Xc) to the line reactance (X_L), expressed as a percentage, is known as the percentage compensation denoted as (k). For Example, if XL= 1 ohm, 40% compensation produces XL - XC= 0.6 ohm. Depending on the specific requirements of the power system, the percentage compensation is typically in the range of 25 to 70%.

By reducing the reactance, series compensation increases the synchronizing torque that can be interchanged between the machines. The synchronizing torque is the torque that tends to bring two machines into synchronism, and it depends on the system reactance. Therefore, by reducing the reactance, the synchronizing torque increases, and the machines become more stable. For same power transfer and for the same value of sending and receiving end voltage, the power angle δ in the case of the series impedance line is less that for the uncompensated line. The reduced value of δ gives higher stability. Series capacitor compensation has the following advantages; enhancing the voltage profile and supporting the voltage of long transmission lines, leading to improved power quality. Increasing the transmission capacity of lines which can help reduce costs associated with building new lines and improving power system stability during transient events, enabling additional power transfer when it is most needed.

However, one major setback with series capacitor compensation is that special protection devices are required to protect the capacitors and bypass the high current produced at the event of short circuit. More so, inclusion of series capacitors establishes a resonant circuit that can oscillate at a frequency below the normal synchronous frequency when stimulated by a disturbance. This phenomenon is referred to as sub-synchronous resonance. If the synchronous frequency minus the electrical resonant frequency approaches the frequency of one of the turbine-generator natural torsional modes, considerable damage to the turbine-generator may occur. To control these effects of sub-synchronous resonance, automatic protection devices must be installed to bypass high currents during faults and to reinsert the capacitor banks after fault clearing.

2.4. Static VAR compensators (SVD)

A static VAR compensator known as "SVC" for short is set of electrical devices used for providing fast-acting reactive power on transmission networks [5]. The SVCs are part of flexible AC transmission system device family regulating voltage, power factor, harmonics and stabilizing the system. SVC is a shunt connected static VAR generator or absorber whose output is adjusted to exchange capacitive or inductive current so as to maintain or control specific parameters of the electrical power system. SVC is based on thyristors without gate turn-off capability. The operating characteristics of thyristors shows variable reactive impedance of SVC. It includes 2 main components and their combinations are; Thyristor controlled and thyristor switched reactor (TCR & TSR) and thyristor switched capacitor (TSC). When TSC is switched on the reactive power in SVC increases. This shows that SVC supplies reactive power to the AC power source. Similarly, when TCR firing angle is decreased reactive power in SVC increases. This indicates that SVC absorbs more and more reactive power from AC power source.

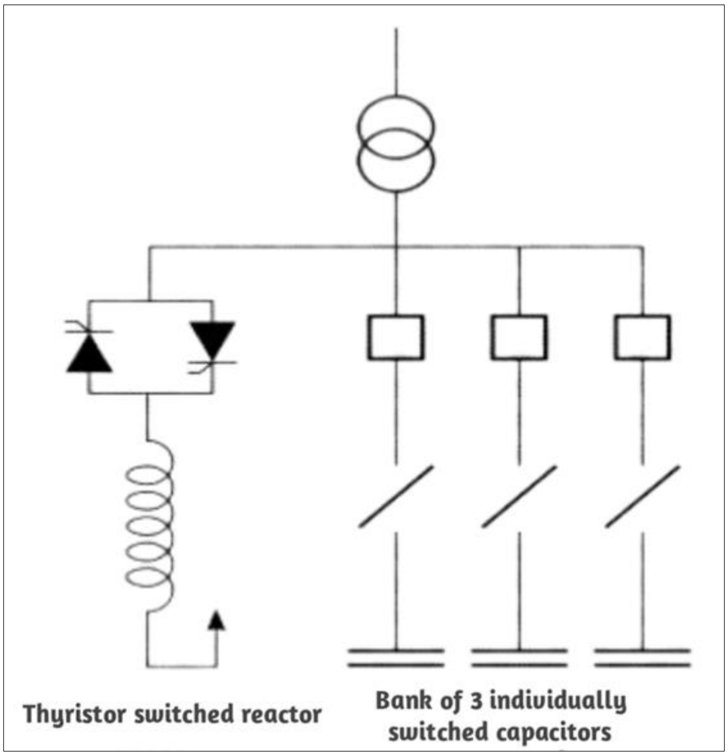

Figure 5 Thyristor switched reactor

2.5. Self-commutated VAR compensator

They contain switched valve devices such as Gate turn-off thyristor (GTOs) & Insulated Gate Bipolar Transistors (IGBTs). Static synchronous compensators, unified power flow controllers etc. operate on the principle of self commutated VAR compensator. They can generate or absorb reactive power as per requirement in the system.

2.6. Static Synchronous Compensator (STATCOM)

It is a member of FACTS family of devices. It is a regulating device used on AC transmission network. It is based on power electronics voltage source converter and can act as either a source or sink of reactive AC power to an electricity network. A STATCOM is a voltage source converter (VSC) based device with the voltage source behind a reactor. The voltage source is created from a DC capacitor. The reactive power at the terminals of the STATCOM depends upon amplitude of voltage source. For example if the terminal voltage of VSC is higher than AC voltage at the point of connection the STATCOM generates reactive current conversely when terminal voltage of VSC is lower than AC voltage it absorbs reactive power.

2.7. Synchronous Condenser

It is a conventional synchronous machine which runs without prime mover and connected to improve the power factor of the electrical system. It is rotating equipment. Its maintenance is low with the advent of brushless synchronous condensers. If the field excitation of synchronous condenser is controlled it can generate or absorb reactive power. When they are over-excited they supply reactive power and when under-excited they absorb reactive power. When the reactive power is supplied by synchronous condenser current in the system is reduced. Thus the losses get decreased and it gives a better efficiency.

3. Conclusion

Voltage control in an electrical power system is very essential for proper operation for electrical power equipment to prevent damage. It maintains adequate voltages throughout the transmission and distribution system for both current and contingency conditions. It seeks to minimize real power losses, improve power factor, maintained a balanced voltage profile, improved system efficiency and stability at all levels of the power system network.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Ibekwe B.E., Mgbachi C.A. and Nwobodo N.H (2017), Reactive Power Compensation Using 500kv, 180km Line to Maintain Substantially Flat Voltage Profile At All Levels Of Ac Transmission System, International Journal of Advanced Research in IT and Engineering, Vol 6 (9)

[2] Seema D. (2015), Reactive Power Compensation Techniques in Transmission lines, International Journal on Recent and Innovation Trends in Computing and Communication, Volume: 3 Issue: 5, 3224 – 3226

[3] Sivanagaraju S and Shankar V (2006), Electrical Power Distribution and Automation, Dhanpat Rai and Co. Publications.

[4] Miller, T.J.E, (1982), Reactive power control in electric systems, John Wiley.

[5] Alper Cetin, (2007) "Design and Implementation of VSC based STATCOM For Reactive Power Compensation and Harmonic Filtering", Middle East Technical University.