

Reactive Power Compensation Techniques in Transmission lines

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Abstract-- This paper highlights the concept of reactive power compensation technologies. By means of reactive power compensation techniques, reactive power is controlled in such a way that the performance of electric power system gets improved. This paper gives the brief idea about the principles of operation, design characteristics of various types of VAR compensators etc. These compensation techniques are used to change the performance of AC transmission & distribution systems as per the need. VAR compensators enhance the stability of the AC system by increasing the maximum active power that can be transmitted. By managing the line reactive power, the working of overall electric power system can be enhanced. In the case study, after implementing series and shunt compensation techniques in the system, results are shown for comparison.

Keywords: Reactive power, AC transmission, distribution, Series compensation

I. INTRODUCTION

Reactive power (VAR) compensation is nothing but the control of reactive power to enhance the performance of AC system. The important features are:

I. Load Compensation – The aim of load compensation is to boost the power factor of the system, to support the real power drawn from the system, to compensate the voltage regulation and to remove current harmonics.

II. Voltage Support – The aim of voltage support is to reduce the voltage variations at a given terminal of transmission line.

II. NECESSITY OF REACTIVE POWER COMPENSATION

I. AC power source generates the reactive power. In the first quarter part of AC cycle, capacitor or reactor stores the reactive power (VAR) and in the next quarter cycle, the reactive power gets returned back to the AC power source. Thus the reactive power moves back-and-forth between AC source and capacitor or reactor at a frequency double the rated frequency. So in order to prevent to-and-fro movement of reactive power between the load and source it has to be controlled.

II. Also to adjust the power factor of the system and to maintain the voltage stability we need to compensate reactive power [7]

III. Due to reactive power compensation techniques the working of HVDC conversion terminal becomes better [4].The efficiency of transmission increases. Also it regulates the steady state and temporary overvoltages and therefore the disastrous blackouts can be avoided.

III. METHODS OF REACTIVE POWER SHUNT COMPENSATION

a) Shunt compensation-- Here the device is connected in parallel with the transmission line. A shunt compensator is always connected in the middle of the transmission line [5] along with either a current source, voltage source or a

capacitor. It supplies reactive power to the system. The voltage equation is given as:

$$P + jQ = -j4V^2(1 - \cos\delta)/x$$

Since the real part of the power is 0, therefore the reactive power in the system is added by shunt compensator.

Shunt-connected reactors are connected in the system to control the reactive power. By consuming the reactive power shunt connected reactors decrease the over voltages in the transmission line.

The capacitors connected in parallel with transmission line are also used to regulate the voltage level by controlling the reactive power to the transmission line.

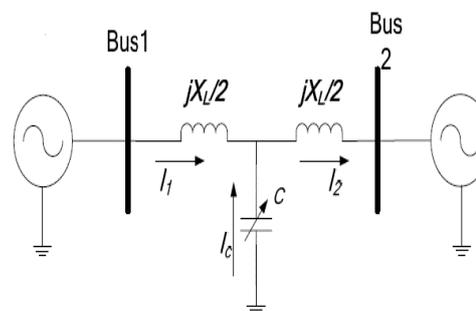


Figure 1: Transmission line with shunt compensation

b) Series compensation

Here a device is connected in series with the transmission line[9] Thus it is called a series compensator. There are two modes of operation – capacitive mode of operation and inductive mode of operation.

A simplified model of a transmission system with series compensation is shown in Figure 2 .The voltage magnitudes of the two buses are assumed equal as V, and the phase angle between them is δ .

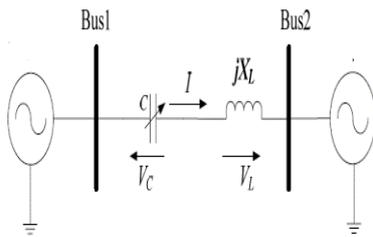


Figure 2: Transmission line with series compensation

c) Static VAR compensators

A static VAR compensator (or SVC) is set of electrical devices for providing fast-acting reactive power on transmission networks [11]. 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-

- 1) Thyristor controlled and thyristor switched reactor (TCR & TSR)
- 2) Thyristor switched capacitor(TSC)

When TSC is switched on the reactive power in SVC increases. This indicates 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.

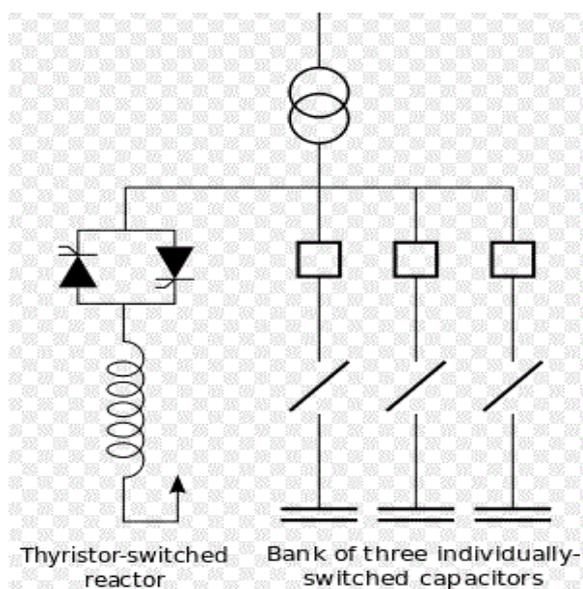


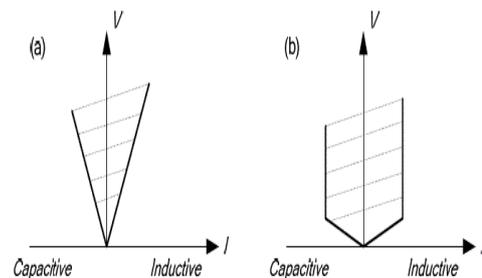
Figure 3: Thyristor switched reactor

d) Self commutated VAR compensator

They contain switched valve devices such as GTOs(Gate turn-off thyristor)& IGBTs(Insulated Gate Bipolar Transistors).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.

e) Static Synchronous Compensator(STATCOM)

It is a member of FACTS family of devices. It is a regulating device used on alternating current electricity 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.



V-I characteristics of SVC and STATCOM: (a) SVC; (b) STATCOM

Figure 4: VI characteristics of SVC and STATCOM

f) Synchronous Condenser

It is a synchronous machine which runs without prime mover or a mechanical load and connected to improve the power factor of the electrical system.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 provides a better efficiency. Due to this large amount of power can be delivered to the load.

IV. EXAMPLE

The objective of study how to maintain load voltage at a particular value without variation is given with help of an example which would also study how to improve regulation of voltage, efficiency in transmission of power and related

power factor. Table 1 shows the system data in the example and Table 2 shows final results and comparison.

Table 1: System Data

	Parameter	Rated Value
Induction motor	Supply voltage	3-phase
	Frequency of supply voltage	50 Hertz
	Winding Connection	Star connection
	Rated value	500 HP
	Voltage	4200 V
	Full-load efficiency	89 %
	Power factor	0.75 lagging
Line conductor	Resistance	0.16 ohms/r phase
	Inductance	1.03 mH/ phase

Table 2: Final results and comparison

Electrical parameter	Base case value	Values after compensation	
		Series Compensation	Shunt compensation
Sending end voltage (V)	4257	4228.06	4247.41
Active power loss (KW)	2.9799	2.9799	2.068
Reactive power loss (KVAR)	7.229	2.571	5.020
System power factor	0.7484	0.7613	0.8983

V. CONCLUSION

- I. Sending end voltage for shunt compensator is more than that required for series compensator.
- II. In shunt compensator active power loss is reduced. In series compensator the active power loss remains unaffected.

- III. Total reactive power loss is reduced to substantial amount by a series compensator as compared to shunt compensator.
- IV. Shunt compensator gives improved power factor than that of series compensator.
- V. The response time of STATCOM is shorter than that of static VAR compensator due to fast switching time of IGBT of voltage source converter.
- VI. STATCOM gives better reactive power support at low AC voltages than static VAR compensator
- VII. STATCOM provides better voltage stability than static VAR compensator
- VIII. STATCOM exhibits higher losses and may more expensive than static VAR compensator/

REFERENCES

- [1] M.W. Gustafson and J.S. Baylor, (1988), "Transmission loss Evaluation for Electric Systems", IEEE Transactions on Power Systems, 3(3), pp 1026 1032.
- [2] Van Cutsem T., 1991, "A method to compute reactive power margins with respect to voltage collapse", IEEE Transactions on Power Systems, 6(1), pp 145 156.
- [3] B.M.Weedy, (1979), Electric power systems , John Wiley.
- [4] B.R.Gupta, (1998), Power System Analysis And Design, Third Edition , S.Chand and Company Ltd.
- [5] M.L.Soni, P.V.Gupta and U.S.Bhatnagar, (1994), A Course In Electrical Power,Dhanpat Rai and Sons Pvt Ltd.
- [6] S.Sivanagaraju and V.Shankar, (2006), Electrical Power Distribution And Automation, Dhanpat Rai and Co. Publications.
- [7] Dr.V.Kamaraju, (2008), Electrical Power Distribution Systems, Third Edition, Overseas Publishers Pvt. Ltd.
- [8] C.L.Wadhwa, (2005), Electrical Power Systems, Fourth Edition, New Age International Publishers.
- [9] T.J.E.Miller, (1982), Reactive power control in electric systems, John Wiley.
- [10] Turan Gonen, (1986), Electric Power Distribution System Engineering, McGrawHill book company.