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Review of Reactive power compensation using STATCOM

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***Abstract*:** *This paper introduces various methods of reactive power compensation in power system. The study of shunt connected FACTS (Flexible AC transmission system) devices is a connected field with the problem of reactive power compensation and better mitigation of transmission related problems in today's world. In this paper the study of STATCOM, its principle of operation and control is done. This paper describes the PWM technique as a control strategy using instantaneous reactive power theory (PQ theory). STATCOM besides compensation is also used for improving system stability, Improve Power Transmission Capability of Transmission and Distribution Lines, Reduce Line Losses which is achieved through implementation of various control algorithms, switching techniques which have been reported in the literature.*
***Keywords*:** *FACTS, Instantaneous Reactive Power Theory, PWM technique, STATCOM.*

I. Introduction

Reactive Power is both the Solution and Problem to the power system network. Even though it plays an important role in creating and maintaining magnetic flux in machines used in the power system, it reduces the system power factor and acts as an additional load. For efficient transmission of power, the sending end voltage should be near to the receiving end voltage as far as possible. Since majority of load in power system is inductive, it draws excessive reactive power from the source which causes voltage sag in the transmission lines leading to bad voltage profile and poor power factor. Several methods have been introduced to compensate for the reactive power, compensation using FACTS (Flexible AC Transmission System) devices is one of the methods.

FACTS is alternating current transmission system incorporating power electronics based and other static controllers to enhance controllability and increase power transfer capability [2]. The compensator can be of two types, series compensator and shunt compensator. The static synchronous compensator (STATCOM) is one of shunt compensators. It can be based on voltage sourced or current sourced converter. Voltage source converter is preferred considering overall cost. In STATCOM, a single capacitor is required for compensation which acts as an input to the inverter. Switching of the inverter can be controlled by using PWM techniques. Capacitive and inductive current of the STATCOM can be controlled with ac voltage. For this closed loop control is achieved by using PI controller.

II. Reactive power

Power which does the actual work in the system is called as an active power, measured in KW. Reactive power is not used to do work but it is needed in the system, measured in KVAR. Resultant of the real and reactive power is called as an apparent power, measured in KVA, as shown in Fig.2

Reactive Power is both the Problem and the Solution to the power system network. Even though it plays an important role in creating and maintaining magnetic flux in machines used in the power system, it reduces the system power factor and acts as an additional load. Therefore, compensation is required.

From the power triangle it can be clearly seen that as apparent power equals to the real power less compensation is required.

A.Reactive power compensation techniques

In case of capacitor bank, for reactive power compensation whole capacitor bank is deployed across the transmission line which compensates lagging reactive demand immediately. this is known as fixed compensation. But in this case there is danger of over voltage in case of no load condition. Therefore, for larger electrical systems automatic reactive power compensation is employed. In Automatic compensation like Automatic Power Factor Controllers (APFC) the capacitors are controlled by using relays or thyristors. In APFC number of small units of capacitor banks are connected to main power distribution system or substation. Whenever reactive power is demanded by the load unit(s) of capacitor banks are switched to serve the reactive power. In case of FACTS devices, firstly reactive power demand of the load is calculated by the controllers by sensing voltages and currents at the PCC (Point of Common Coupling). And Compensating Currents are generated which are then compared with the reference currents to generate the PWM pulses. PWM pulses are used to switchIGBT's hence controlled power is transferred from STATCOM to the system using VSC. Therefore, single capacitor is required for compensation in case of STATCOM.

B. STATCOM

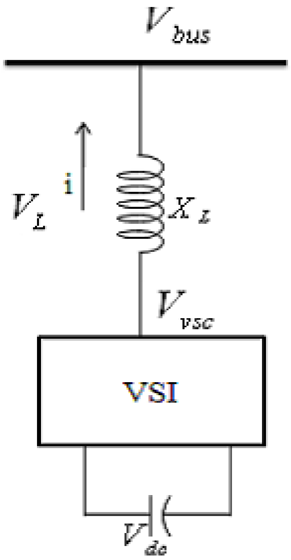

Fig (2): Basic block diagram of STATCOM

C. Voltage Source Converter (VSC)

VSC has received most attention in practical realization of STATCOM principle. In VSC dc voltage always have one polarity and the power reversal takes place through reversal of dc current polarity. It basically generates AC voltage from dc voltage and often referred as an inverter. With VSC, the magnitude, the phase angle and the frequency of the output voltage can be controlled. IGBT (Insulated Gate Bipolar Transistor), a new generation of device which require less energy for switching process are available with ratings that can be used for a STATCOM.

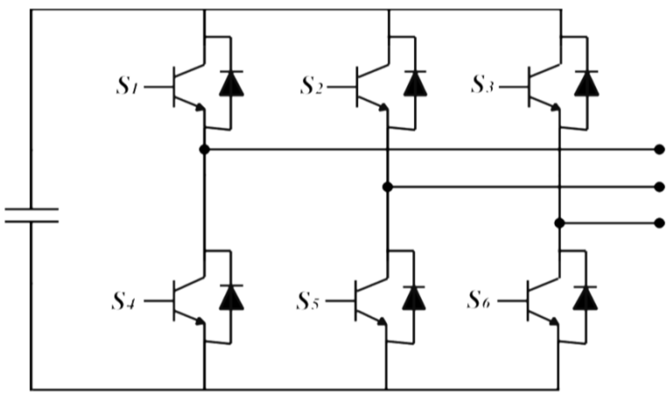

Fig (3): voltage source converter

III. Instantaneous Reactive Power Theory

H. Akaqi introduced pq theory in 1983. The pq theory is based on the set of instantaneous power defined in time domain[3]. The pq theory uses clark's transformation to convert both three phase currents and three phase voltages from abc coordinates to αβ0 coordinates as in eq.(1). STATCOM can be used for compensation of harmonics wherein the active power calculated is passed through the High Pass Filter(HPF) to get harmonic component of active power. Then by using eq.(5) compensating currents can be calculated. These currents are compared with the reference currents as shown in Fig (5).The whole block diagram representation of generation of compensating currents from measured voltages and currents is explained in Fig(4).

In the $\alpha\beta 0$ domain:

$$\begin{bmatrix} v_0 \\ v_\alpha \\ v_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1/\sqrt{2} & 1/\sqrt{2} & 1/\sqrt{2} \\ 1 & -1/2 & -1/2 \\ 0 & \sqrt{3/2} & -\sqrt{3/2} \end{bmatrix} \begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix}. \quad (1)$$

Without the zero-sequence component, the instantaneous power can be written as

$$\begin{aligned} s(t) &= p(t) + jq(t) \\ &= v_{\alpha\beta}\, i^*_{\alpha\beta} = (v_\alpha + jv_\beta)(i_\alpha - ji_\beta) \\ &= (v_\alpha i_\alpha + v_\beta i_\beta) + j(v_\beta i_\alpha - v_\alpha i_\beta) \end{aligned}$$

(2)

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} (v_\alpha i_\alpha + v_\beta i_\beta) \\ (v_\beta i_\alpha - v_\alpha i_\beta) \end{bmatrix} = \begin{bmatrix} v_\alpha & v_\beta \\ v_\beta & -v_\alpha \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix}. \quad (3)$$

$$p = \bar{p} + \tilde{p}$$

$$q = \bar{q} + \tilde{q} \quad (4)$$

$$\begin{bmatrix} i^*_{c,\alpha} \\ i^*_{c,\beta} \end{bmatrix} = \frac{1}{v_\alpha^2 + v_\beta^2} \cdot \begin{bmatrix} v_\alpha & v_\beta \\ v_\beta & -v_\alpha \end{bmatrix} \cdot \begin{bmatrix} \tilde{p}_L \\ \bar{q}_L + \tilde{q}_L \end{bmatrix} \quad 5)$$

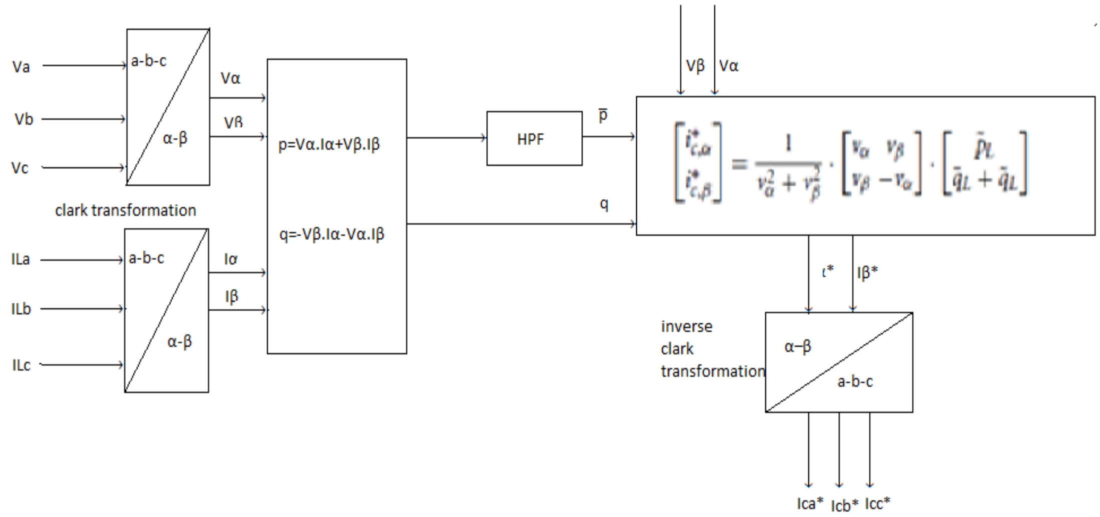

Fig (4): *Generation of Compensating Current Using Instantaneous Reactive Power Theory*

IV. PWM Generator

It is used to drive the IGBT switches for inverter operation. The modulator sends triggering pulses to each switch according to the pwm generation.

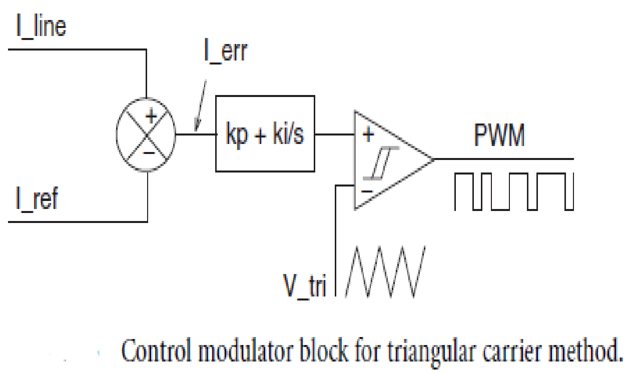

Fig (5) PWM generation

V. conclusion

By study of various compensation techniques, it can be concluded that STATCOM is an effective way of compensation of reactive power and can be used under voltage dip and unbalanced current condition. The self-commutating VSC based on power electronics switching devices like IGBTs is the backbone of this compensator. With advances in solid-state switching devices, STACOM being a versatile compensator has taken the place of the line commutating SVC, a relatively slow-acting dynamic shunt controller.

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