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PERFORMANCE ANALYSIS OF PI BASED STATCOM FOR THE 132 KV TRANSMISSION LINE

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ABSTRACT

This paper presents simulation model of the 132KV transmission line with PI based STATCOM. The STATCOM being the state-of-the-art VSC based dynamic shunt compensator in FACTS family is used now a days in transmission system for reactive power control, increase of power transfer capacity, voltage regulation etc. Such type of controller is applied at the middle of the transmission line to enhance the power transmission capacity of the line. The simulation result show that the STATCOM is effective improve the power factor and voltage regulation for the 138kV line loading.

KEYWORDS: STATCOM, PI control strategy, MatLab simulink.

INTRODUCTION

With the current expansion and growth of the electric utility manufacture, including deregulation in many countries, changes are endlessly. Although electricity is a highly engineered product, it is increasingly being considered and handled as a commodity.

New power generation is mainly determined based on environmental and economic reasons, and are somewhat inexpensive and relatively easy to build and operate, especially nowadays with the availability of "cheap" natural gas and high performance gas turbines. Thus,transmission systems are being pushed closer to their stability and thermal limits while the focus on the quality of power delivered is greater than ever.

On the other hand, new transmission systems are expensive and take considerable amount of time to build. Hence, in order to meet increasing power demands, utilities must rely on power export/import arrangements through existing transmission systems. In the evolving utility environment, financial and market forces are, and will continue to, demand a more optimal and profitable operation of the power system with respect to generation, transmission, and distribution. To achieve both operational reliability and financial profitability, it has become clear that more efficient utilization and control of the *existing* transmission system infrastructure is required.

Improved usage of the existing power system is provided through the application of advanced control strategy. Power electronics based equipment, or Flexible AC Transmission Systems (FACTS), provide proven technical solutions to address these new operating challenges being presented today. FACTS technologies allow for improved transmission system operation with minimal infrastructure investment, environmental impact, and implementation time compared to the construction of new transmission lines

The limitations of the transmission system can take many forms and may involve power transfer between areas or within asingle area or region (referred to here as a regional constraint) and may include one or more of the following characteristics: Steady-State Power Transfer Limit, Voltage Stability Limit, Dynamic Voltage Limit, Transient Stability Limit, Power System Oscillation Damping Limit, Inadvertent Loop Flow Limit, Thermal Limit, Short-Circuit Current Limit.

The power system today is largely inter connected and very complex. To improve the efficiency, security and reliability of existing system some methods have to be employed. FACTS (Flexible AC Transmission Systems) technology is one such which has found a wide spread application in the power industry for active and reactive power control. FACTS devices enhance the capacity of the transmission lines, stability operating limits and provide control of the power system. Optimized utilization of the existing power system capacities by replacing mechanical controllers can be achieved by reliable and high-speed FACTS devices.

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THE BASIC PRINCIPLE OF SYNCHRONOUS LINK BASED STATCOM

In a synchronous link where two ac sources () of same frequency are together by means of a link inductor, active power flows from the leading bus to the lagging one and reactive power flows from the source with higher voltage magnitude to the one with lower voltage magnitude . If the output voltage is equal to the AC system voltage, then the reactive power exchange is zero.

MODES OF OPERATION

$$s = 3\frac{V_{bus}V_{vsc}}{X_L}\, sin\delta - j3\left(\frac{V_{bus}V_{vsc}}{X_L} cos\delta - \frac{V_{bus}^2}{X_L}\right)$$

$$P = \frac{V_{bus}V_{vsc}}{X_L}\, sin\delta$$

$$Q = \left(\frac{V_{bus}V_{vsc}}{X_L} cos\delta - \frac{V_{bus}^2}{X_L}\right)$$

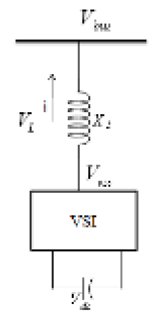


Fig 1 Static Synchronous Compensator.

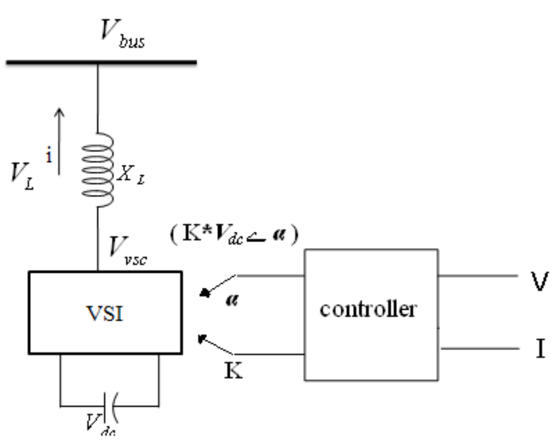
The real and reactive power transfer between the system and STATCOM are given by following equations. where 'δ' is the angle difference between system bus voltage and STATCOM output voltage.

CONTROL APPROACHES FOR STATCOM

The mode of operation is decided by the magnitude and phase angle of inverter voltage , which is controlled by the controller. The input commands to the STATCOM are K (a constant which relates the dc-side voltage to the amplitude (peak) of inverter output ac voltage) and alpha (α, the phase and difference between converter output voltage Vvsc and bus voltage Vbus). Depending upon the technique used for controlling the compensator current STATCOM can be control in two ways:

A) By changing the switching angles of multilevel inverter devices (i.e. varying the modulation index) while maintaining the dc capacitor voltage at a constant level (inverter type I control/ direct control) or
B) Keeping the switching angles fixed and varying the dc capacitors voltages (inverter type II control/indirect control).

The variation of dc capacitors voltages is simply achieved by varying the active power transfer between STATCOM and power system by adjusting phase angle difference between Vbus and Vvsc. All these control schemes have their own merits and demerits. In general, inverter type I control is preferred where very fast voltage control is required but THD of Vvsc



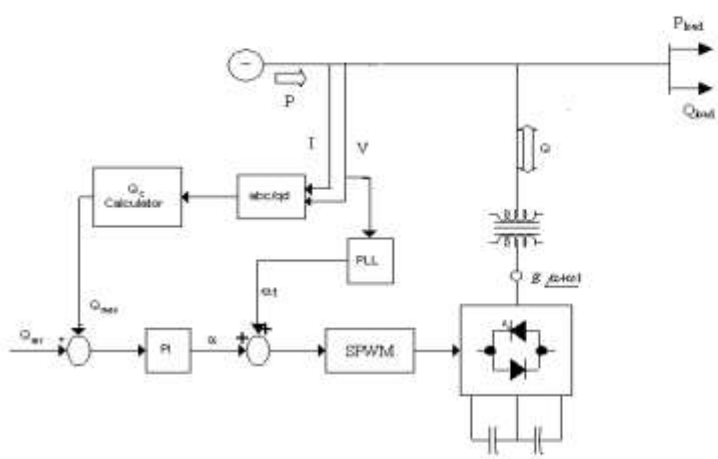


Fig 2 STATCOM Control system Fig 3: Schematic Representation of the Control Circuit.

varies with modulation index, thereby producing more harmonic distortion in the Vbus at low modulation index. On contrary to this, inverter type II operation is slow as ac output voltage of STATCOM varies according to variation of dc capacitor voltages (i.e. presence of capacitor dynamics make the response slow) but harmonic injection in the power system bus voltage can be kept at very low level by operating the inverter at high modulation index where THD of Vvsc is least.

CONTROL METHOD

The main objective of this control method is to control the phase angle of the inverter output with respect to the changes in the system reactive power. The quantities obtained from above algorithms are used to calculate the system reactive power and phase angle (α). The measured reactive power is then compared with reference value to produce error signal, which is then passed through a PI controller to obtain the required phase angle α. Pulses required for the inverter are generated from SWPM block. By controlling the phase angle α of inverter output voltage, the DC capacitor voltage can be changed. Thus, the amplitude of the inverter output voltage can be controlled. Schematic representation of the control circuit as shown in fig. 3.

PI CONTROL STRATEGY

When a STATCOM is connected to a transmission line for reactive power compensation and power factor improvement. The following response can be seen ie. Current waveform is in phase with voltage so unity power factor which means maximum power transfer. From the above figure we can observe that reactive power(Q) is calculated using a PQ block and this calculated reactive power(Q) is compared with the references value ie(0) then this error is given to a PI controller after which it is added with (wt) which is calculated from PLL block.the output of this adder is further processed with SPWM technique to generated pulses. This pulses is given the STATCOM where the switching of the VSC are adjusted to generated the required output Voltage(Vvsc) .

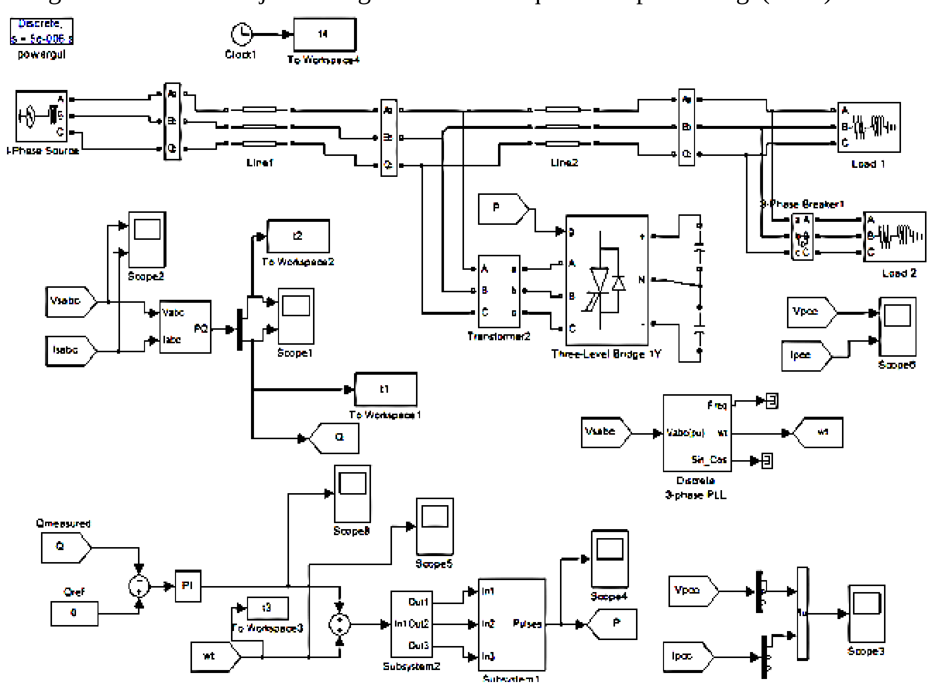


Fig. 4. Simulation diagram for the PI based STATCOM

SIMULATION STUDIES

In this chapter simulation of STATCOM circuit for reactive power compensation for power factor improvement is shown.

Parameters of test system : Three phase AC source : 132 Kv Rated voltage (phase-phase rms), 60 Hz Frequency, 200 Km Transmission line Length

Three phase loads : 50 MW Active Power, 30MVAR Inductive reactive Power, STATCOM : Inverter 3 Level NPC inverter employing GTOs, 1980 Hz Switching frequency, 1000 µF Capacitor.

SIMULATION RESULT

Performance analysis of uncompensated system

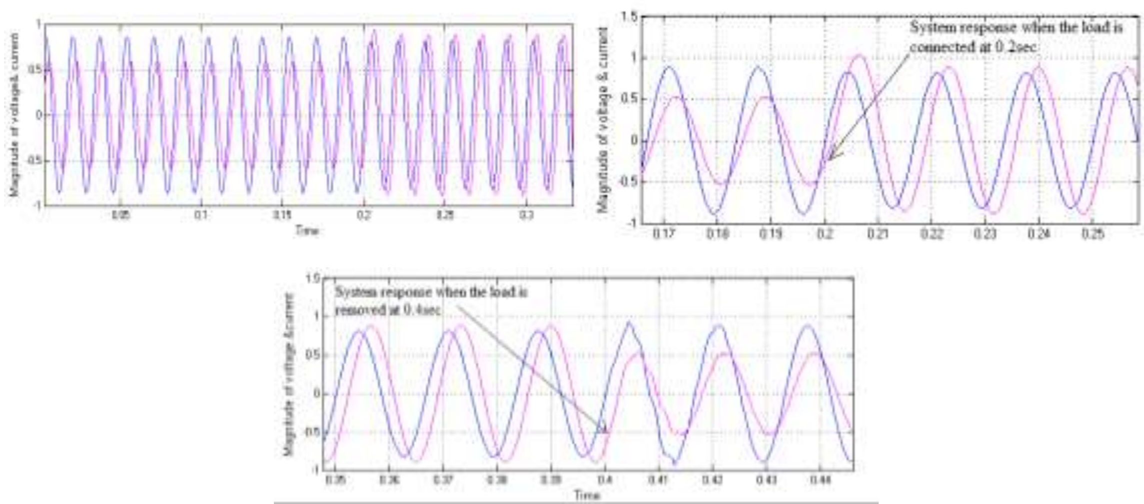


Fig. 5. a. Phase Voltage and Current Waveform for Uncompensated Syste, b. Phase Voltage and Current Waveform for Uncompensated System for change in the Load, c. Phase Voltage and Current Waveform for Uncompensated System when the load is ***removed***

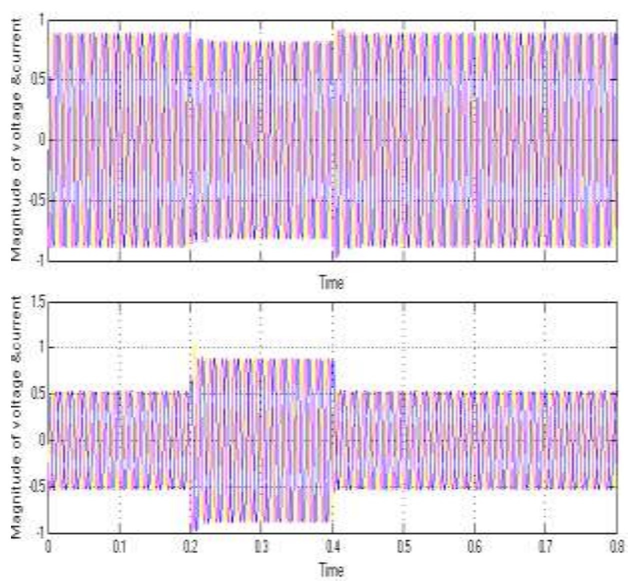


Fig. 6. 3-phase Voltage and Current Waveform for Uncompensated System

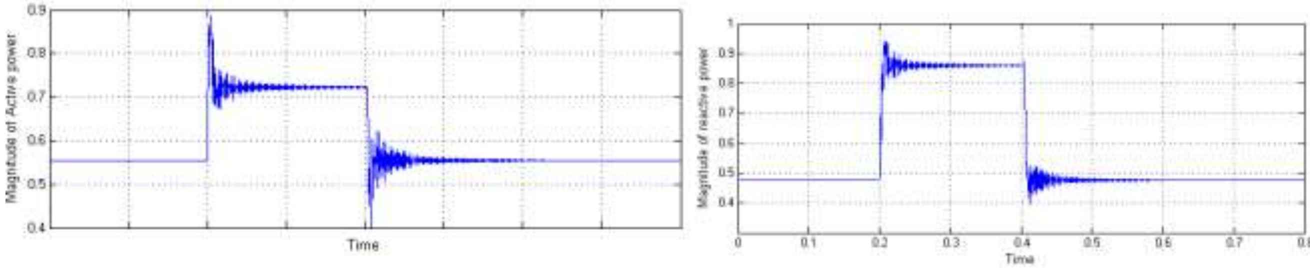


Fig. 7. Active and Reactive Power flow in uncompensated system

Performance analysis of compensated system

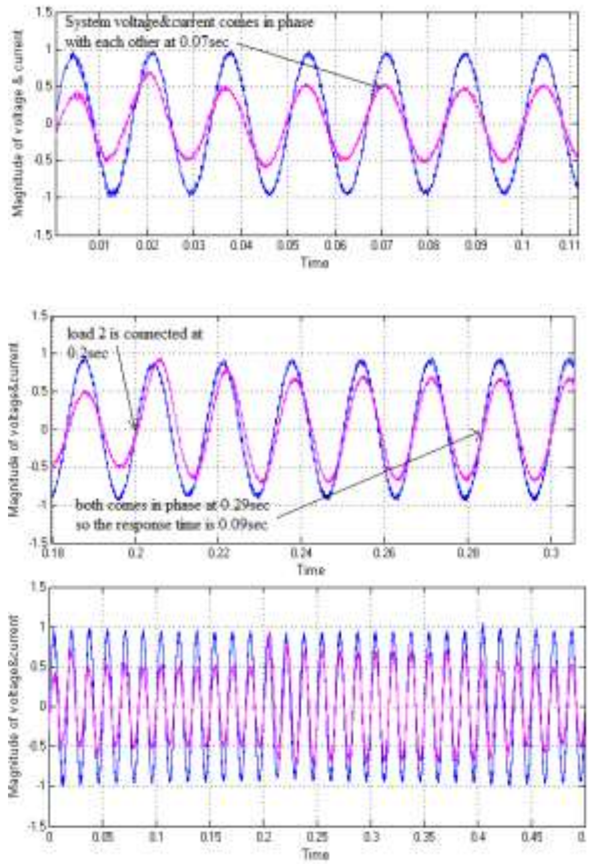


Fig 8.a. 1-phase current and voltage waveform using STATCOM, b. Phase Current and Voltage waveform when the STATCOM is ON, c. Phase Current and Voltage waveform when Load is Varied in the system

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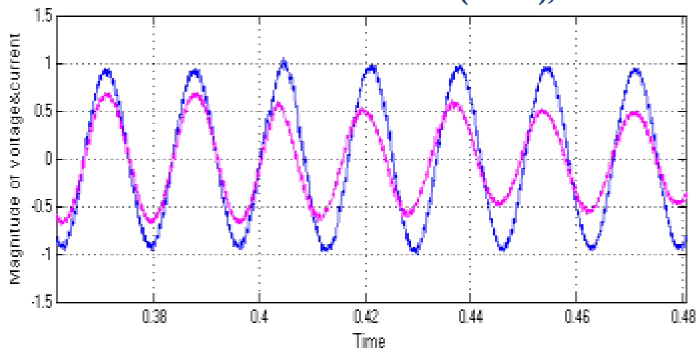

Fig. 9. . Phase Current and Voltage waveform when suddenly a Load is remove from the system at 0.4sec

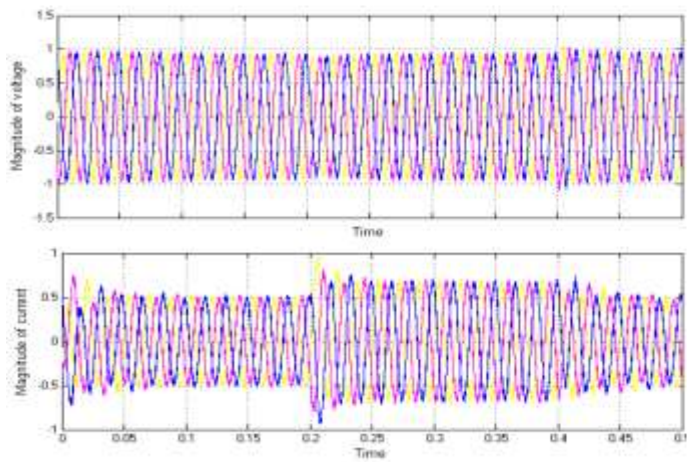

Fig. 10. 3-phase current and voltage waveform using STATCOM

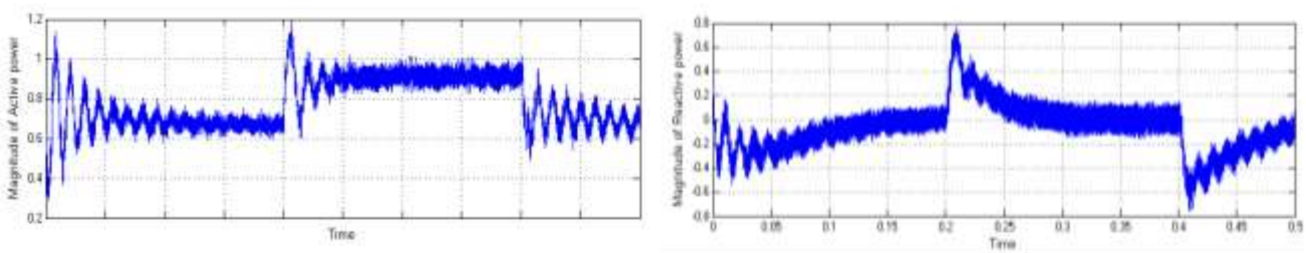

Fig 11. Active and Reactive power flow in Transmission system using STATCOM

Initially when the STATCOM is on it take around 0.07sec to bring voltage and current in phase ie. Unity power factor. Now when suddenly load2 is switch on or connected to the transmission system a voltage sag is created but the STATCOM supply the required amount of voltage to maintain the voltage profile.this affect the voltage and current phase difference .But it takes 0.08 sec to maintain zero phase difference between voltage and current.Similarly when the load 2 is suddenly disconnected from the supply voltage swell occurs .Here STATCOM absorbs the required amount of voltage to maintain the voltage profile and reduce the fluctuation in voltage. This also affect the voltage and current phase difference which is corrected by STATCOM which takes appox 0.08sec to get a zero phase difference. So we can conclude that the response time of STATCOM used in this system is around appox 0.07sec to 0.09 sec i.e (70 milliseconds to 80 milliseconds)

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CONCLUSION
It is found that the STATCOM bring the power factor to the unity thereby enhancing the power transfer capability by supplying or absorbing controllable amount of reactive power by using a simple PI controller.

FUTURE SCOPE
Although the given response time of the STATCOM using PI controller is considerable amount, But in real time application system it should be much lesser. So in order to improve the response time of the system a better control strategy must be implemented. The ANN based control strategy can be implemented.

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