A Novel Approach to Harmonics Analysis and Control for Dynamic Power System using STATCOM

Dr. T. Govindaraj and S. Vasanth

Abstract: In power systems, there exists a continuous challenge to improve dynamic performance of power system. The Static Synchronous Compensator (STATCOM) is a power electronic based device that has the capability of controlling the power flow through a line. This study applies the Static Synchronous Compensator (STATCOM) to control the power flow during dynamic period. To verify the effect of the STATCOM on dynamic performance, the mathematical model and control strategy of a STATCOM are needed to be presented. The converters of STATCOM are represented by variable voltage source with associate transformer leakage reactance and the voltage source and the reactance are transformed into current injection. The current injection model of STATCOM are modeled into power flow equation and thus it has used to determine control strategy. This study applies the PI control to determine the control strategy of STATCOM. The Harmonics elimination and THD values are arrived and displayed in results using MATLAB Simulink.

Keywords: STATCOM, Series Compensation, Shunt Compensation, PI Controller.

I.INTRODUCTION

Power system oscillation is one of the important aspects in modern power system. Currently, power engineers are much more concerned about stability problem due to blackout AStatic Synchronous Compensator (STATCOM) is a member of the FACTS family that is connected in shunt with system. The STATCOM consists of a solid state voltage source converter with GTO thyristor switches or other high performance of semi-conductor and transformer. The STATCOM can electrically mimic reactor and capacitor by injecting a shunt current in quadrature with the line voltage.

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The reactive power (or current) of the STATCOM can be adjusted by controlling the magnitude and phase angle of the output voltage of the shunt converter this study presents the PT controller law of STATCOM. The mathematical model of power system with a STATCOM is systematically derived. The nonlinear control of fuzzy logic control is applied to determine the control strategy. The simulation results are tested on a sample system. A dynamic model of the SEIG-STATCOM feeding nonlinear loads using stationary d-q axes reference frame is developed for predicting the behavior of the system under transient conditions [2]. Reactive power control through the static compensator (STATCOM) has gained wide attentions due to its outstanding performance. But for a STATCOM with traditional control strategies, unbalanced utility voltages will greatly affect the performance of the STATCOM and, in severe cases, may even cause the shutdown of the STATCOM for over current protection[3].A long transmission line needs controllable series as well as shunt compensation for power flow control and voltage regulation. This can be achieved by suitable combination of passive elements and active FACTS controllers[4]. Two novel controllers for the STATCOM and SSSC are presented in this paper based on a decoupled current control strategy[5]. Comparisons with field measurements show that both the disturbance level and the spectrum of the harmonics are correctly modeled by the three-pulse method[6] The approach uses only measurements at points where internal (retained) and external (reduced) systems are interfaced, and requires no knowledge of parameters and topology of the external subsystem[7]. The result is a low order and hence very fast computation with not only detailed but also quite precise results for those parts of the system which are critical [8]. The Harmonic analysis of the STATCOM using the proposed analytical approach reveals that the total harmonic distortion of the STATCOM output voltage is minimal as the modulation index is fixed at unity at steady state[9]. When a STATCOM is used for transient stability improvement, common practice is to design the control system to keep reactive current at maximum level until the voltage has returned to its initial value[10].

A static synchronous compensator (STATCOM), also known as a "static synchronous condenser" ("STATCON"), is a regulating device used on alternating current electricity transmission networks. It is based on a power electronics voltage-source converter and can act as either a source or sink of reactive AC power to an electricity network. If connected to a source of power it can also provide active AC power. It is a member of the FACTS family of devices[11]-[49].

A static VAR compensator (SVC) can also be used for voltage stability. However, a STATCOM has better characteristics than a SVC. When the system voltage drops sufficiently to force the STATCOM output current to its ceiling, its maximum reactive output current will not be affected by the voltage magnitude. Therefore, it exhibits constant current characteristics when the voltage is low under the limit. In contrast the SVC's reactive output is proportional to the square of the voltage magnitude. This makes the provided reactive power decrease rapidly when voltage decreases, thus reducing its stability. In addition, the speed of response of a STATCOM is faster than that of an SVC and the harmonic emission is lower. On the other hand STATCOMs typically exhibit higher losses and may be more expensive than SVCs, so the (older) SVC technology is still widespread.

Usually a STATCOM is installed to support electricity networks that have a poor power factor and often poor voltage regulation. There are however, other uses, the most common use is for voltage stability. 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 and therefore a STATCOM has very little active power capability. However, its active power capability can be increased if a suitable energy storage device is

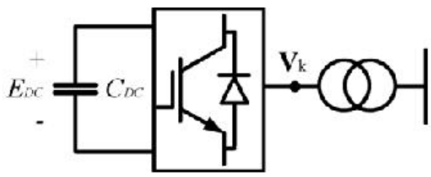

Fig 1 .Statcom basic model

connected across the DC capacitor. The reactive power at the terminals of the STATCOM depends on the amplitude of the voltage source. For example, if the terminal voltage of the VSC is higher than the AC voltage at the point of connection, the STATCOM generates reactive current; on the other hand, when the amplitude of the voltage source is lower than the AC voltage, it absorbs reactive power. The response time of a STATCOM is shorter than that of an SVC, mainly due to the fast switching times provided by the IGBTs of the voltage source converter[50]-[89].

The STATCOM also provides better reactive power support at low AC voltages than an SVC, since the reactive power from a STATCOM decreases linearly with the AC voltage (as the current can be maintained at the rated value even down to low AC voltage).The Static Synchronous Condenser (STATCOM) proposed is a new concept for the compensation and effective power flow management of multi-line transmission systems. In its general form, the STATCOM employs a number of inverters with a common DC link, each to provide series compensation for a selected line of the transmission system. Because of the common DC link, any inverter within the STATCOM is able to transfer real power to any other and thereby facilitate real power transfer among the lines of the transmission system. Since each inverter is also able to provide reactive compensation, the STATCOM is able to carry out an overall real and reactive power compensation of the total transmission system. This capability makes it possible to equalize both real and reactive power flow between the lines, transfer power from overloaded to under loaded lines, compensate against reactive voltage drops and the corresponding reactive line power, and to increase the effectiveness of the compensating system against dynamic disturbances.

A.Interpretation of the damamping Characteristics

In a conventional damping controller, such as a PSS on an electrical machine, changing the PSS gains usually retains the resonance frequencies near their original values but increases the damping. In contrast, when a STATCOM or STATCOM is included, the aforementioned are not only indicate improved damping,but also show a significant change in the resonant frequencies (Eigen values) of the network.

This section attempts to interpret this seemingly anomalous behavior. The STATCOM is used for the purpose of explanation, but the argument applies to the STATCOM as well as Highlights.

1. A method is presented to improve power system stability using STATCOM.
2. Re-current neural network controllers damp oscillations in a power system.
3. Training is based on back propagation with adaptive training parameters.
4. Selection of effectiveness damping control signal carried out using SVD method.

II.SERIES COMPENSATION

Series compensation is defined as insertion of reactive power elements into transmission lines. For these tasks, Siemens offers various solutions that have already been proven in numerous applications. Applications are the Fixed Series Capacitor (FSC), the Thyristor – Controlled

Series Capacitor (TCSC) and the Thyristor - Protected Series Capacitor (TPSC).

The task of series compensation is to reduce the transmission lines inductivity. This means, that the line length is "virtually" shortened. As a consequence, the transmission angle is reduced and thus the power transfer can be increased without reduction of the system stability

In the table the impact on the short-circuit level, the transmission phase angle and the voltage after load rejection are shown. Applications for each type of series compensation are included.

Series compensation makes use of capacitors, reactors or power electronic devices offering high flexibility. Depending on the application three different types of Series Compensation are provided. The most common application is the Fixed Series Capacitor (FSC). Thyristor-Valve Controlled Systems (TCSC) and Thyristor-Valve Protected Systems (TPSC) may also be installed.

III.SHUNT COMPENSATION

In shunt compensation, power system is connected in shunt (parallel) with the FACTS. It works as a controllable current source. Shunt compensation is of two types:

A. Shunt capacitive compensation

This method is used to improve the power factor. Whenever an inductive load is connected to the transmission line, power factor lags because of lagging load current. To compensate, a shunt capacitor is connected which draws current leading the source voltage. The net result is improvement in power factor.

B.Shunt inductive compensation

This method is used either when charging the transmission line, or, when there is very low load at the receiving end. Shunt capacitance in the transmission line causes voltage amplification (Ferranti Effect). The receiving end voltage may become double the sending end voltage (generally in case of very long transmission lines). To compensate, shunt inductors are connected across the transmission line. The power transfer capability is thereby increased depending upon the power equation.A SVC (Static Var Compensator) is a high voltage system that controls dynamically the network voltage at its coupling point. Its main task is to keep the network voltage constantly at a set reference value.

IV. PI CONTROLLER

The model used in P-control will be used again. The only thing to be changed is the content of the controller block i.e. the block "Controller - PI-controller.

The controller shown here is a PI controller. where the PI controller get the speed feedback and it is given as the input .Then the speed error is compared with the reference speed and the output of the PI controller is used to control the inverter switches, i.e. as depends on the output of PI controller the gate pulse to the inverter switches are produced. A simple PI controller scheme is given as

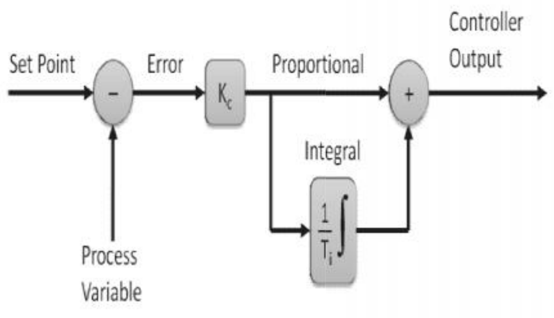

Fig2. PI Controller

PI controller will eliminate forced oscillations and steady state error resulting in operation of on-off controller and P controller respectively. However, introducing integral mode has a negative effect on speed of the response and overall stability of the system. Thus, PI controller will not increase the speed of response. It can be expected since PI controller does not have means to predict what will happen with the error in near future. This problem can be solved by introducing derivative mode which has ability to predict what will happen with the error in near future and thus to decrease a reaction time of the controller.

PI controllers are very often used in industry, especially when speed of the response is not an issue. A control without D mode is used when: Fast response of the system is not required Large disturbances and noise are present during operation of the process There is only one energy storage is in process (capacitive or inductive) There are large transport delays in the system.The definition of proportional feedback control is still

$$u = K_P e \qquad (1)$$

$$U = K$$

Where is e the "error"
K_P = Proportional gain

The definition of the integral feedback is

$$u = K_I \int e\, d\tau \qquad (2)$$

Where K_I is the integration gain factor.

In the PI controller we have a combination of P and I control,

$$u = K_P e + K_I \int e\, d\tau \qquad (3)$$

$$u = K_P e + \frac{1}{\tau_I} \int e\, d\tau \qquad (4)$$

$$u = K_P\left(e + \frac{1}{\tau_N}\int e\, d\tau\right) \qquad (5)$$

Where τ_I =Integration time

τ_N =Reset time

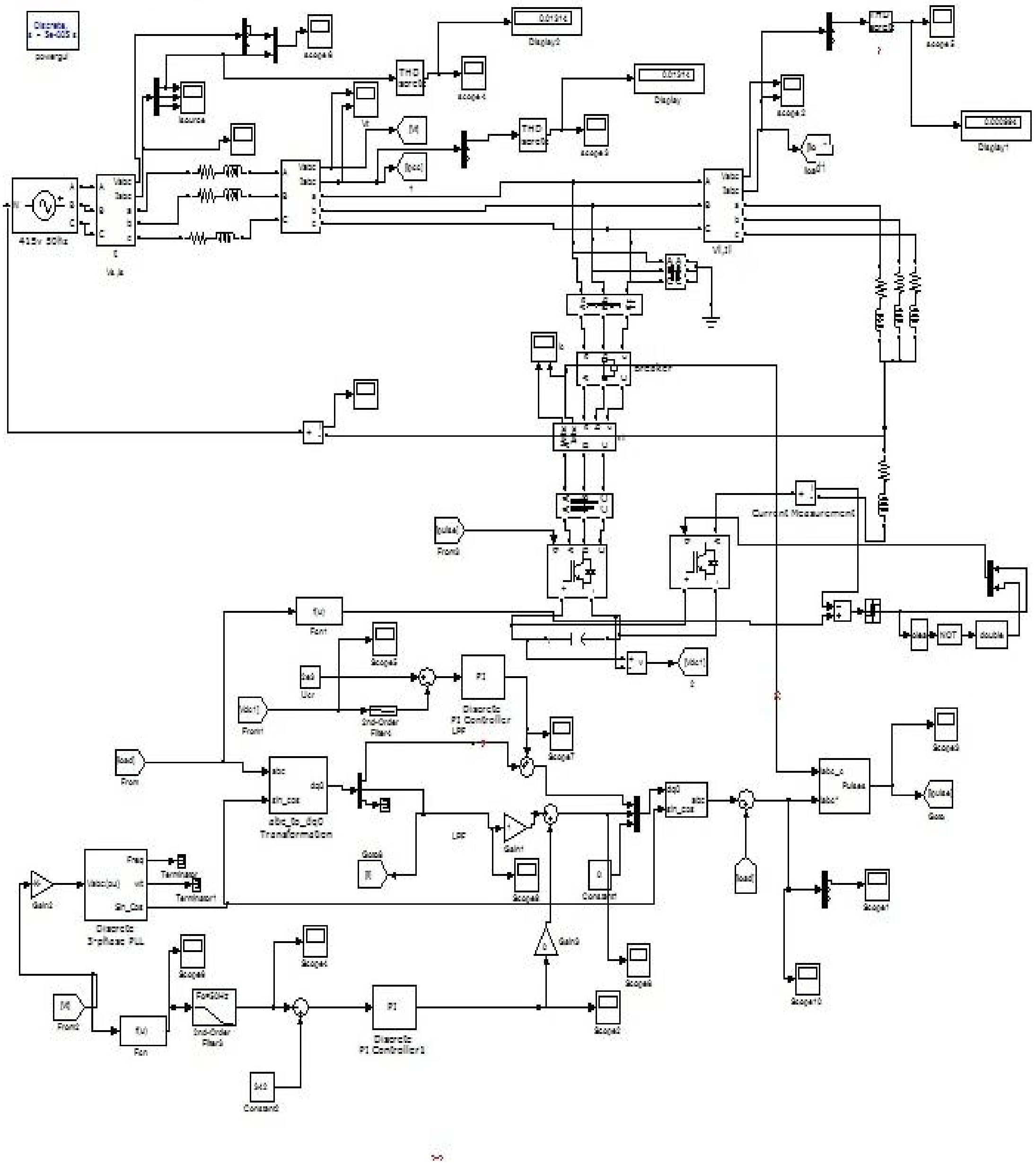

Fig 3. Simulation diagram

V.SIMULATION AND EXPERIMENTAL RESULTS

New designs of power electronics systems are the norm due to new applications and lack of standardization in specifications is because of varying customer demands. Accurate simulation is necessary to minimize costly repetitions of designs and bread boarding and hence reduce the overall cost and the concept-to-production time. There are many benefits of simulation in the design process, some of them are listed below here:

Simulation is well suited for educational purpose. It is an efficient way for designer to Learn how a circuit and its control working. It is normally much cheaper to do a thorough analysis than to build the actual circuit in which component stresses are measured. A simulation can discover the possible problems and determine optimal parameters, increasing the possibility of getting the prototype New circuit concepts and parameter variation (including tolerances on components) are easily tested. Changes in the circuit topology are implemented at no cost. There is no need for components to be available on short notice Simulated waveforms at different places in the circuit are easily monitored without the hindrance of measurement noise. As switching frequencies increases, the problem of laboratory measurements becomes increasingly difficult. Thus, simulations may become more accurate than measurement Destructive tests that cannot be done in the lab, either because of safety or because of costs involved, can easily be simulated. Response to faults and abnormal conditions can also be thoroughly analyzed.

This waveform is a single phase voltage and current wave form. This waveform brought from current and voltage measurement. The harmonics is present in it.

A.OUTPUT WAVE FORM

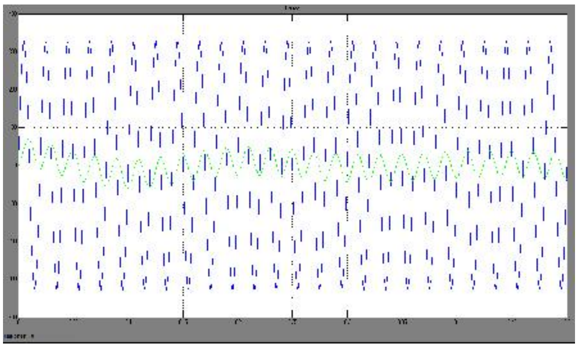

Fig 4. Input voltage and current waveform

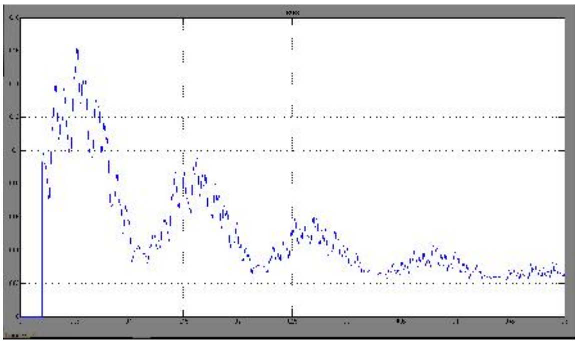

Fig 5. Harmonics waveform of before implementation.

We can see is harmonics waveform .the harmonics waves goes to peak value up to 0.16 and it drops down spontaneously up to 0.02.This harmonics waveform depend on input voltage and current.

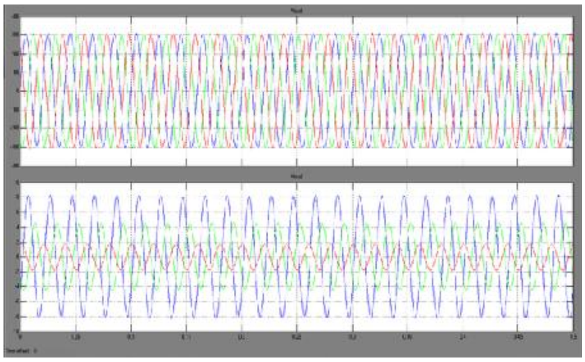

Fig 6.3 Phase voltage and unbalanced current waveform.

This is 3 phase voltage and current waveform. This peak range varies between -300 to 300.The 3 phase unbalanced load are present in current waveform. We can easily reduce harmonics when unbalanced load is present.

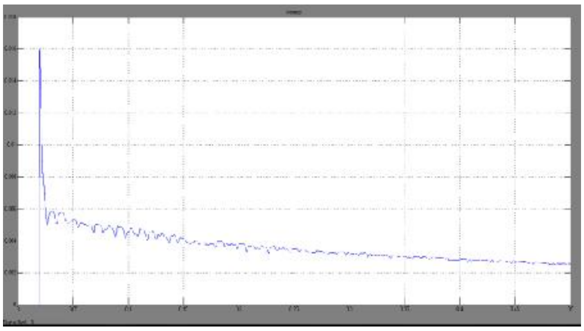

Fig7. Harmonics waveform of after implementation.

This is a harmonics waveform .This shows good impact against harmonics noise reduction. The harmonics goes to peak range of up to 0.016 and it drops to about 0.005.we can get good performance

After implementation

VI.CONCLUSION

A new STATCOM model for dynamic simulations of large scale power systems has been put forward in this paper whose modeling concepts do not rely on an equivalent voltage source but rather on the use of a complex phase-shifting transformer as its key element. The model solution is carried out using the PI Controlled tuned STATCOM Devices and this method which solves simultaneously the algebraic and differential equations at each time step. A comparative study was carried out to demonstrate that the main output variables and the number of iterations that the new model takes to converge at each time step is consistent with those of a STATCOM model based on conventional voltage source. This is in spite of the modeling approaches being fundamentally different. For instance, the inner active power losses are calculated in a quite different manner and the DC-bus representation in the new STATCOM leads to a much more flexible model. The latter is something that the equivalent voltage source-based model of the STATCOM definitely lacks.

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