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Control of Statcom to Enhance Stable Power System Operation

M.Tech.Scholar S. Reddiah Raju
Dept of EEE
MJR College of Engg. & Tech.
Piler, AP, India

Asst. Prof. P.Chinnaiah
Dept. of EEE
MJR College of Engg. & Tech.
Piler, AP, India

Asst.Prof. V.Sunil Kumar Reddy
Dept. of EEE
MJR College of Engg. & Tech.
Piler, AP, India

Abstract- **In this paper, two control methods namely adaptive voltage control method and d-q axis control method are proposed to ensure proper operation of static synchronous compensator (STATCOM) to provide an efficient and effective means of controlling power system stability. In the aforesaid control methods PI controller has been used to regulate the constant DC link voltage in the DC link capacitor as well reactive power, grid voltage and current. The simulations are conducted in MATLAB/SIMULINK platform. The performance of the STATCOM is investigated both for normal state and disturbances of the power system network. The obtained results ensure that the STATCOM with the mentioned controller has performed well to maintain power system stability by controlling both bus voltages and reactive power in the power system network.**

Keywords- **FACTS, PI controller, D-Q controller, static synchronous compensator (STATCOM), adaptive voltage control.**

I. INTRODUCTION

Electrical Energy is the most significant element for any developing country to ensure economic development. The stability of existing transmission networks are close to their limit due to the increase of industrialization of electrical system [1, 2]. As a result, it is essential to build new transmission system. However, in order to relieve the overhead transmission lines and offer adequate transient stability, the building of new transmission lines are not always possible due to political, environmental and economic reasons [3].

By considering all these issues, in this paper an attempt to improve the power system stability has been taken place where FACTS devices are used. Among different types of FACTS devices STATCOM has been chosen in this paper as it gives fast response and can be used for compensating lagging and leading VAR. In the past a new type of STATCOM is described which is built by CASCADING VOLTAGE SOURCE INVERTERS. In order to control the switching devices SPWM technique is used in every VSI [4].

A multilevel optimal modulation scheme was developed on behalf of static synchronous compensators (STATCOMs) by cascaded multilevel inverters. In a research [5] by using space vector theory a precise model of STATCOM has been developed. In this theory voltage equations are converted into DQ-axis frames. Another approach over STATCOM is focused on modeling of a fundamental frequency switching based 24- pulse 2-level 100MVAR for high power applications was described in [6]. A new model for Distribution Static Synchronous Compensator (D-STATCOM) founded on Voltage Source Converter (VSC) was suggested in [7] to achieve desired voltage by giving/taking the necessary reactive power. A research based on adaptive PI control was presented in [8] that can automatically adjust the control gains when a disturbance is occurred. Therefore the performance is always up to the mark without considering any changes in the operation.

A feasibility study of Reactive Power Compensation was conducted in [10] where STATCOM is connected with 33kV Grid by conventional control scheme. A model of STATCOM was proposed in [11] which were designed for Voltage Regulation using Fuzzy self-Tuning PI Controller. In this paper a promising way of improving power system stability is presented. This study concentrates on designing controllers for STATCOM in MATLAB/SIMULINK to confirm the steady operation of a designed network. In addition after implementing fault in the power system network the operation of STATCOM has been observed.

Section II of this summary focuses on the methodology of total work. Section III presents the implementation of STATCOM with power system network and Section IV describes the design of Adaptive voltage control and D–Q axis current based STATCOM controller. Once the paper work is implemented, the simulation results and discussions are presented in section V. The last section of this paper contains the conclusion indicating main points.

II. METHODOLOGY

Fig. 1 shows the flowchart of the entire work. At first power system network is designed in MATLAB/SIMULINK. After that voltage, current and power of the total system are measured. Then two control strategies of STATCOM are designed individually. To check whether the system is stable or not, V-measured and Q-measured are compared with its reference values. If the system is found stable then the simulation will stop or else the gains of PI controller need to be adjusted.

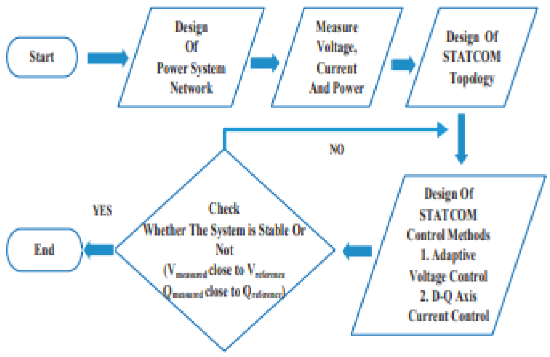

Fig. 1. Flowchart of designing STATCOM control strategies

III. IMPLEMENTATION OF STATCOM

The proposed model of STATCOM has been designed in MATLAB/SIMULINK. The block diagram is shown in Fig. 2 where a Voltage sourced inverter (VSI) is connected with a DC link capacitor. These two are connected to transmission line through LC filter and a transformer.

VSI is consisted of six (g1-g6) Insulated gate bipolar transistors (IGBTs) switches where anti-parallel diode is also connected [11]. Low pass AC filters are used in every phase to preclude the flow of harmonic currents due to IGBT switching.

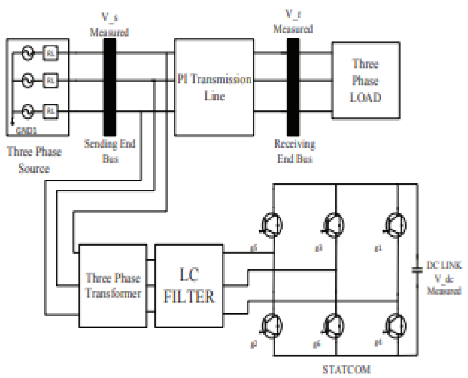

Fig. 2. Schematic diagram of STATCOM connected to power system

IV. STATCOM CONTROL STRATEGY

1. Adaptive PI Voltage Control-

Adaptive PI voltage control based STATCOM has been modeled to regulate the bus voltage. STATCOM controller is developed on MATLAB simulation software as a self governing module. This controller is called PI controller [14]. Figure 3 shows the block diagram of Adaptive PI voltage controller of STATCOM. In this control method in order to control bus voltage, Vdc_error is found by subtracting DC link voltage (Vdc_measured) from its reference value (Vdc_reference).

This error is the input of a PI controller. Again Vs_error is calculated by measuring sending-end voltage (Vs_measured) and by subtracting it from its reference value (Vs_reference). These calculations are made in per unit (PU). This error signals have been given as input to another PI controller. Orthogonal components (Vq and Vd) are found from the outputs of two PI controllers. From two outputs of PI controllers, magnitude and angle is obtained which is the input of Sinusoidal pulse width modulation (SPWM) technique. Fig. 4 shows the generation of gate pulses for IGBTs by using SPWM technique.

The modulating signals are compared with the carrier wave which is a triangular wave having unit amplitude and certain frequency. The magnitude (Vmag) and phase angle of the sine wave of SPWM technique is determined according to the following equations [12, 13].

$$Vmag = \sqrt{(V_d^2 + V_q^2)} \quad (1)$$

$$angle = \tan^{-1}(V_d/V_q) \quad (2)$$

The reference signals are calculated from the Vmag and angle. This reference signal is compared with triangle signal. The carried signal has a frequency of 5 KHz. The IGBTs of the Inverter receive their firing signals from comparators output.

2. D-Q Axis Current control-

The purpose of modeling this current control technique (DQ axis control) of STATCOM is to regulate the reactive power of the power system network as shown in Fig. 3. This controller is also designed and implemented in MATLAB/SIMULINK. There are two components of STATCOM voltages. One is in-phase with the bus voltage and another is in quadrature. The reference values of the shunt currents (D and Q) are found from the two PI controllers and they are subtracted from their measured values. The D and Q component of the shunt voltages are obtained from the PI controllers which have been used to determine the magnitude (Vm_sh) and phase angle (Į_sh) of the injected voltage by following equations [12, 13]:

$$Vm\_sh = \sqrt{(V^2_{shd} + V^2_{shq})} \quad (3)$$

$$\alpha\_sh = \tan^{-1} (V_{shd} / V_{shq}) \quad (4)$$

Here, Vshd is the shunt voltage of the d orthogonal component and Vshq is the shunt voltage of the q orthogonal component.

V. SIMULATION

In MATLAB/SIMULINK a power system network is designed by using power system blocks and simulation results are obtained. The results are specified in the following simulation studies for before connecting STATCOM, using STATCOM by adaptive PI voltage controlled method and after using d-q axis control method. Simulation model of STATCOM connected power system network is shown in Fig. 4. Table I provides all the parameter which are used in model.

TABLE I. SIMULATION PARAMETERS

Parameters	Values
Source Voltage	25 KV (r.m.s), 50 Hz
Load Voltage	25 KV (r.m.s), 50 Hz
Transmission Line	50 Hz, R= 0.01273 ohms/km , L = 0.9337 x 10^{-3} H/km, C= 12.74 x 10^{-9} F/km, Length 100 km.
DC link capacitor	4700 uF
Transformer	Primary Winding (600V), Secondary Winding (25KV)
LC and RL Filter	R= 5 ohm, L=10 mH, C= 2500 uF

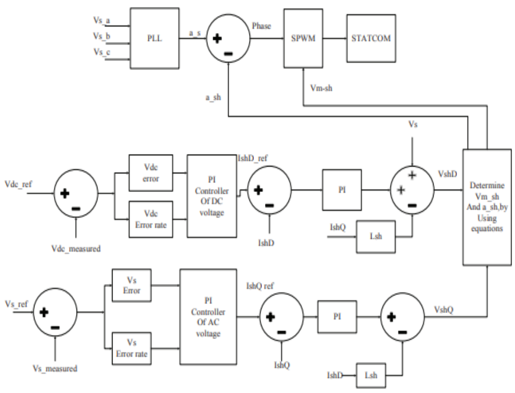

Fig.3 D-Q axis based STATCOM controller.

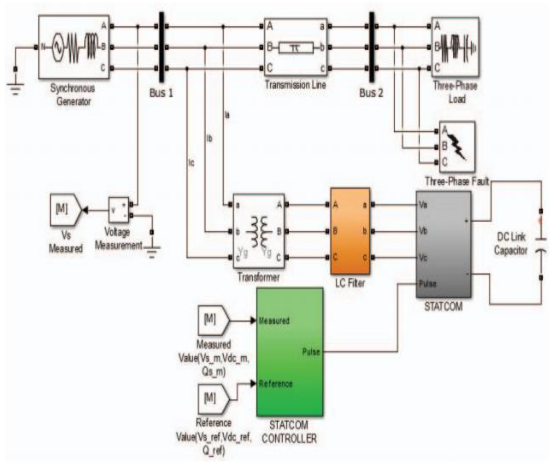

Fig.4 Simu link Model of STATCOM connected Power System.

VI. RESULTS AND DISCUSSIONS

In this section, by connecting STATCOM in power system network the performances have been evaluated for the proposed controllers. A. Simulation Results by using Adaptive PI Voltage Control method By Adaptive PI Voltage Control method, the voltage has been controlled. Before connecting the STATCOM, magnitude of the voltage was 1 p.u and after connecting STATCOM voltage has been improved to 1.05 p.u which is shown in Fig. 5 The simulation result of real and reactive powers without and with STATCOM is shown in Fig. 8 and Fig. 6 respectively. It is found that without and with STATCOM the flow of real power is the same which is 9.2 MW because the voltage has been controlled in this particular controller and real power has not influence by it. In case of reactive power it is different. It has been observed that without STATCOM reactive power was -2.2 MVAR. As soon as STATCOM has been connected to the system reactive power flow have become -1.9 MW.

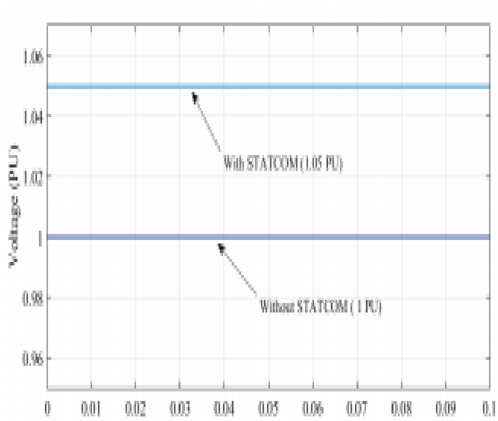

Fig.5 Voltage with and without STATCOM Network.

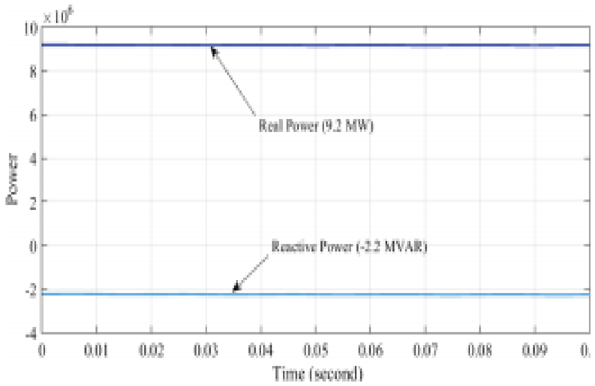

Fig.6 Real and Reactive Power (Without STATCOM)

VII. CONCLUSION

In this study, by implementing adaptive PI voltage control and D-Q axis based STATCOM, transfer capability has been improved in power system network. From the simulation it has been observed that these two control schemes for STATCOM showed a very satisfactory performance. Adaptive voltage control technique has proved its effectiveness by improving bus voltages of the networks. Before connecting STATCOM the bus voltage was 1.0 p.u and after connecting it the bus voltage improved to its reference value 1.05 p.u. The D-Q axis PI based STATCOM has improved the real power by encountering a significant decrement in reactive power flow. Before connecting STATCOM the reactive power was 1.0p.u and when the STATCOM is connected, the reactive power decreased to 0.48p.u. Moreover, these two control methods have been evaluated with simulations under faulty condition. It has been observed in the simulation part that the symmetrical and unsymmetrical faults have been cleared by integrating STATCOM to the system.

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Author's Profile


S.Reddeiah Raju pursuing M.Tech. in MJR College of Engineering & Technology, Piler, Chittoor Dist.


P.Chinnaiah, received master's degree in energy systems from JNTU ANANATAPUR. He is currently working as an Asst. Professor in the Dept of EEE at MJR College of Engineering & Technology, Piler, Chittoor Dist.


V. Sunil Kumar Reddy received master's degree in Electrical Power systems from JNTUA. He is currently working as Head of the Department in the Dept of EEE at MJR College of Engineering & Technology, Piler, Chittoor Dist.