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A STATCOM Control Scheme for Power Quality and THD Improvement

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ABSTRACT

A growth of energy is utilizing by the renewable energy resources like wind, biomass, hydro, co-generation etc. In sustainable energy system, energy conservation and the use of renewable source are the main paradigm. The need to integrate the renewable energy like wind energy into power system is to make it possible to minimize the environmental impact on conventional plant. The integration of wind energy into existing power system presents a technical challenges and that requires consideration of voltage regulation, stability, power quality problems. The power quality is an essential customer- focused measure and is greatly affected by the operation of a distribution and transmission network. The issue of power quality is of great importance to the wind turbine.

KEYWORDS: *STATCOM (static compensator), FACTS (Flexible AC transmission system)*

I. Introduction

There has been an extensive growth and quick development in the exploitation of wind energy in recent years. The individual units can be of large capacity up to 2MW, feeding into distribution network, particularly with customers connected in close proximity. Today, more than 28000 wind generating turbines are successfully operating all over the world. In the fixed-speed wind turbine operation, all the fluctuation in the wind speed are transmitted as fluctuations in the mechanical torque, electrical power on the grid and leads to large voltage fluctuations. During the normal operation, wind turbine produces a continuous variable output power. These power variations are mainly caused by the effect of turbulence, wind shear, and tower-shadow and of control system in the power system. Thus, the network needs to manage for such fluctuations. The power quality issues can be viewed with respect to the wind generation, transmission and distribution network, such as voltage sag, swells, flickers, harmonics etc. However the wind generator introduces disturbances into the distribution network. One of the simple methods of running a wind generating system is to use the induction generator connected directly to the grid system.

II. Modeling of STATCOM

A STATCOM based control technology has been modular for improving the power quality which can technically manages the power level associates with the commercial wind turbines. The modular STATCOM control scheme for grid connected wind energy generation for power quality improvement has following objectives.

- Unity power factor at the source side.
- Reactive power support only from STATCOM to wind Generator and Load.

Simple bang-bang controller for STATCOM to achieve fast dynamic response

FACTS (Flexible AC transmission system) devices, widely used in today's power system, are critical for reactive power compensation and voltage support control in a renewable energy conversion system. Traditionally, reactive power compensation within the FACTS devices has been handled with the thyristor-based static VAR compensator (SVC).

III. Fundamentals of STATCOM Operation

A STATCOM primarily consists of a three-phase step-down transformer and a three-phase PWM rectifier/inverter (i.e., a three-phase bridge, a three-phase filter, line inductors, and a controller). A large capacitor (C_{BUS}) is used as a dc power source for the three-phase PWM rectifier/inverter.

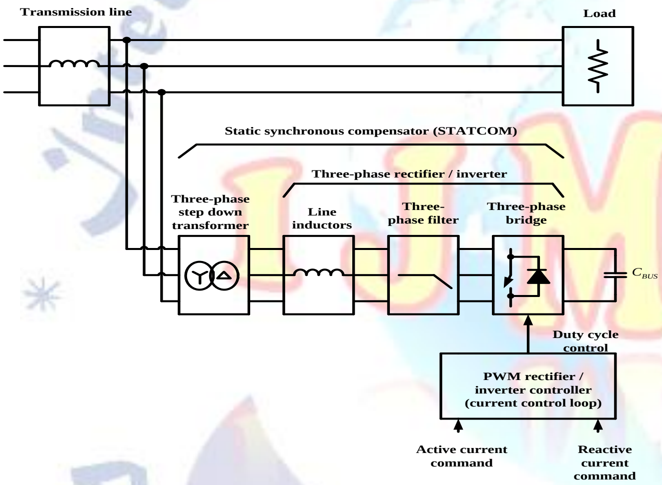


Fig. 2.1 Block diagram of a typical STATCOM

A. Basic Principle Mathematical Model of STATCOM

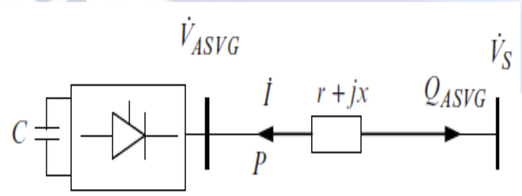


Fig 3.1 basic model of STATCOM

Reference vector, the fundamental frequency component of the inverter output voltage is V_{ASVG} and lagged phase angle is δ. With $y = 1/\sqrt{r^2+x^2}$, α=arctg$\frac{r}{x}$, we have the real power consumed by the inverter as

$$P = V_s V_{ASVG}\, y \sin(\delta+\alpha) - V_{ASVG}^2\, y \sin\alpha \qquad (3.1)$$

The reactive power injection from STATCOM is

$$Q_{ASVG} = \mathrm{Im}\left[-\dot{V}_s \dot{I}^*\right] = \mathrm{Im}\left[V_s \frac{V_{ASVG}\angle\delta - V_s}{r - jx}\right]$$

$$= V_s V_{ASVG}\, y\cos(\delta-\alpha) - V_s^2\, y\cos\alpha \qquad (3.2)$$

In steady state, the inverter neither consumes nor generates real power. Based on (3.2), making P zero yields

$$V_{ASVG} = V_s \frac{\sin(\delta+\alpha)}{\sin\alpha} \qquad (3.3)$$

Taking (3.5) into (3.4) and (3.2) yields

$$Q_{ASVG} = \frac{V_s^2}{2r}\sin 2\delta \qquad (3.4)$$

$$V_C = \frac{V_s \sin(\delta+\alpha)}{K \sin\alpha \sin(\theta/2)} \qquad (3.5)$$

From the above two equations, we know that the adjustment of phase angle δ while maintaining constant pulse width θ can change the output reactive power as well as the capacitor voltage. The simultaneous adjustment of θ and δ can maintain capacitor voltage and change the reactive power output. The vector diagram of STATCOM steady-state operation is shown in Fig. 3.5. We use the equivalent resistance r to represent the inverter real power loss so that the inverter model neither consumes nor generates real power. In the diagram, compensation current $\dot{I}$ is perpendicular to inverter output voltage $\dot{V}_{ASVG}$. The inverter injects reactive power into the system when $\dot{I}$ leads $\dot{V}_{ASVG}$. Otherwise it consumes reactive power. While an SVC changes its equivalent inductance through adjusting the timing of its connection to the system, the STATCOM controls the magnitude and phase-angle of its output voltage.

As shown in the vector diagram, the reactive power provided by STATCOM is

$$Q_{ASVG} = \pm I V_S \cos\delta$$

IV. Experimental Work

The control scheme approach is based on injecting the currents into the grid using "bang-bang controller." The controller uses a hysteresis current controlled technique. Using such technique, the controller keeps the control system variable between boundaries of hysteresis area and gives correct switching signals for STATCOM operation.

The control system scheme for generating the switching signals to the STATCOM is shown

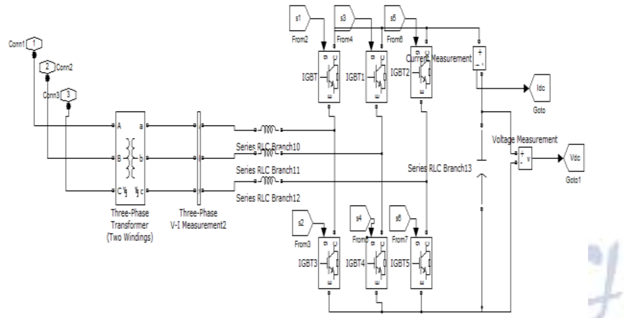


Fig 4.1 Control scheme of STATCOM

The control algorithm needs the measurements of several variables such as three-phase source current $i_{S_{abc}}$, DC voltage V_{dc}, inverter current i_{iabc} with the help of sensor. The current control block, receives an input of reference current $i^*_{S_{abc}}$ and actual current $i_{S_{abc}}$ are subtracted so as to activate the operation of STATCOM in current control mode.

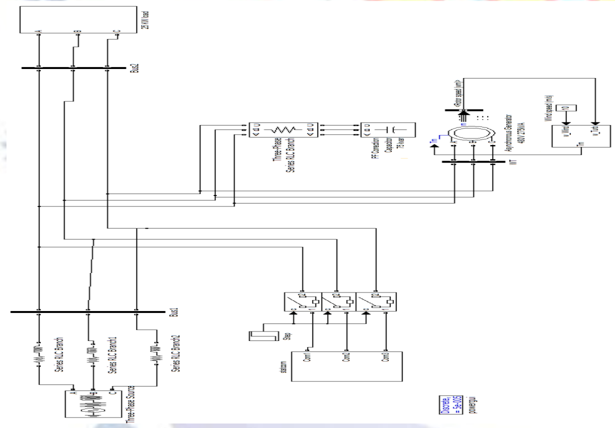
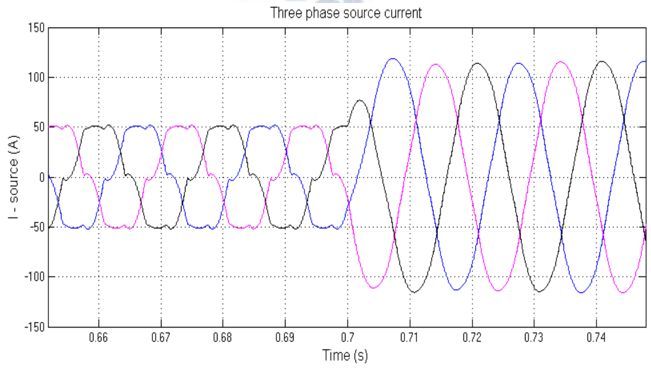


Fig 4.2

V. Results

The simulation is performed using MATLAB/ current, load current, Source Voltage waveforms are shown in the Fig. 5.1



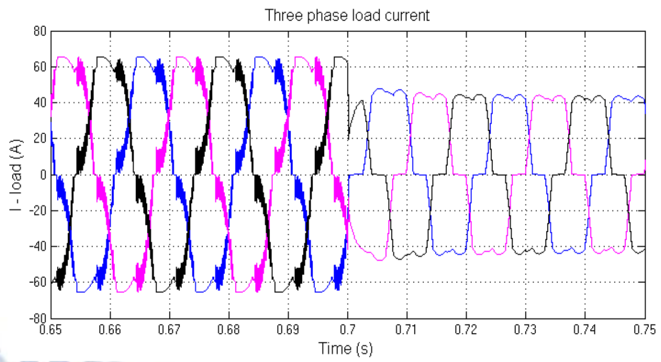


Fig.5.1-Phase Source current, load current, Source Voltage waveform

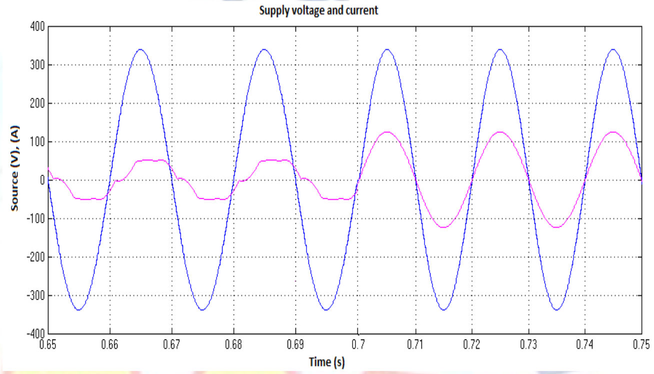


Fig.5.2 Supply voltage and current

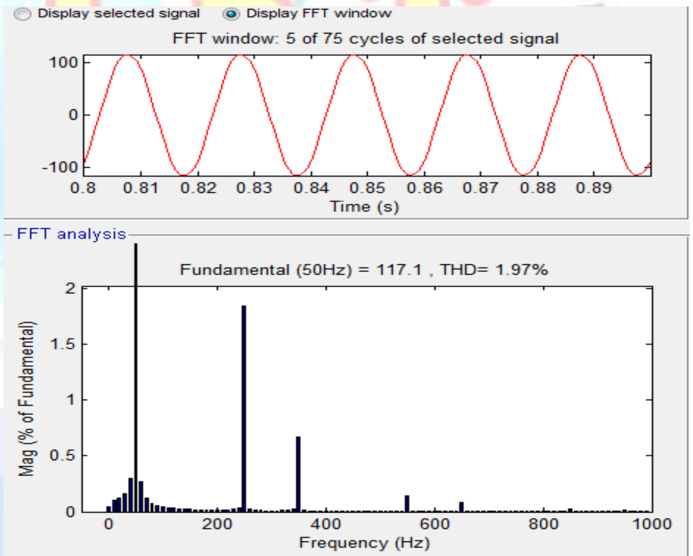


Fig.5.3 Total Harmonics Distortion Result

VI. Conclusion

FACTS devices like DVR, D-STATCOM, UPQC and UPFC can improve the power quality of the distribution system. Now, based on the different power quality problems at the load side or at the distribution system or at the main grid, one can choose a particular custom power device with their particular compensation technique. A STATCOM is mainly a shunt connected device. This is basically a Voltage source converter which injects a compensating current of variable magnitude in the main grid to mitigate or cancel the harmonics part of the source current.

In this project a control scheme has been used to operate the STATCOM. It is connected at PCC. It works according to the signal obtained from the controller. "The control scheme for power quality improvement in grid connected wind energy system using STATCOM" is simulated in the MATLAB/SIMULINK using power system toolbox. It has the potential to remove the harmonic parts produced in the load current. It basically maintains the source current in-phase with source voltage and in this way it provide support to the reactive power demand for the WPGS and the load connected at PCC in the main grid, thus it basically improve the power quality and thus the utilization factor of the transmission line.

The integration of the WPGS along with the nonlinear load and STATCOM has given the exceptional outcome. Hence the anticipated control strategy in the grid connected wind energy system has fulfilled the power quality rules as per the International electro technical commission standard.

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