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Reactive Power Control Using STATCOM to Support AC Voltage under Unbalanced Sag

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Abstract: ***This work deals with reactive power control using STATCOM to support AC voltage using Equal PWM and sine PWM. Voltage drop occurs in the system due to addition of load into the system which causes real and reactive power change in the system. To overcome these effects, PWM based STATCOM is used in the system, to provide AC voltage support as well as real and reactive power control. The simulation of two bus system will be done with and without PWM based STATCOM.***

Keywords: STATCOM, PWM and Modified PWM Inverter, FFT analysis

1.Introduction

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 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. 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)

A Static Variable 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.

2.Reactive Power Control

The control of voltage and reactive power is a major issue in power system operation. This is because of the topological differences between distribution and transmission systems, different strategies have evolved. This paper contains contributions of novel reactive power control and voltage stability schemes for distribution and transmission systems. A particular interest is taken to the development of control schemes to avoid so-called voltage collapse, which can result in widespread outages. In order to achieve efficient and reliable operation of power system, the control of voltage and reactive power should satisfy the following objectives

- Voltages at all terminals of all equipment in the system are within acceptable limits
- System stability is enhanced to maximize utilization of the transmission system
- The reactive power flow is minimized so as to reduce R I and X I losses.

This ensures that the transmission system operates mainly for active power. Thus the power system supplies power to a vast number of loads and is feeding from many generating units, there is a problem of maintaining voltages within required limits. As load varies, the reactive power requirements of the transmission system vary. Since the reactive power cannot be transferred or transported over long distances, voltage control has to be effected by using special devices located through the system which possess difficulties in keeping sufficient levels of voltage in the power system network. This has been occurring practically since the first power systems started. Increasing requirements regarding both the supply reliability and quality of supplied power force using more modern (faster, more reliable, with a broader range of applications) devices. The proper selection and coordination of equipment for controlling reactive power and voltage stability are among the major challenges of power system engineering [1]. These challenges gave birth to some selected devices to control or compensate reactive power. In order to cover the additional demand for reactive power and maintain the ability to control voltage stability within the target range, various sources of reactive power, such as SVC (Static Var Compensator)-static compensators of reactive power, STATCOM-type systems (Static Compensator) static reactive power generators and systems that combine both these solutions, which are referred to as SVC based on STATCOM. In recent decades there has been significant progress in terms of equipment designed to improve the stability of voltage in power systems. This is mainly due to the development of power supply systems in the world, which requires seeking better ways of adjusting and controlling power flows and voltage levels. Almost all power transported or consumed in alternating current (AC) networks, supply or consume two of powers: real power and reactive power. Real power accomplishes useful work while reactive power supports the voltage that must be controlled for system reliability. Reactive power is essential to move active power through the transmission and distribution system to the customer. For AC systems voltage and current pulsate at the system frequency. Although AC voltage and current pulsate at same frequency, they peak at different time power is the algebraic product of voltage and current. Real power is the average of power over cycle and measured by volt-amperes or watt. The portion of power with zero average value called reactive power measured in Volt-amperes reactive or vars.

3. Statcom Using Single and Modified PWM Inverter

3.1. Single PWM inverter using STATCOM

Pulse-width modulation (PWM), or pulse-duration modulation (PDM), is a modulation technique that controls the width (in time) of an electrical pulse, formally the pulse's duration, based on modulator signal information. Although this modulation technique can be used to encode information for transmission, its main use is to allow the control of the power supplied to electrical devices, especially to inertial loads such as motors. In addition, PWM is one of the two principal algorithms used in photo voltaic solar battery chargers, the other being MPPT.

The average value of voltage (and current) fed to the load is controlled by turning the switch between supply and load on and off at a fast rate. The longer the switch is on compared to the off periods, the higher the total power supplied to the load. The PWM switching frequency has to be much higher than what would affect the load (the device that uses the power), which is to say that the resultant waveform perceived by the load must be as smooth as possible. Typically switching has to be done several times a minute in an electric stove, 120 Hz per minute in a lamp dimmer, from few kilohertz (kHz) to tens of kHz for a motor drive and well into the tens or hundreds of kHz in audio amplifiers and computer power supplies.

The term duty cycle describes the proportion of 'on' time to the regular interval or 'period' of time; a low duty cycle corresponds to low power, because the power is off for most of the time. Duty cycle is expressed in percent, 100% being fully on.

The main advantage of PWM is that power loss in the switching devices is very low. When a switch is off there is practically no current, and when it is on and power is being transferred to the load, there is almost no voltage drop across the switch. Power loss, being the product of voltage and current, is thus in both cases close to zero. PWM also works well with digital controls, which, because of their on/off nature, can easily set the needed duty cycle. PWM has also been used in certain communication system where its duty cycle has been used to convey information over a communications channel.

3.2. Modified PWM Inverter using STATCOM:

In Multiple Pulse width technology, waveforms that contain a number of narrow pulses are used. The frequency of these narrow pulses is called Switching or Carrier frequency. The MPWM technology is used in Inverters driving variable frequency motor control systems. This allows wide range of output voltages and frequency adjustments. More over the MPWM technology overall improves the quality of the waveform. The harmonic content can be reduced by using several pulses in each half-cycle of output voltage. The generation of gating signals for turning on and off transistors is shown in Figure (3). The gating signals are produced by comparing reference signal with triangular carrier wave. The frequency of the reference signal sets the output frequency (fo) and carrier frequency (fc) determine the number of pulses per half cycle,

$$p = \frac{fc}{2f0}$$

The variation of modulation index (M) from 0 to 1 varies the pulse from 0 to π/p and the output voltage from 0 to Vm.

4.Results and Discussion

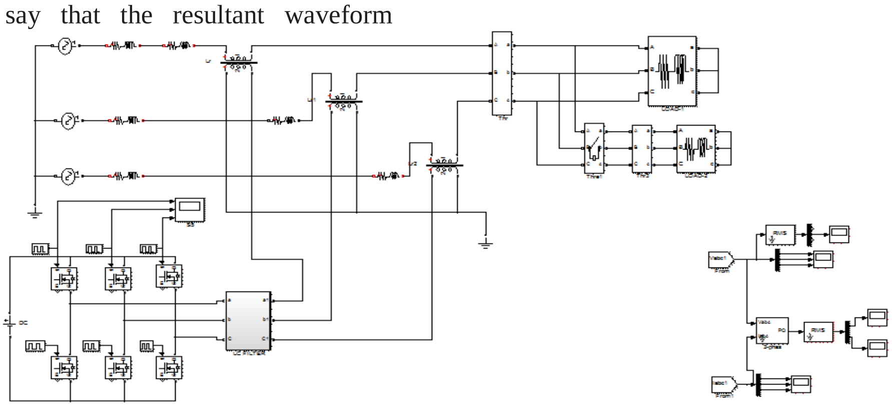

Figure 1: STATCOM with normal PWM inverter

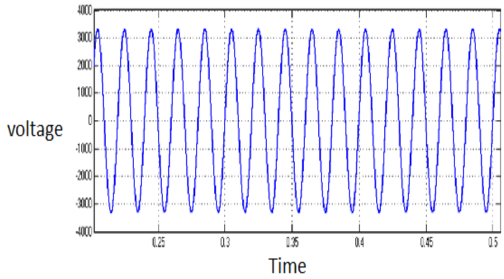

Figure 2: sending end voltage

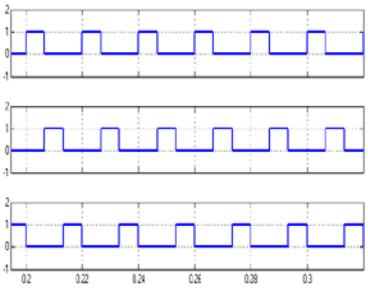

Figure 3: Switching pulse

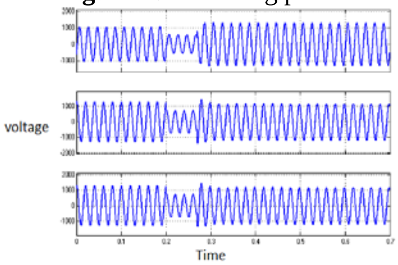

Figure 4: Receiving end voltage

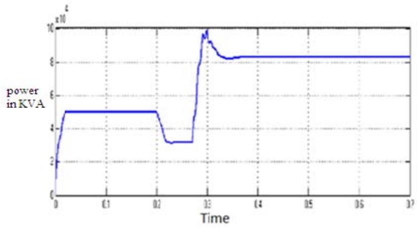

Figure 5: Real power

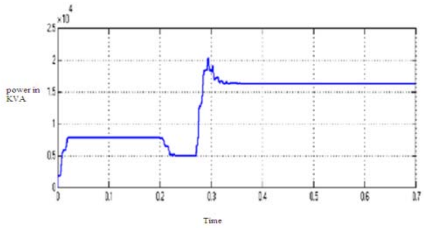

Figure 6: Reactive power

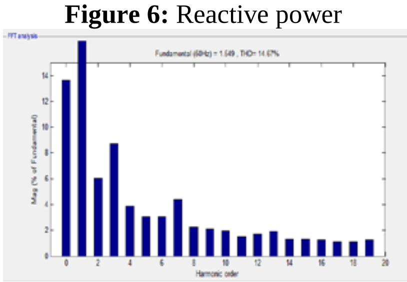

Figure 7: THD for STATCOM using normal PWM inverter

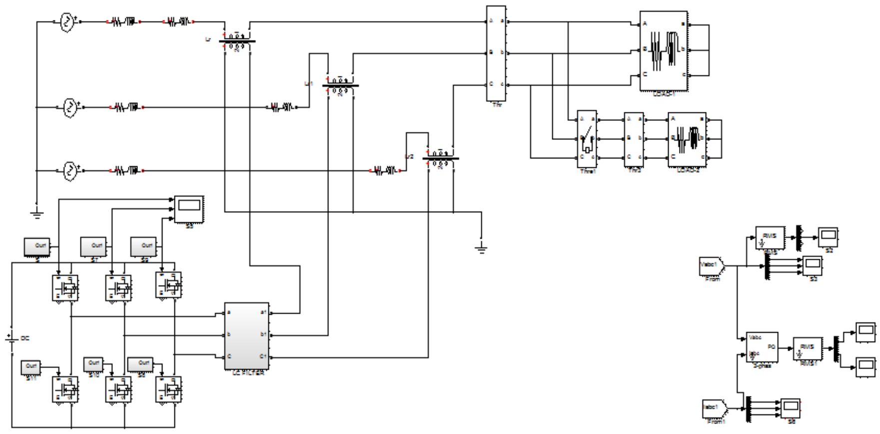

Figure 8: STATCOM WITH MODIFIED SINE PWM INVERTER

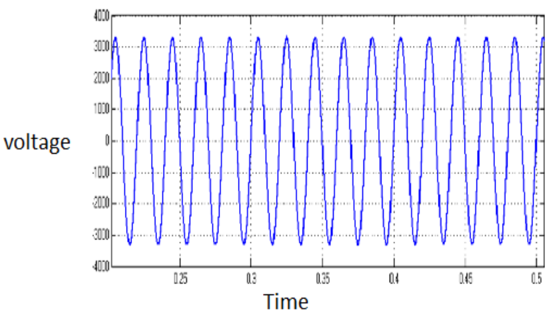

Figure 9: sending end voltage

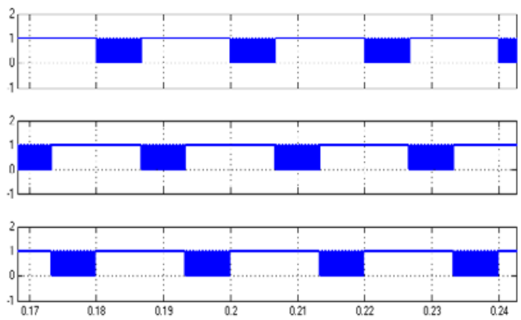

Figure 10: switching pulse

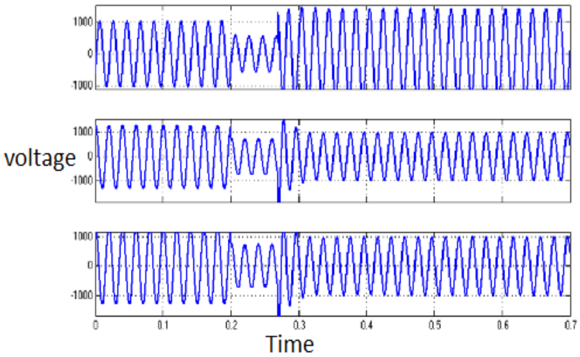

Figure 11: Receiving end voltage

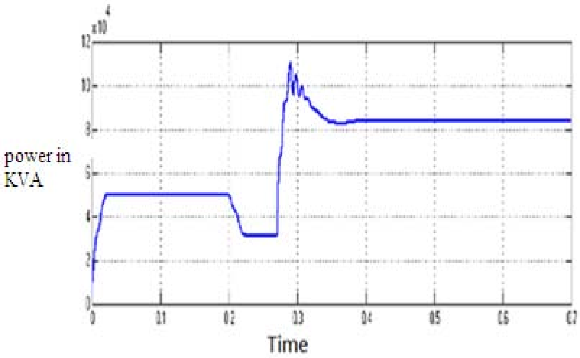

Figure 12: Real power

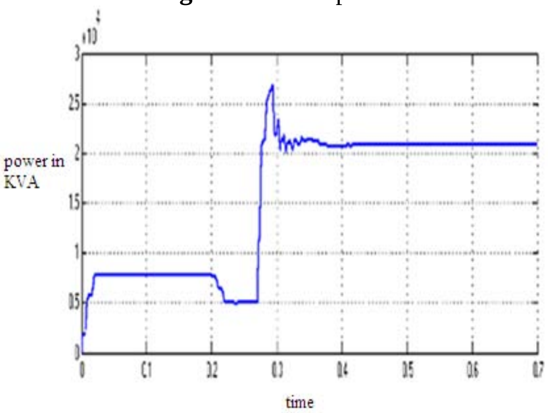

Figure 13: Reactive power

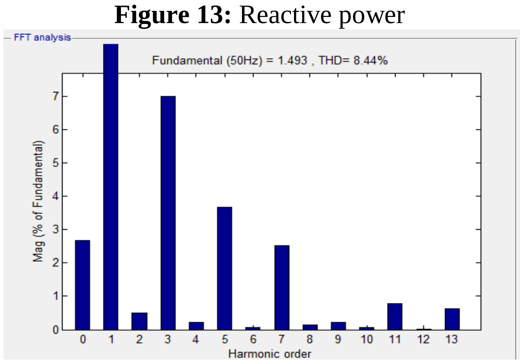

Figure 14: THD for STATCOM with modified sine PWM inverter

5.Conclusion

In this chapter the simulation results for single and multiple pulse width modulation is presented. In single pulse width modulation the harmonics is reduced but, in the multiple pulse width modulation the harmonics reduction is better when compared with single pulse width modulation.

Table 1

	Input Voltage (KVA)	*Reactive Power (MVAR)*	*THD*
Without STATCOM	3.3	0.151	Above 25-30%
STATCOM Normal Pwm	3.3	0.178	14.67%
STATCOM Modified Pwm	3.3	0.211	8.44%

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