ACTIVE FILTER AND REACTIVE COMPENSATION USING DSTATCOM

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ABSTRACT:
This paper presents to exploit demo model of DSTATCOM & the block Parameters of the controller is being tuned by using matlab Simulation. The main objective of the paper is to show that using DISTRIBUTION STATCOM (DSTATCOM), it is possible to reduce the voltage fluctuations like sag and swell conditions in distribution systems. In this paper different topologies of DSTATCOM (distribution static compensator) are discussed. The distribution static compensator (DSTATCOM) shunt connected device capable of compensating power quality problems in the load current. A shunt active filter is intended for installation on a power distribution system. The active filter has an additional capability to regulate the distribution line voltage by means of adjusting reactive power. Theoretical analysis investigates the dynamic performance of combined harmonic damping and voltage regulation. As a result, harmonic damping makes it possible to improve the stability of the control loop for voltage regulation, and the combined harmonic damping. The system with control scheme is implemented in Matlab/Simulink. The simulation results are shown in figures. The main objective of the paper is to show that using DSTATCOM it is possible to reduce the voltage fluctuations like sag and swell conditions in distribution systems.

KEYWORDS: PWM; DSTATCOM; DVR; artificial immune system; direct current control; voltage source converter; power quality

I. INTRODUCTION

Power quality is certainly a major concern in the present era; it becomes especially important with the introduction of sophisticated devices, whose performance is very sensitive to the quality of power supply. Modern industrial processes are based on a large amount of electronic devices such as programmable logic controllers and adjustable speed drives. As commercial and industrial customers become more and more reliant on high quality and high-reliability electric power, utilities have considered approaches that would provide different options or levels of premium power for those customers who require something more than what the bulk power system can provide. Insufficient power quality can be caused by firstly failures and switching operations in the network, which mainly result in voltage drops, interruptions, and transients and secondly network disturbances from loads that mainly result in flicker (fast voltage variations), harmonics, and phase imbalance. When PQ problems are arising from nonlinear customer loads, such as arc furnaces, welding operations, voltage flicker and harmonic problems can affect the entire distribution feeder. Several devices have been designed to minimize or reduce the impact of these variations. The primary concept is to provide dynamic capacitive and reactive power to stabilize the power system. This is typically accomplished by using static switching devices to control the capacitive and reactive, or by using an injection transformer to supply the reactive power to the system.

II. Techniques of tuning controller

The output from DSTATCOM can be controlled by different types of controllers using various types of control algorithm. Some of them are discussing below.

A. Genetic Algorithm (GAs)

The GAs is well-known close by survive a hundred of works employing the GAs technique to design the controller in various forms. The GAs is a stochastic search technique that leads a set of population in solution space evolved using the principles of genetic evolution and natural selection, called genetic operators e.g. crossover, mutation, etc. With successive updating new generation, a set of updated solutions gradually converges to the real solution. Because the GAs is very popular and widely used in most research areas where an intelligent search technique is applied, it can be summarized briefly as shown in the flowchart. The GAs is selected to build up an algorithm to tune kp parameters. The procedure to perform the proposed parameter tuning is described as follows. First, time-domain results of the load voltage obtained by simulating are collect then is employed to generate a set of initial random parameters. With the searching process, the parameters are adjusted to give response best fitting close to the desired response in the dq reference signals [4].

B. Particle Swarm Optimization (PSO)

The particle swarm optimization is a population based search algorithm modelled after the motion of flock of birds and school of fish. A swarm is considered to be a collection of particles, where each particle represents a potential solution to a given problem. The particle changes its position within the swarm based on the experience and knowledge of its neighbours. Basically it ‘flies’ over the search space to find out the optimal solution. Initially a population of random solutions is considered.

C. Neural Network

Electrical distribution system suffers from problems like reactive power burden, unbalance loading and voltage regulation. Reactive power burden increases line losses and unbalance loading results in excessive neutral current. The use of distribution static synchronous compensator (DSTATCOM) is well
established to cater these problems. Two core issues with the use of DSTATCOM are its control and rating. The heart of the control of DSTATCOM is the derivation of reference currents, which decide the switching of voltage source inverter (VSI) used in DSTATCOM. With neural network based system reference current extractor which operates on LMS algorithm

D. Instantaneous Reactive Power (IRP) Theory

The major power consumption has been in reactive loads, such as fans, pumps etc. These loads draw lagging power-factor currents and therefore give rise to reactive power burden in the distribution system. Moreover, situation worsens in the presence of unbalanced loads. Excessive reactive power demand increases feeder losses and reduces active power flow capability of the distribution system, whereas unbalancing affects the operation of transformers and generators. A Distribution static compensator (DSTATCOM) can be used for compensation of reactive power and unbalance loading in the distribution system. The performance of DSTATCOM depends on the control algorithm used for extraction of reference current components. For this purpose, many control schemes are reported in literature, and some of these are instantaneous reactive power (IRP) theory, instantaneous symmetrical components, synchronous reference frame (SRF) theory and current compensation using dc bus regulation, computation based on per phase basis, and scheme based on neural network technique. Among these control schemes, SRF theories are most widely used [13].

III. Triggering techniques used for DSTATCOM

There are many techniques to trigger the IGBT’s of DSTATCOM for desire value of sine wave output.

A. Pulse Width Modulation

Pulse width modulation technique is uses by many of DSTATCOM’s voltage source inverters and current source inverters for triggering. Pulse width modulation is basically the switch on and off of different interval of time to make output nearly sine wave [13].

B. Sine PWM

Many nonlinear electrical loads will cause various power quality problems, such as violent voltage fluctuation, power loss and harmonic current, abnormal operation of electric equipments and so on. A distribution static synchronous compensator (DSTATCOM) is one of the equipments to compensate the reactive power dynamically, and can be used to improve power quality. Compared with the saturated reactor and static VAR compensator based on thyristor phase control, DSTATCOM has an advanced performance in distribution system. DSTATCOM of often developed to compensate reactive power of three-phase symmetry loads. But the three-phase loads in the low-voltage system are usually unbalanced; therefore we expected that the compensator could provide different reactive power for different phase

C. Inverted Sine PWM

Inverters based on Voltage Source Converters (VSC) are widely used as a basic component in custom power devices. These devices should improve power quality problems such as voltage sag and swell, flicker and harmonics. These controllers produce voltage harmonics due to switching operation of power electronic converters. The harmonics in the output voltage of power electronic converters can be reduced using Pulse-Width Modulation (PWM) switching techniques. PWM methods reduce the harmonics by shifting frequency spectrum to the vicinity of high frequency band of carrier signal. In the case of sinusoidal PWM (SPWM) scheme, the control signal is generated by comparing a sinusoidal reference signal and a triangular carrier. The SPWM technique, however, inhibits poor performance with regard to maximum attainable voltage and power. A novel PWM technique, called Inverted-Sine PWM (ISPWM), for harmonic reduction of the output voltage of ac-dc converters is presented. In addition, the control scheme based on ISPWM can maximize the output voltage for each modulation index.

IV. Energy delivering sources

DSTATCOM converts the DC source output to sine wave. The DC energy sources are many of types but generally used for DSTATCOM are as follows:-

A. Electrolytic Capacitor Bank

The capacitor bank has a rated capacity in KVAR. It consists of one set of capacitor units, a series reactor and a vacuum switch. These components of the capacitor bank are assembled in one compact package, together with the necessary control and protection equipment. The capacitor bank is designed for outdoor use. The connection between the capacitor bank and the high-voltage switch-gear is made by cables.

B. Ultra Capacitor

Ultra capacitor has no moving parts and require neither cooling nor heating, and because they undergo no internal chemical changes as part of their function, they are very efficient and robust. Also, they require practically no maintenance and the lifetime is measured in decades, with no lifetime degradation due to frequent and deep cycling. They have no significant fringe fields and they are intrinsically modular which enhances reparable and allows capacity to be easily incremented. Ultra-capacitors store only a relatively modest quantity of energy, but they are capable of high power discharge rates and fast recharge [20].

V. Types of Controller

A. Proportional Integral (PI) controller

The voltage controller analyzed in this work is exhibited in which employs the dq0 rotating references frame because it offers higher accuracy than stationary frame-based techniques. The three-phase terminal voltages are the three-phase currents injected by the DSTATCOM into the network, \( V_{rms} \) is the root-mean-square (rms) terminal voltage, \( V_{dc} \) is the dc voltage measured in the capacitor, and the superscripts indicate reference values.

B. Proportional derivative (PD) Controller

D mode is used when prediction of the error can improve control or when it necessary to stabilize the system. From the frequency characteristic of D element it can be seen that it has phase lead of 90°. Often derivative is not taken from the error signal but from the system output variable.PD controller is often used in control of moving objects such as flying and underwater vehicles, ships, rockets etc. One of the reason is in stabilizing effect of PD controller on sudden changes in heading variable \( y(t) \).
Often a "rate gyro" for velocity measurement is used as sensor of heading change of moving object.

C. Proportional Integral derivative (PID) Controller

PID controller has all the necessary dynamics: fast reaction on change of the controller input (D mode), increase in control signal to lead error towards zero (I mode) and suitable action inside control error area to eliminate oscillations (P mode). Derivative mode improves stability of the system and enables increase in gain K and decrease in integral time constant Ti, which increases speed of the controller response. PID controller is used when dealing with higher order capacitive processes (processes with more than one energy storage) when their dynamic is not similar to the dynamics of an integrator (like in many thermal processes). PID controller is often used in industry, but also in the control of mobile objects (course and trajectory following included) when stability and precise reference following are required. Conventional autopilot is for the most part PID type controllers.

VI. Scope of the problem

The next 20 years will present both technical and business opportunity challenges to utilities in their distribution of electrical energy. The evolving nature of distribution system operations and end-use equipment performance presents a mixed bag of tasks that will need to be well executed for utilities to succeed in the new highly competitive marketplace. A growing number of loads are sensitive to customer’s critical processes, which have costly consequences if disturbed by poor power quality. At the moment most projects in active power filtering are concentrated in the field of harmonic current compensation. The demand on harmonic and reactive power compensation devices is increasing day by day in the world. DSTATCOM is a device gaining popularity due to increasing sensitivity of industry to voltage sags/swells.

The literature survey carried on the alone sited DSTATCOM motivated to get comparative study of ultra capacitor and electrolytic capacitor with DSTATCOM to help for go through the problems. The DSTATCOM with electrolytic capacitor bank and ultra capacitor energy source is used in simulation. It is because the electrolytic capacitor bank is cheaper than battery bank and ultra capacitor. Ultra capacitor is costlier than electrolytic capacitor but charging and discharging time is less and life is more than battery bank and electrolytic capacitor bank.

VII. Available Custom Power Devices

This section presents an overview of the VSC-based custom power controllers mentioned above:-

a) Dynamic Voltage Restorer (DVR)

The DVR is a powerful controller that is commonly used for voltage sags mitigation at the point of connection. The DVR employs the same blocks as the D-STATCOM, but in this application the coupling transformer is connected in series with the ac system as illustrated in Figure 1. The VSC generates a three-phase ac output voltage, which is controllable in phase and magnitude. These voltages are injected into the ac distribution system in order to maintain the load voltage at the desired voltage reference.

b) Unified Power Quality Conditioner (UPQC)

The Universal Power Quality Conditioner (UPQC) is a more complete solution for the power quality problem. The basic structure of this equipment is shown in Figure 2. In this figure 2, the UPQC is an association of a series and shunt active filter based on two converters with common dc link [5],[6]. The series converter has the function to compensate for the harmonic components (Including unbalances) present in the source voltages in such a way that the voltage on the load is sinusoidal and balanced. Custom Power Devices is classified in to three categories by their structure such as Dynamic Voltage Restorer (DVR), Distribution STATCOM (DSTATCOM) and Unified Power Quality Compensator (UPQC The shunt active filter has the function of eliminating the harmonic components of nonlinear loads in such a way that the source current is sinusoidal and balanced. This equipment is a good solution for the case when the voltage source presents distortion and a harmonic sensitive load is close to a nonlinear load as shown in Figure 2.
The ac voltage control is achieved by firing angle control. Ideally, the output voltage of the VSI is in phase with the bus (where the DSTATCOM is connected) voltage. In steady state, the dc side capacitance is maintained at a fixed voltage and there is no real power exchange, except for losses. The DSTATCOM differs from other reactive power generating devices (such as shunt Capacitors, Static VAR Compensators etc.) in the sense that the ability for energy storage is not a rigid necessity but is only required for system unbalance or harmonic absorption.

There are two control objectives implemented in the DSTATCOM. One is the ac voltage regulation of the power system at the bus where the DSTATCOM is connected and the other is dc voltage control across the capacitor inside the DSTATCOM. It is widely known that shunt reactive power injection can be used to control the bus voltage. In conventional control scheme, there are two voltage regulators designed for these purposes: ac voltage regulator for bus voltage control and dc voltage regulator for capacitor voltage control. In the simplest strategy, both the regulators are proportional integral (PI) type controllers. Thus, the shunt current is split into d-axis and q-axis components. The reference values for these currents are obtained by separate PI regulators from dc voltage and ac-bus voltage errors, respectively. Then, subsequently, these reference currents are regulated by another set of PI regulators whose outputs are the d-axis and q-axis control voltages for the DSTATCOM.

XI. Simulation Results and Discussion

Basically, DSTATCOM is consists the PWM voltage source inverter circuit and a DC capacitor connected at one end. At the distribution voltage level (11kv), the integrated gate bipolar transistors (IGBT) are uses for inverter circuit due to its lower switching losses and compact size. Moreover, the power rating of custom power devices is relatively low. Consequently, the output voltage control may be executed through the pulse width modulation (PWM) switching method. IGBT based PWM inverter is implemented using Universal bridge block from Power Electronics subset of Sims Power Systems. A 25kV/1.25kV coupling transformer which ensures coupling between the PWM inverter and the network. A voltage-sourced PWM inverter consisting of two IGBT bridges. This twin inverter configuration produces less harmonics than a single bridge, resulting in smaller filters and improved dynamic response. In this case, the inverter modulation frequency is 28*60=1.68 kHz so that the first harmonics will be around 3.36 kHz. LC damped filters connected at the inverter output. Resistances connected in series with capacitors provide a quality factor of 40 at 60 Hz. A 10000-microfarad capacitor acting as a DC voltage source for the inverter voltage regulator that controls voltage at bus B3 A PWM pulse generator using a modulation frequency of 1.68 kHz. A 25KV Power Dstatcom pwm demo model used in this Paper shown in figure 4.

Figure 4: 25kv Simulink model diagram of DSTATCOM

SIMULATION RESULT OF DSTATCOM USING MATLAB/SIMULINK.

Voltage and current in per unit with electrolytic and ultra capacitor.

Fig. 4.1 The current and voltage in per unit with electrolytic capacitor

Fig. 4.2 The current and voltage in per unit with ultra capacitor

Fig. 4.3 The voltage across the converters with electrolytic capacitor

Fig. 4.4 The voltage across the converters with ultra capacitor
Ultra capacitor. Ultra capacitor produces good voltage stability in a distribution system when we observe voltage of DSTATCOM. However, when we compare the harmonics stability in DSTATCOM when we observe voltage of capacitor, the result are much better with ultra capacitor.

CONCLUSIONS
The voltage sag and swell problems in a distribution system can be investigated. The consumption of active or reactive power by the DSTATCOM is represented by positive values and the generation by negative values. Hence, by the application of DSTATCOM in to the network the voltage sag and swell conditions are improved and the voltage is recovered to approximately to 1 pu of voltage. Power quality is an issue that is becoming increasingly important to electricity consumers at all levels of usage. Sensitive equipment and non-linear loads are commonplace in both the industrial and the domestic environment; because of this a heightened awareness of power quality is developing. The type of controller used in DSTATCOM is PID controller. The modulation technique which is used to trigger IGBT’s is PWM. The DSTATCOM with capacitor bank energy source is used in simulation. It is because the capacitor bank is cheaper, requires less maintenance and less time of charging and discharging. The loads which are connecting to the DSTATCOM is distribution network load. For simulations and results of DSTATCOM using ultra capacitor and electrolytic capacitor, the matlab/simulink software is used. Ultra capacitor produces less distortion than the electrolytic capacitor. Modulation index is improves in case of ultra capacitor. Ultra capacitor produces good voltage stability in DSTATCOM when we observe voltage of converter. But when we compare the harmonics produces by DSTATCOM with electrolytic and ultra capacitor bank, the result are much better with ultra capacitor.

DSTATCOM provide in many cases higher performance compared with traditional mitigation methods. However, the choice of the most suitable solution depends ultimately on the characteristic of the supply at the point of connection, the requirements of the load and economics, i.e. the customer value added by the installation of power electronics based device. Ongoing development and commercial availability of high power semiconductors will further increase opportunity and cost effectiveness of advanced technologies like DSTATCOM.

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