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MATLAB SIMULATION OF D-STATCOM USING SVPWM

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Abstract:

In this paper, A Distribution Static Synchronous Compensator (D-STATCOM) is used for improving the power factor, power quality and to control power flow control in the distribution line. It used to give reactive and active power compensation in the distribution line. The power depends on the power factor of the loads connected to the transmission line. In this paper we have used a new DSTATCOM using modified SVPWM technique. The previous DSTATCOM are basically controlled by PWM, or SPWM technique which produce high harmonics distortion but using SVPWM technique distortion reduces to maximum possible level. In our system we also have examined the losses due to DSTATCOM when connected in the distribution system. To decrease the reactive power and to minimize the undesirable load to require maintains the flow of reactive power. As a result, the power a factor of the load descant, leading to the limitation of the active power flow in the line. The D-STATCOM is a power electronics based on advanced device can be used to control power flow in the distribution line. The construction of system is able to recover the drop-in bus voltage when any loading effect arises, but due to 5th harmonic performance of DSTATCOM reduces somewhere.

Keywords: FACTS; THD; SVPWM; Reactive Power; D-STATCOM.

1. Introduction

Now days, the whole world economy emphasizes on providing qualitative and uninterrupted services in every sector. As every sector depends on electric power and different electric equipment's, maintaining the quality of power is a major issue for profit of all industry.

The Electrical Power Distribution system Nonlinear equipment's like light emitting diode lamps, switching mode power supplies, equipment's which use the electronic controllers and switching devices are very sensitive to poor voltage quality. They cannot provide continuous service and also can be damaged due to the poor voltage quality is used to provide active and reactive power in the connected loads through the distribution line using the distribution transformer. The load center is located away from power generation units, so power transmission and distribution network is to meet the load demand. The distribution lines are equivalent more resistive, so in order to minimize the voltage drop being generated by the resistance of the distribution line of real power compensation. Reactive power is used in the inductive and capacitive loads.

Distribution Static Synchronous Compensator (D-STATCOM) is power electronic based static compensating device that is used in the distribution line to provide reactive and real power compensation. D-STATCOM is also used in energy storage devices for real power support in the distribution line. The main reasons to select D-STATCOM as load compensation, its ability to generate reference compensator current. D-STACOM circuit provides three-phase current in the ac system by tracking the reference current and decreased the   disturbances present at the load. In this paper D-STATCOM is used to provide direct control scheme to generate the gate pulses for switching devices of Voltage Source Converter (VSC) by active and reactive power control and removed the reference current. The D-STATCOM control strategy is providing required power flow control fluctuate load problem.
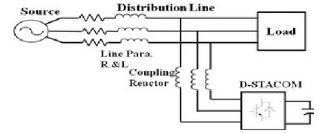
In this work, D-STATCOM has been modeled to provide current compensation with active and dynamic type nonlinear load and D-STATCOM as load compensator is used for power factor improvement. D-STATCOM can be connected at coupling point of low voltage feeders to provide voltage controllability.

2. Need for Compensation in Distribution Line

The D-STATCOM is a power electronics device connected across three phase shunt terminal. It is connected near the load at the distribution system. It is also a voltage-source converter, which converts a DC input voltage into AC output voltage in order to compensate the active and reactive power needed by the system. The D-STATCOM primarily consists of DC voltage source back of self-commutated inverters employing IGBT and coupling transformer. A three phase IGBT based current controlled voltage source inverter with a dc bus capacitor is used as a D-STATCOM. DSTATCOM improves supply power factor, provide load balancing & improve load terminal voltage.

To minimize the unsuitable effects caused by loads, the reactive power compensation is required. The distribution loads are approximately more resistive and consequently even by providing reactive power compensation the voltage drop being caused by the resistance of the distribution line can't be fully compensated. So, the compensation of this voltage drop, the real power compensation is also essential to be provide increased the reactive power compensation in the distribution line. The voltage control is used to increase the system stability, better performance of machines connected to the system and to decrease the losses associated with the system. Undesirable voltage drops lead to increased losses which need to be supplied by the source and are leading to outages in the line due to stress on the system to carry this imaginary power.

3. Basic Structure and Operation Principle of D-STATCOM

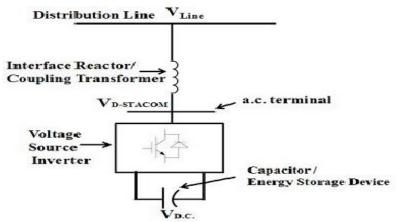Figure 1: Connection of D-STATCOM to 3-phase Distribution line

Figure 2: Basic Construction of D-STATCOM

The D-STATCOM is operated on three-phase shunt connected power electronics-based device. It is coupled across the load at the distribution systems. Fig.1 represents the connection of a D-STATCOM to the 3-phase distribution line. D-STATCOM works for transfer reactive & real power with the distribution line. The reactive power & real power is transfer between the distribution line and D-STATCOM is easily controlled by controlling the magnitude & phase angle of the voltage of D--STATCOM respectively. The three phase power supplies transferred at the load side. This load absorbs both real and reactive power, due to its inductive nature; all the loads are not purely resistive. It reduces the power quality. So the compensation of reactive power is necessary, to improve the power quality. So, D-STATCOM is used to compensate the reactive power. It is very beneficial for control the D-STATCOM to inject reactive power to the load for compensation. If the voltage becomes higher then, higher voltage side delivers reactive power to the lower voltage side. Based on this approach the controller achieves and generates pulse to the inverter. The controller depends on the basics of reference frame theory. The D-STATCOM worked as an inverter to convert the DC link voltage Vdc on the capacitor to a voltage source of adjustable magnitude and phase.

4. Operational Principal of DSTATCOM

The DSTATCOM is a shunt connected custom power device connected across the load end of a distribution network. A capacitor, three phase inverter module, AC filter, coupling transformer and a controller are the basic components of it. The voltage source converter (VSI) helps to convert the input DC voltage to an output of three phase of AC voltage with constant frequency. The phase of the thyristor based inverter voltage (Vi) is maintained at a controlling level of distribution system voltage (Vs).

The three basic modes of operation of a D-STATCOM are as follows:

i. When Vi = Vs, the reactive power become zero, it indicates that D-STATCOM neither generates nor absorbs any reactive power.
ii. When Vi > Vs, it indicates an inductive reactance connected across the terminal of D-STATCOM. It represents inductive mode of operation. The current flows from a D-STATCOM to the AC system through transformer reactance. At this stage, the DSTATCOM generates capacitive reactive power.

iii.   When Vi < Vs, it indicates a capacitive reactance connected across it terminals. It represents capacitive mode of operation. The current flows from AC system to D-STATCOM. In this case it absorbs inductive reactive power. Thus, DSTATCOM can either absorb or deliver reactive power to the system.

5. Application of Space Vector Pulse Width Modulation for Voltage management of D-STATCOM

SVPWM modulator is based on the reference voltage in the αβ-coordinate system which generates control impulses that lead to the base of transistor in Control Bridge and there by creates to symmetrical voltage system. Reference voltage may be simply is a sine wave of the desired amplitude, frequency and initial phase. Then, from such references voltage simply placing Klarkine transformation receives a reference to αβ- domain. So, all that is needed to produce the output voltage is proportionate to reference amplitude value (effective value) and the initial phase of the required system. This is substantially a rated voltage bus, that is connected DSTATCOM.

Reference phase signal can be found by using the PI controller. The PI controller introduces the different normalized rms values, reference voltage and measured voltage phase A. The output of the PI controller is the value of phase which will be used to generate the sine reference signal.

In space vector modulation approach, three phase quantities are converted to their equivalent two phase quantities, in the stationary reference frame. From these two-phase components, the magnitude of reference vector is computed, which is used for modulating the inverter output.

Length of work D-STATCOM's, in the event of a failure of improvement, It should not be more than 30 periods of 50 [Hz] signal is reflected in the definition of collapse voltage. The D-STATCOM is primarily design for the improvement of a voltage dip. Ruin voltage (Voltage sag), according to the IEEE 1159-1995 is defined as a voltage which is typically equal to the amplitude of 10% to 90% of nominal voltage, the amplitude and duration this voltage is typically from 0.5 to 30 periods of the signal frequency of 50 [Hz].
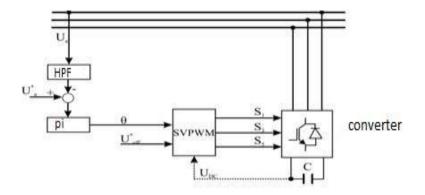

Figure 3: Block diagram of the control system with SVPWM

6. Modification of SVPWM Algorithm for use in Management of D-STATCOM

It is necessary to maintain a constant voltage on the buses for consumers. In this case, DSTATCOM become operational when the detected voltage drops bus bars. For this purpose, there are already constructed electronic circuits used and in relay protection.
Using this control approach, the values of the reference currents are calculated based on required compensation.

The previous SVPWM algorithm is complex and was designate for smooth management of asynchronous machines. It is requirement of time to simplify the algorithm as much as possible to make it possible to be performed and the simpler hardware (microcontroller). Keeping the main goal in mind, algorithm is designed so, that necessity cannot be changed. The main changes that can be made is to not let the reference poly phasor goes through all sectors because it takes a lot of processing time and slows down the performance of the algorithm. It is suitable that the current phase of the reference poly phasor decreased to the first sector, and to poly phasor still recognized only in the first sector. It then mention that simplifies the equation for calculating the time of application Reference poly phasor given as

$$T_\alpha = \frac{\sqrt{3}}{\pi} mT_s \sin\left(k\frac{\pi}{3} - \theta\right)$$
$$T_b = \frac{\sqrt{3}}{\pi} mT_s \cos\left(\theta - (k-1)\frac{\pi}{3}\right)$$

Other simplification means that the budget is done at periodic PWM and not in the half-period. In this way we can get half the equation for the budget. The reason for this simplification is that the algorithm for specific management of asynchronous machines may not accurate be applied to DSTATCOM's. It can be said that DSTATCOM does not require so much precision. When you combine these two mentioned simplification, then we get.

$$T_\alpha = \frac{\sqrt{3}}{U_D^c} U^* T_s \sin\left(\frac{\pi}{3} - \theta\right)$$
$$T_b = \frac{\sqrt{3}}{U_D^c} \cos(\theta)$$
$$T_O = T_s - T_\alpha - T_b$$

7. Practical Set up for Transmission of Electrical Power with D-STATCOM

To perform a simulation on a computer, it is necessary, among other things, to know the exact parameters that will be used in the simulation. This includes the value of voltage, current, capacitance of the capacitor battery, and the value element filter. The parameters are determined on the basis of known size, or on the basis of the size of which is obtained by calculating.

First of all, a brief description will be given part of the system on which the simulation work done DSTATCOM. Based on the known parameters of the network, it is possible to determine some of the size required for dimensioning DSTATCOM.

The required reactive power of the load is fed by DSTATCOM and controller is tuned to compensate harmonic current injected by the load. In the present work a general compensation method is used for generating reference currents for the DSTATCOM.

In order to minimize strain on the MATLAB simulation, the system performance that is seen is quite simplified. This implies that it is not used coupling transformer, and that is seen only one part of the distribution system and to a voltage of 0.4 [kV]. This method has a unique capability of compensating for load reactive power, unbalance, harmonics and load active power. The results from the system simulation validates the efficiency of the SVPWM based DSTATCOM in providing balanced sinusoidal source currents, although the load currents are unbalanced and distorted.

It is assumed that this part of the network is powered by the secondary distribution transformers. At the same bus is connected to a sensitive consumer and consumer group that have a difficult start. At the time t = 0.1 [s] closes the switch, which these consumers are connected to the network. This only simulates engaging consumers, who at the start have a high starting current value. This causes the collapse of the voltage to 0.7(s).

8. Simulation Results and Discussion

The presented distribution system some interesting results coming out which are briefly explained in this section. With the help of ideal voltage generator electrical energy is transmitted through a secondary distribution transformer having rated voltage of 0.4 [kV]. The energy is transferred to the observed consumer via cable section of 150 [mm2], a distance of 3.5 [km]. On the same bus two consumers R1, R2 are connected. Consumer (R1) requires constant voltage at the ends and the consumer (R2) has a difficult start. DSTATCOM, whose functions is to maintain a constant voltage during start consumer R2. It is taken that the formation of consumers R2 on the network occurs at time t = 0.1s, and start takes about 0.2 s. The parameters of the elements of the system are given in Table:

Table 1: The parameters used for the simulation

Parameter	Value
Consumer R1	R = 0.4963 Ω , L = 62.5 mH
Consumer R2	R = 0.2561Ω ,L = 9.1 mH
D-STATCOM Capacitance	C = 750 μF
Filter	R = 1.1 Ω, L = 680mH, C = 680μF
Line Frequency	50 Hz

We will recognize the first normalized value of the effective value of the voltage on buses when DSTATCOM not connected to the bus. From Figure-5, it is obvious that the voltage is maintained at a value of perceptual = approximately 0.96 V. As the time t = 0.1s occurs R2 enters the network, and bus voltage drops to the 0.7 V for about 0.2s. So for the time interval between 0.1s to 0.3s voltage collapses to 0.7 V. From Figure .6- it can be seen that the time when connection and disconnection of consumers R2 occur, higher harmonics (especially the third and fifth) enters in the network, which results collapse of voltage for a period of about 0.2 s.

In Figure-7 it can be seen that the voltage to consumers controlled all the time at approximately constant value 0.94V. In times of change of switching state switch which simulates engaging consumers R2 and DSTATCOM the Network remain small collapse voltage at approximately 0.85 V but this collapse takes only 0.02s. It should be noted that is approximated by the effective voltage value shown in Figure-7 includes a sum the effective value of the initial, third and fifth harmonic voltage observed. It turns out that these harmonics injected into the network and that their actions affect the total energy that is delivered to the consumer.

Figure-8 shows the waveform of the phase voltage in the case where the DSTATCOM included for the purpose of restore of voltage drop on the buses. It can be seen that for the duration of the fault, the voltage is not sinusoidal, but there is little deviation, which are the result of higher harmonics which arrived from power electronic converters.

Figure-9 Shows that in addition to the main balance automatically expressed and third, fifth and seventh harmonics. It can be seen that fifth harmonic carries significant power. In addition, the determined THD is only 5.87 [%], which is an acceptable value.

Figure-10 it can be seen that when the DSTATCOM-a-way capacitor voltage is maintained approximately constant at a value of approximately 500 [V]. Speed establishing AC voltage is suitable and is approximately 0.02 [s].

It is exactly the time that is obtained by a slight decline of phase voltage at the time of inclusion DSTATCOM.

When the DSTATCOM is controlled using PI controller with SVPWM algorithm, the simulation results are shown in Figures. It is found that the DC capacitor voltage, active power and reactive power controllers have large transient responses.

The supplied reactive power also maintains grid voltage constantly at 1 pu as shown in Figure-11. During the load variation, DSTATCOM is controlled in such a way that it does not supply any active power to the system.

When the DSTATCOM is controlled using PI controller with SVPWM algorithm, the simulation results are shown in Figures. It is found that the DC capacitor voltage, active power and reactive power controllers have large transient responses whereas the HCC, a robust controller, does not have any transient delay, with reduced switching losses.

The D-STATCOM has been employed mainly for regulation of voltage, correction of power factor and elimination of current harmonics. This device is used to maintain continuous voltage regulation using an indirectly controlled converter. In this paper, the D-STATCOM is used to minimize the voltage at the point of connection. The control is based on sinusoidal PWM and only requires the measurement of the rms voltage at the load point.

D-STATCOM MATLAB Simulations and Results for THD Total harmonic distortion, is the summation of all harmonic components of the Voltage or current waveform compared against the

fundamental component of the voltage or current wave. DSTATCOM works in inductive mode and is trying to return the voltage to a reference value.

In this paper hysteresis current control scheme has been used to provide the gate pulses for the switching devices of VSC unit of D-STACOM. Using the proposed control strategy based on instantaneous symmetrical component theory, D-STATCOM can also give real power compensation in the distribution. D- STATCOM improves power factor, provide load balancing & improve load terminal voltage. DSTATCOM control the short circuit current, improves the system transient stability limit and increases the load ability of the system. D- STATCOM controller is extremely effective in improving the power quality at the distribution level.
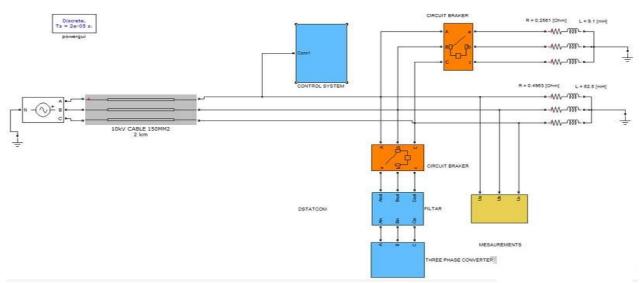

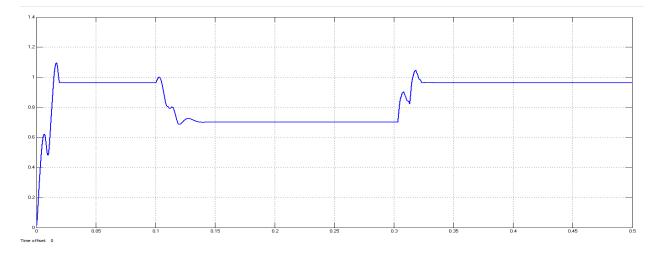Figure 4: The network configuration used in the simulation

Figure 5: Normalized effective value of the phase voltage phase A bus bar when not connected DSTATCOM
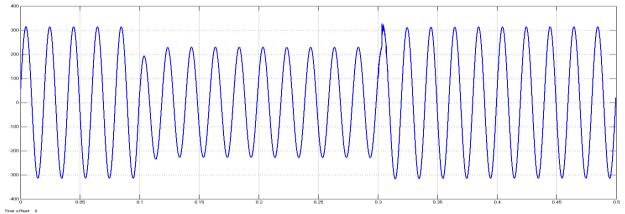
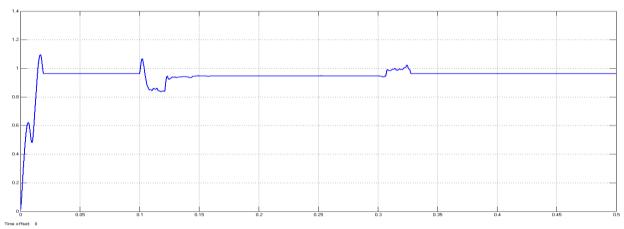Figure 6: Waveform phase voltage phases on the bus when it is not connected DSTATCOM

Figure 7: Phase voltage of bus bar when connected DSTATCOM, the sum of the first, third and fifth harmonic voltage.
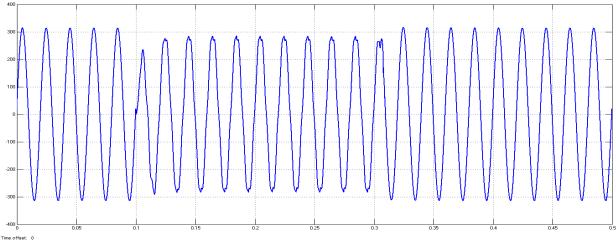

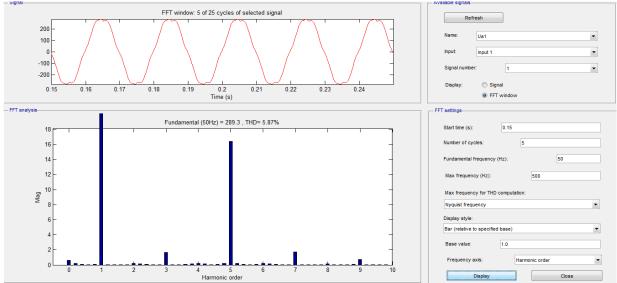Figure 8: phase voltage phases on the bus when the connected DSTATCOM

Figure 9: Distribution of harmonics in the spectrum of phase voltage for the case when the DSTATCOM connected to the network
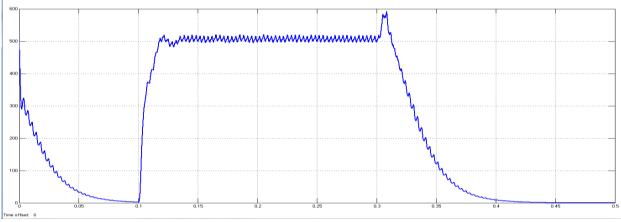

Figure 10: voltage across capacitor of DSTATCOM

9. Conclusion

This paper authenticates the simulation for the implementation of D-STATCOM and its controller. D-STATCOM which works on low voltage and compensate of reactive power, equally injects the reactive power in the line. D-STATCOM operates as VSC which employment at the load side of the system can be which improve the voltage profile of system and reduce the power losses. In reactive power control mode, the amount of reactive power delivered from the source can be made equal to the desired value by injecting required amount of reactive power from D-STATCOM. In this paper we present a comparative performance study for D-STATCOM for power factor improvement using PI controlled SVPWM techniques. It improves the quality of power delivered to the consumer by improving voltage conditions.

The simulation result shows the role of the SVPWM based D-STATCOM in delivering balanced sinusoidal source currents, though the load carries unbalanced and distorted currents. When D-

STATCOM is used as full reactive power compensation, the source no need to essential supplying any reactive power and all reactive power supply by D-STATCOM. This system also provides continue support of the source voltage and current phase with each other after compensation. So, the power factor of the utility supply is always remaining at unity. Thus D-STATCOM provides compensation in the distribution line and hence overall performance of distribution network also gets enhanced.

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