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REACTIVE POWER COMPENSATION USING D-STATCOM FOR 3-PHASE INDUCTION MOTOR LOAD

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Abstract: Modern AC supply system is characterized by two kinds of power i.e Active power and reactive power and both of these powers are necessary for the proper functioning of modern AC supply system. Active power represents the useful work done while reactive power represents the artificial loading and limits the flow of Active power through the AC supply system thereby decreasing the efficiency of existing system. Reactive power provides some positive attributes to the supply system by maintaining system voltage which is necessary for the flow of active power. Reactive power is also necessary for electromechanical energy conversion because it is required for generation of magnetic field which is essential for the energy conversion. If the flow of reactive power in AC supply system is localised then the efficiency of existing system can be increased. This work presents the reactive power compensation by D-STATCOM in distribution system feeding induction motor load under varying loading conditions. Firstly a supply system of line to line voltage 50 Hz is simulated in MATLAB environment and a squirrel cage induction motor load of 75 kW is directly connected. At first under varying loading conditions flow of power from supply to motor is recorded and analysed. Then D-STATCOM is designed using voltage source converter (VSC). Suitable filter is to be selected for smoothening the current waveform which will be injected by D-STATCOM. A suitable control algorithm should also be selected for the generation of reference voltage. This reference voltage will be used to produce triggering pulse for the VSC of D-STATCOM. Then this realized simulation model of D-STATCOM with suitable filter will be connected to the existing system to compensate the reactive power demand of induction motor load. After recording and analysing power flow data under varying loading conditions it was found that D-STATCOM supplies almost majority of reactive power demand of induction motor load while at the same time active power demand is fulfilled by supply system thereby localising the flow of reactive in supply system.

Index Terms: Distributed generation power system, renewable energy resources, energy storage systems, PV system, grid-connected systems.

I. INTRODUCTION

The most common problem faced by modern distribution system is voltage dip at the load terminals. Due to excessive reactive power demand by the load there is reduction in voltage below the rated value. This reduction in voltage due to excessive reactive power demand causes malfunction of sensitive loads connected to that same system. Fault is also one of the main reason for dip in voltage and it severely affects the power quality of the system. Better power quality is essential for todays modern industries [6]. Consumer's awareness has also increased regarding power quality and reliability of power supplies. Due to this awareness there have been significant increase in small distributed generation. These systems are getting popular in those areas where electricity transmission via overhead lines or underground cables is not possible or very costly. Small distributed generation has the capability to cater local loads and hence improves reliability with very low cost. But there is a limitation of small distributed generation when several 3 phase induction motor is connected to it. These small distributed generation gets derated because of heavy reactive power demand due to several motors connected simultaneously [7]. In this scenario D-STATCOM comes into picture as it has the capacity to compensate reactive power demand. D-STATCOM is realized using voltage source inverter which can absorb inductive as well as reactive power in very short span of time. The main advantage of D-STATCOM is that its response is very fast and can cater to variable reactive power demand in a very short span of time. Prior to D-STATCOM thyristor based system was used to cater reactive power demand but the main disadvantage associated with that was it provides fixed compensation and is very huge in size [8]. Characteristics of D-STATCOM is very similar to rotating synchronous compensator(synchronous motor) but the main difference is that it doesn't have any mechanical inertia and therefore its response is very fast as compared conventional synchronous condenser.

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Reactive power is the most important parameter of AC power system as it limits the flow of active power and reduces the system performance. It has always been challenge to strike balance between minimum reactive power demand and required reactive power demand to maintain voltage profile of the system.

- Reactive power is necessary to maintain system voltage for proper active power flow.
- Increasing voltage level above certain value becomes uneconomical as insulation requirement increases and the obvious solution is to compensate the reactive power and increase the voltage profile of the system.
- Reactive power mismanagement can cause whole blackout of the system and it can turn into catastrophic failure
- Industrial units are charged for reactive power consumption and therefore its management is of utter importance.

It is because of these reasons D-STATCOMs (3rd generation FACTS devices) are employed for management and control of reactive power in power system. As compared to conventional compensating devices D-STATCOM has several advantages

- very fast response
- less space is required for installation as bulky components are eliminated
- It can be connected with real power sources like battery, fuel cell etc
- It has much better performance as compared to conventional compensating devices as it can supply continuous reactive current.
- It doesn't support fault current during faults
- It is static device and therefore wear and tear is very less
- loss of synchronism is not an issue in this device

II. PRINCIPLE OF OPERATION AND CONTROL OF D-STATCOM

The main function of D-STATCOM is to counter current based power quality problems like reactive power compensation, load balancing, neutral current compensation, harmonics reduction and remove voltage fluctuations present at distribution end of the supply system. In this work reactive power compensation objective of D-STATCOM is achieved via simulation in MATLAB ENVIORNMENT.

D-STATCOM has a voltage source converter connected which is PWM current controlled to inject required current at PCC. Hall Effect sensors are required to sense voltage and current to feedback into control algorithm. Control algorithm first charge the DC bus capacitor to appropriate value and then load reactive current is estimated and control mechanism generates pwm pulses according to the load requirement and compensates the reactive component.

III. CONTROL ALGORITHM FOR D-STATCOM

The Different time domain and frequency domain control mechanism has been reported in literature
Some of the time domain control algorithms reported in literatures are
1) Power balance theory
2) PI controller based theory or Unit template theory
3) Single phase PQ theory
4) Single phase DQ theory
5) Instantaneous symmetrical component theory (ICST)
6) Synchronous reference frame (SRF) theory or D-Q theory
7) Instantaneous reactive power theory (IRPT) or P-Q theory
8) Conductance based control algorithm.
9) Adaptive detecting control algorithm
10) Enhanced phase locked loop (EPLL) based control algorithm
Similarly there are several frequency domain control algorithm reported in literatures are
1) Fourier series theory
2) Discrete Fourier series theory
3) Fast Fourier transforms theory
4) Recursive discrete Fourier transforms theory
5) Kalman filter based control algorithm
6) Hilbert-huang transforms theory
7) Wavelet transformation theory
D-Q control algorithm has been used for the generation of reference current of D-STATCOM for reactive power compensation for three phase induction motor load. In this control algorithm PCC voltage, load currents and DC bus voltage are sensed using Hall Effect sensors and feedback into controller. Loads current which are sensed are then converted to D-

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Q frame using park's transformation. A three phase PLL (phase locked loop) is used to provide synchronization D-Q currents with PCC voltage.

IV. SIMULATION RESULTS AND DISCUSSION

Minimum DC bus voltage of the capacitor should be greater than twice of the peak of phase voltage of the distribution system..

$$V_{DC} = 2\sqrt{2}V_{LL} / \left(\sqrt{3}m\right) \quad (1)$$

V_{LL} = Line Voltage=415V
m = Modulation index
For V_{LL} = 415 V
V_{dc} > 677.79 V
We have selected V_{dc} as 800 V

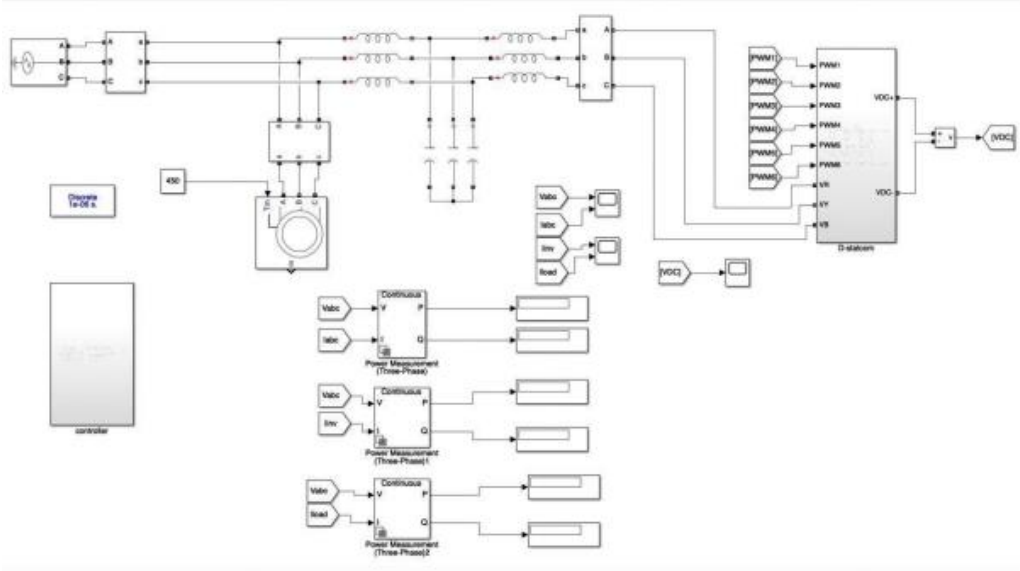

Fig 1: Reactive Power Compensation by D-STATCOM

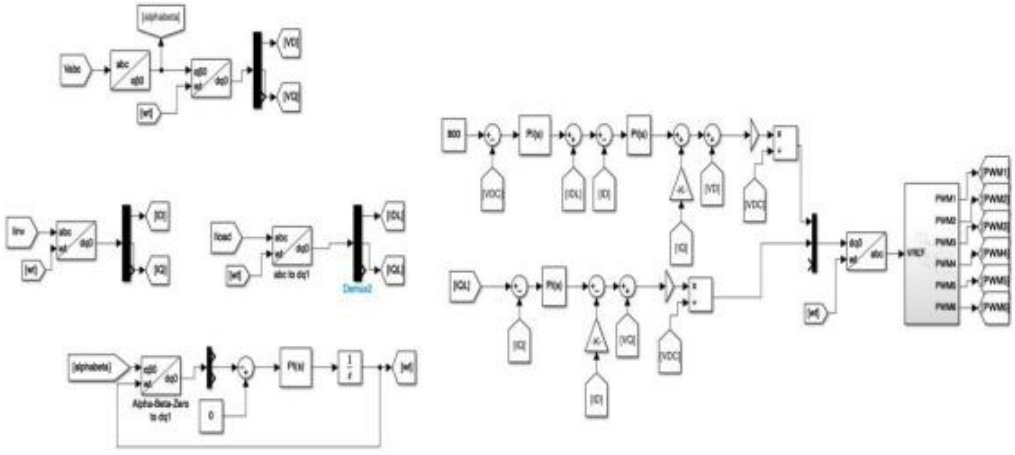

Fig 2: Control Circuit

The simulation results of the reactive power compensation using D-STATCOM for induction motor load based on simulink model are shown and discussed. The reactive power compensation using D-STATCOM for induction motor load model is made on simulink software of Matlab 2022 version. The tool boxes used here are based on SimPower system tool. Different waveforms are recorded and have been shown as follows.

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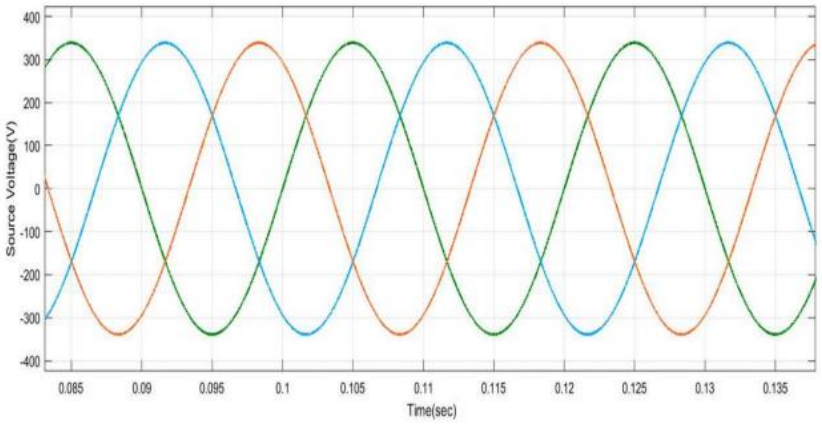

Fig 3: Source Voltage Waveform

Three phase ideal source is used as supply with 415 as line to line voltage and 50 Hz as supply frequency. This is visualized from source voltage scope in MATLAB simulation.

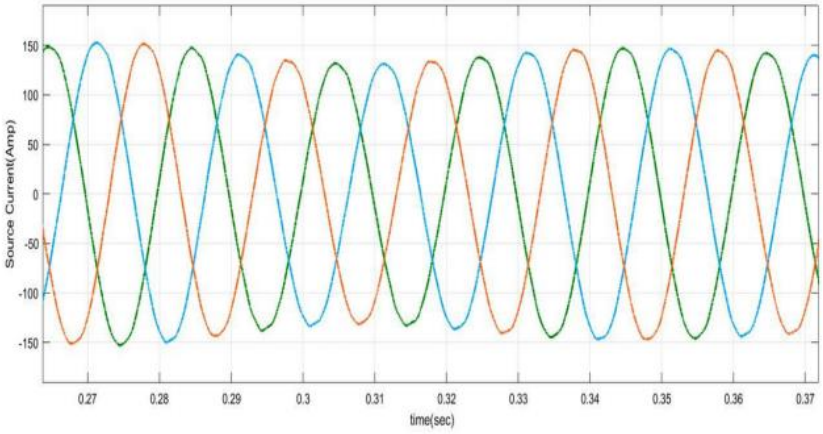

Fig 4: Source Current Waveform

Three phase ideal voltage source supply real current to three phase induction motor load which can be visualized via source current scope.
Load voltage is same as supply voltage because load is directly connected to the supply and hence load and source voltage is same.

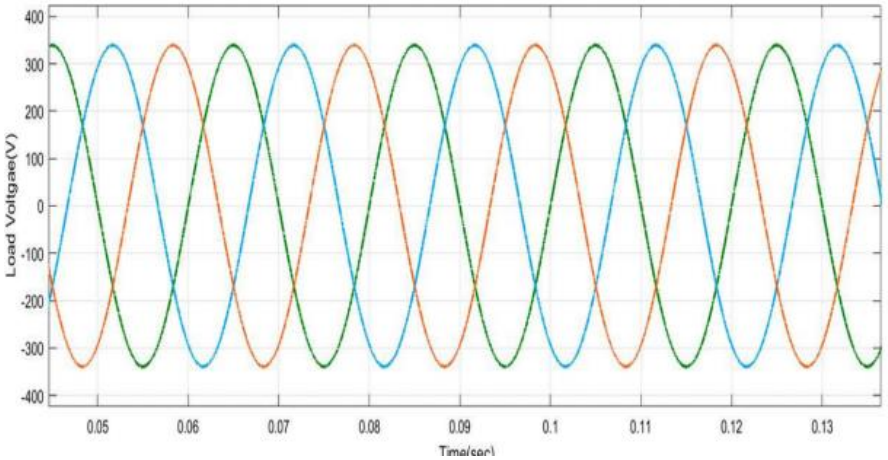

Fig 5: Load Voltage Waveform

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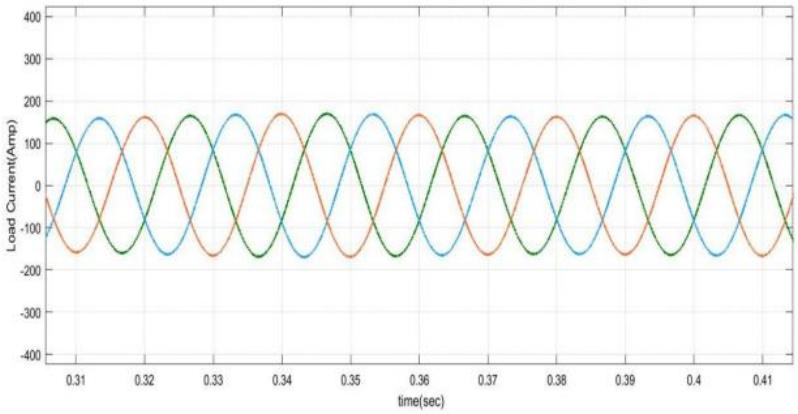

Fig 6: Load Current Waveform

Load current contains both active as well as reactive part and active part of load current is supplied from source while reactive part of current is supplied from D-STATCOM and this is visualized from load current scope.

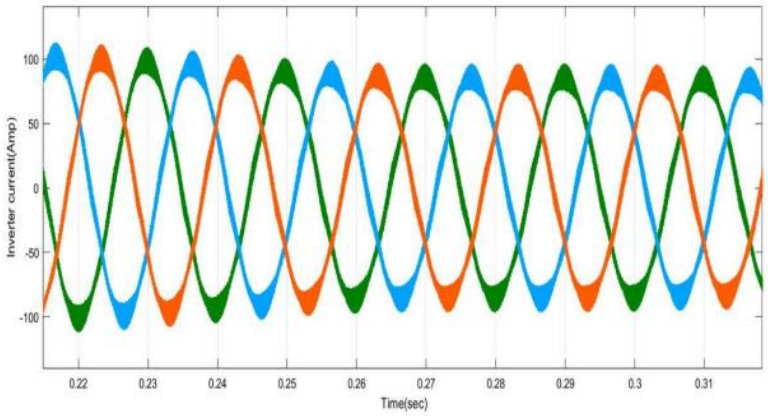

Fig 7: D-STATCOM Current Waveform

D-STATCOM supplies reactive part of the load current and it is evident from the D STATCOM scope.

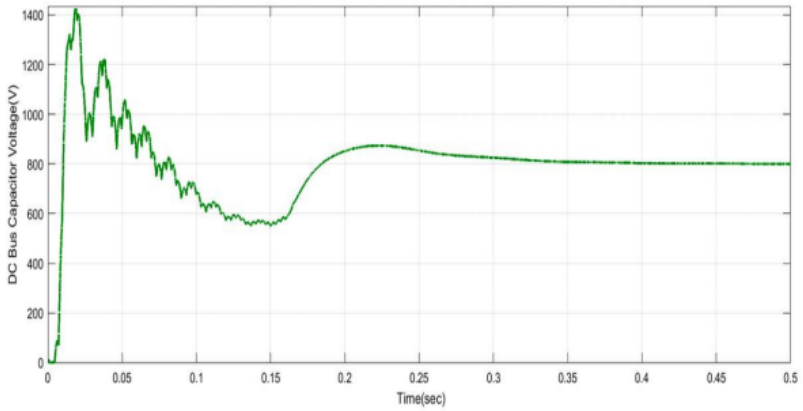

Fig 6: DC Bus Capacitor Voltage Waveform

DC bus voltage capacitor of D-STATCOM is maintained at 800 V after initial transient overshoots which quickly gets settled down.

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V. CONCLUSIONS

Under varying loading conditions power flow analysis has been done and recorded without compensation and with compensation. Load torque has been varied which in turn varied the reactive and active power demand of the load and that has been recorded and analyzed. It can be conducted that all the reactive power demand and active power demand of the load is supplied by the supply when compensator is not connected. But when compensator is connected then reactive power demand of load is compensated by D-STATCOM and active power demand of load is fulfilled by the supply.

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