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Mitigation of Power Quality issues Using DSTATCOM

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ABSTRACT
Utilities are facing with many of the power quality issues in the form of a voltage drop, swelling, and voltage fluctuations and harmonic distortions due to non-linear loads. The Distributed Static Compensator (DSTATCOM) has taken to address these issues along with its flexibility, ease of implementation, the dynamic load allowance, and the diversity of its operations. An attempt is made in this paper for mitigation of voltage sag, swell, voltage fluctuations and harmonic distortions for different loading condition in utility by using custom power devices with PI controller. The MATLAB/Simulink model of DSTATCOM demonstrates that DSTATCOM is a feasible solution for solving few power quality issues.

Key words: FACTs, mitigation, DSTATCOM

INTRODUCTION

Static compensators when connected to the distribution network are known as distributed STATCOM (DSTATCOM). It consists of a two-level voltage source converter, a dc energy storage device along with a coupling transformer connected in shunt to the distribution network through a coupling transformer. DSTATCOM, when connected with a particular load injects compensation current, so that total demand meets the specifications for utility connections. Capacitive and inductive reactive power is produced internally by DSTATCOM. Its control is very fast and provides sufficient reactive compensation to the system. DSTATCOM can be successfully employed to regulate voltage for a series of small induction motor loads which draws large starting current of full rated current and may influence the working of other sensitive loads, linked to the system.

A novel decentralized coordinated voltage control scheme for a distribution system consisting of dc microgrid, doubly fed induction generator-based wind system, on-load tap changer, and DSTATCOM. The proposed scheme considers the response time of various voltage regulating devices and assigns a master/slave role based on the operating conditions of the grid and availability of the device. Two modified IEEE 33 bus systems are implemented in a real-time digital simulator platform to test the effectiveness of the proposed coordinated voltage control scheme [1].

A new voltage control scheme of DSTATCOM combines two methods of DSTATCOM operation to improve its performance. Considering power factor and voltage magnitude as degree of freedom, the DSTATCOM provides features such as mitigation of voltage and current harmonics, balancing of source currents, improvement of power factor, voltage regulation during voltage sag and swell, reduction in inverter losses, and control of load power to achieve energy conservation [2].

A DSTATCOM is implemented for controlling a distributed power generating system. The proposed control technique is employed for the fundamental components extraction of distorted load currents. These extracted components are used in the estimation of reference source currents to generate gating signals of DSTATCOM. The proposed control technique is implemented for the mitigation of reactive power, distortion in term of harmonics, and load balancing under linear/nonlinear loads [3].

Intermittency of renewable energy resources makes reactive power management a challenge in microgrids. Since standards do not recommend the use of distributed energy resources for voltage regulation and reactive power management in microgrids, therefore, traditionally, locally controlled DSTATCOM are widely used. The management of reactive power requirement in microgrids can be improved through communication-based coordinated operation [4].

The DSTACOM voltage regulator is designed to temporarily meet the grid code, postponing unplanned investments while a definitive solution could be planned to solve regulation issues. The power stage is composed of a three-phase four-wire, voltage-source inverter and a second-order low-pass filter. The control strategy has three output voltage loops with active damping and two dc bus voltage loops. The frequency loop allows the voltage regulator to be independent of the grid voltage information, especially the grid angle, using only the information available at the point-of-common coupling [5].

To mitigate the power quality issue in microgrids, a new online reference control strategy for DSTATCOM, is supposed to compensate the reactive power, harmonics, and unbalanced load current in a microgrid utilizing voltage and current parameters. Voltage controller is used to adjust the set point of the reactive power reference, whereas the current based controller tries to compensate the unbalanced load current in distributed resource network through the quadrature axis and zero axis. The proposed control strategy is applied to an autonomous microgrid with a weak ac-supply distribution system under different loads as well as three-phase fault conditions [6].

NEED OF BETTER POWER QUALITY

As indicated by the IEEE principles, "Power quality can be characterized as the technique for grounding and supplying sensitive equipment with power so as to get a reasonable and agreeable performance of the equipment". Overall power quality represents a blend of quality of the current and voltage. Voltage quality at the point of connection is governed by the network operator whereas the quality of current at the connection point is governed by the client's load. Power quality is becoming an important concern because of following major reasons.

- To increase the efficiency of power system many new devices such as shunt capacitors and adjustable-speed motor drives are gaining popularity. These devices increase the harmonic level of the power system which increases the concern.
- Power electronic devices and loads that make use of control based on microprocessor, and microcontroller based are more affected by power quality issues.
- The interconnected networks that are used nowadays are badly affected by the power system disturbances because if any component is failed the entire system is affected.
- The awareness of problems in the quality of power and difficulties faced like under voltage, overvoltage, flickers etc. is among the utility customers or end users is tremendously increasing which arises the demand of a high and better quality of power.

The power disturbances occur on all electrical systems, the sensitivity of today's sophisticated electronic devices make them more susceptible to the quality of power supply. For some sensitive devices, a momentary disturbance can cause scrambled data, interrupted communications, a frozen mouse, system crashes and equipment failure, etc. A power voltage spike can damage valuable components. Power quality problems encompass a wide range of disturbances such as voltage sags, swells, flickers, harmonic distortion.

DISTRIBUTED STATIC COMPENSATOR

Distributed Static Compensator (DSTATCOM), schematic diagram is shown in Fig. 1, consists of a two-level voltage source converter, a dc energy storage device, a coupling transformer connected in shunt to the distribution network through a coupling transformer. Suitable adjustment of the phase and magnitude of the DSTATCOM output voltages allows effective control of active and reactive power exchanges between the DSTATCOM and the ac system. Such configuration allows the device to absorb or generate controllable active and reactive power. The DSTATCOM has been utilized mainly for regulation of voltage, correction of power factor and elimination of current harmonics. Such a device is employed to provide continuous voltage regulation using an indirectly controlled converter.

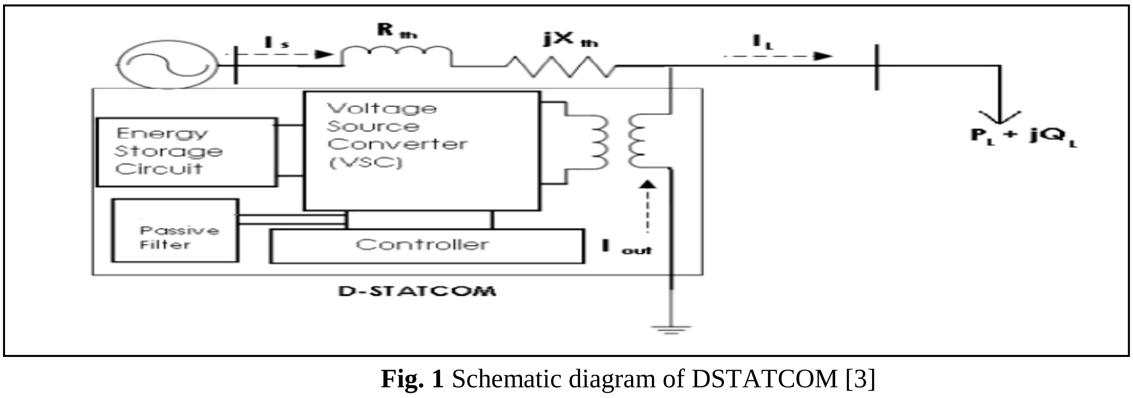

Fig. 1 Schematic diagram of DSTATCOM [3]

1. Voltage Source Converter (VSC): A voltage source converter consists of a storage device and devices of switching, generating a sinusoidal voltage at any required frequency, magnitude and phase angle. In the DSTATCOM application, this temporarily replaces the supply voltage or generates the part of the supply voltage which is absent and injects the

compensating current into the distribution network depending upon the amount of unbalance or distortion. In this work, an IGBT is used as the switching device.

2. Isolation transformer: It connects the DSTATCOM to the distribution network and its main purpose is to maintain isolation between the DSTATCOM circuit and the distribution network.

3. DC charging unit: This unit charges the energy source after a compensation event and also maintains the dc link voltage at the nominal value.

4. Harmonic filters: The main function of harmonic filter is to filter out the unwanted harmonics generated by the VSC and hence, keep the harmonic level within the permissible limit.

5. Energy storage unit: Energy storage units like flywheels, batteries, superconducting magnetic energy storage and super capacitors store energy. It serves as the real power requirements of the system when DSTATCOM is used for compensation. [4]

CONTROL TECHNIQUE

The purpose of the Proportional-integral (PI) controller scheme is to maintain constant magnitude of voltage at the point where a sensitive load is connected, under system disturbances. No reactive power measurements are required; control system only measures the rms voltage at the load point. The switching strategy of VSC is based on a sinusoidal PWM technique which offers simplicity and good response. Modern semiconducting switches such as MOSFETs or IGBTs are suitable components for high efficiency controllers. High switching frequencies can be used to improve on the efficiency of the converter, without incurring significant switching losses in inverter. The input of controller is typically an error signal, which is the difference between reference signal and actual system output signal. The controller input is an error signal obtained from the reference voltage and measured rms voltage of terminal. Such an error is processed by a PI controller and the output is the angle δ, which is provided to the PWM generator. The error signal is generates by comparing the reference value and the actual value. The PI controller is a feedback loop controller, which drives the system to be controlled with the weighted sum of the error signal and the integral of that value. In this case, PI controller will process the error signal to zero that means the load rms voltage is brought back to the reference voltage by comparing the reference voltage with the measured rms voltages.

SIMULATION RESULTS

The DSTACOM is simulated in MATLAB/Simulink, with 11KV source is connected to 3 phase three winding transformer through a distribution parameter. Secondary and tertiary winding of transformer is connected to domestic active load and industrial load reactive load respectively. DSTATCOM is connected at PCC in parallel for sag/ swell compensation. Voltage Sag is a short duration reduction in voltage which can be caused by a short circuit, sudden increase in load or starting of electric motors. Sag generation-sudden increase in the load i.e. breaker is normally open and it is closed in a short duration of 0.4 to 0.6 sec. Voltage Swell is a momentary increase in the voltage, happens when a heavy load turns off in a power system. Swell generation- sudden decrease in the load i.e. breaker is normally close and it is opened in a short duration of 0.4 to 0.6 sec.

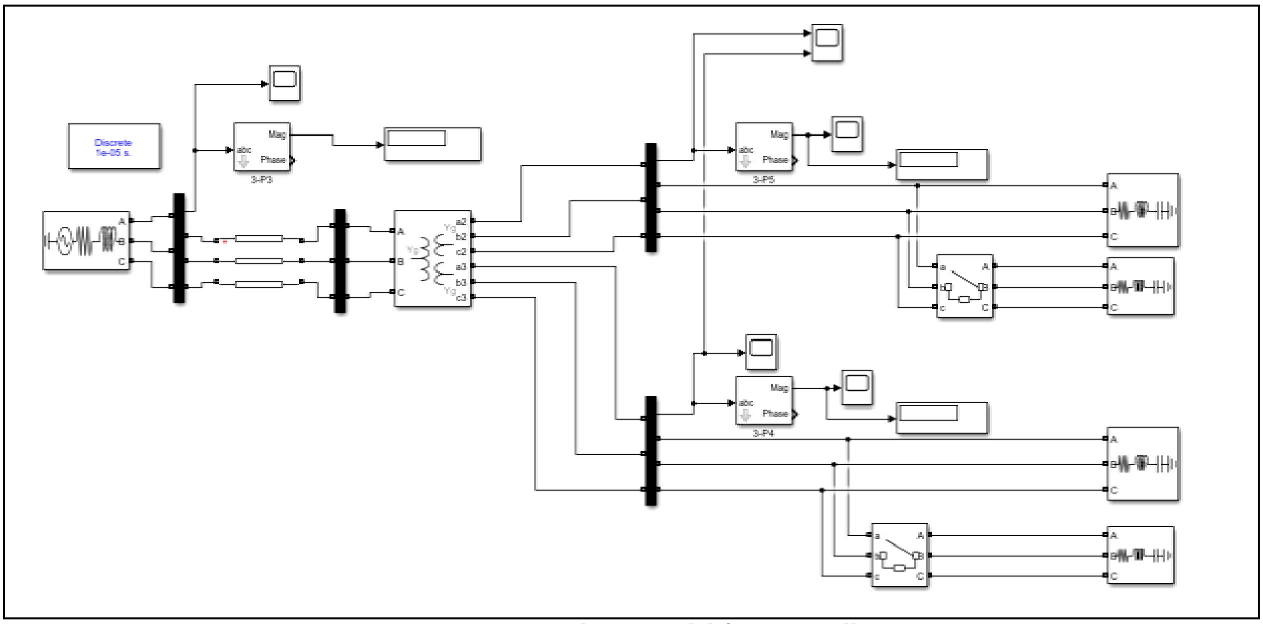

Fig. 2 Simulation model for sag/swell

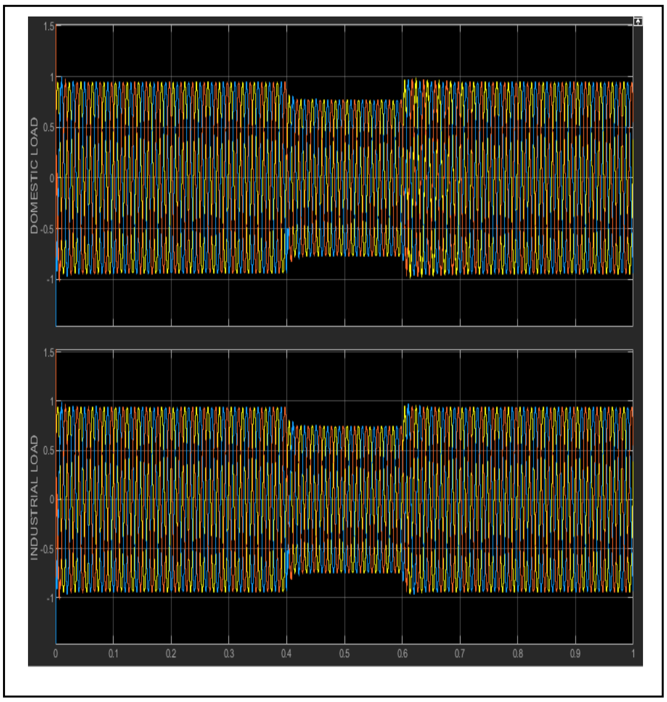

Fig. 3 Domestic and industrial load voltage sag

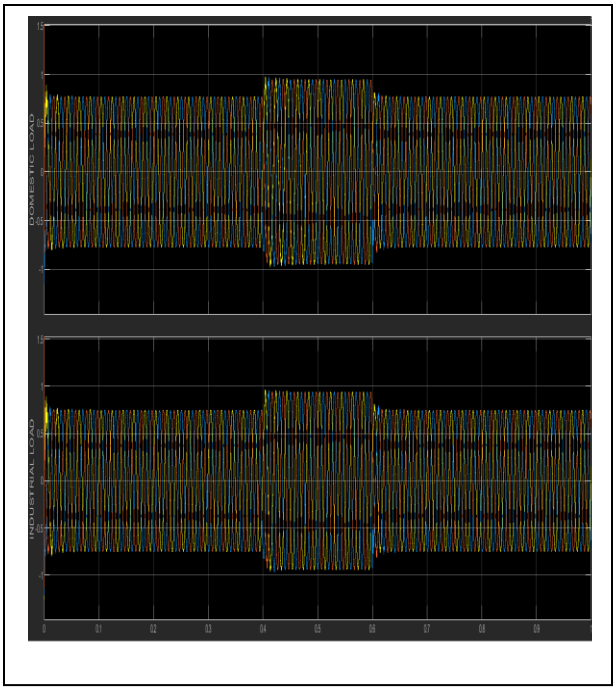

Fig. 4 Domestic and industrial load voltages swell

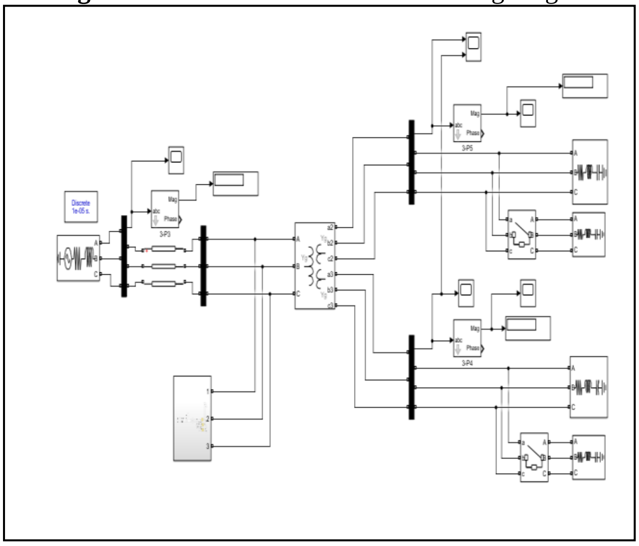

Fig. 5 Simulink model with DSTATCOM

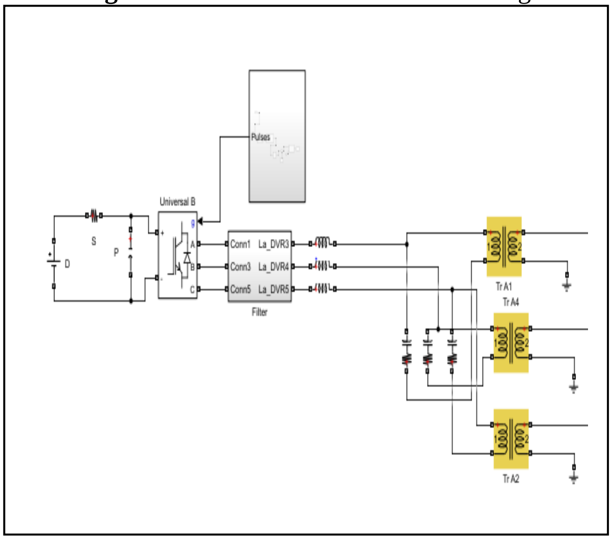

Fig. 6 Simulink model of DSTATCOM

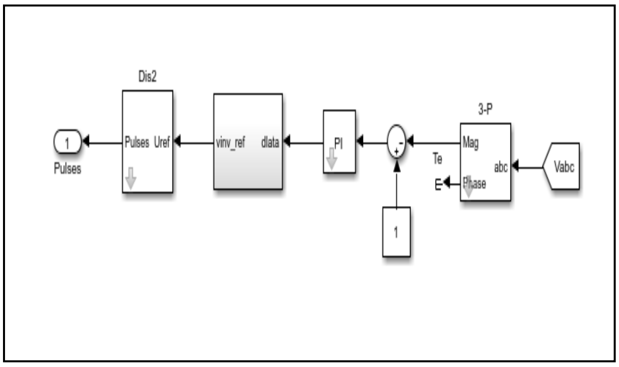

Fig. 7 Simulink model of PI controller

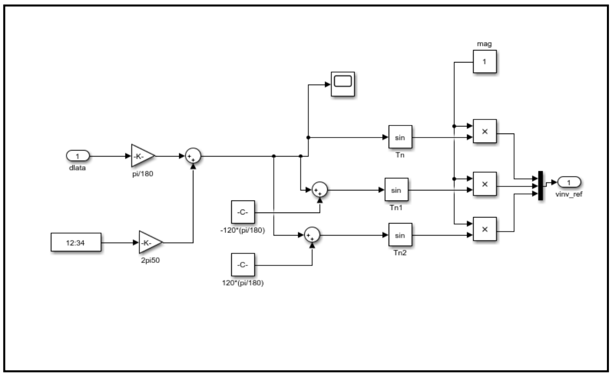

Fig. 8 Simulink model of pulse generation circuit

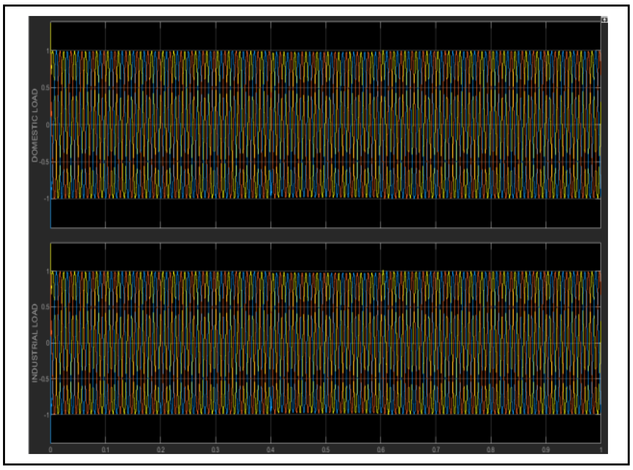

Fig. 9 Compensated voltage sag

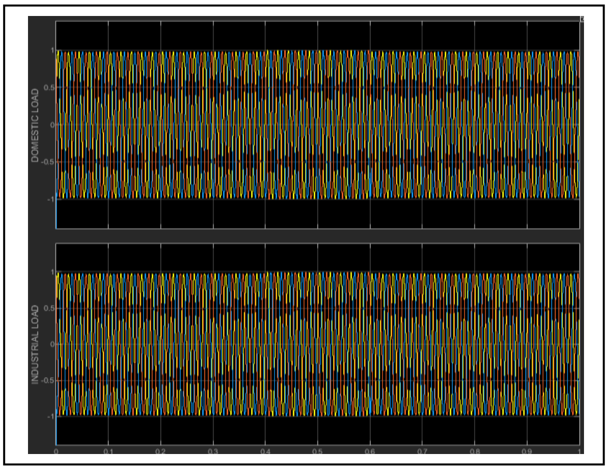

Fig. 10 Compensated voltage swell

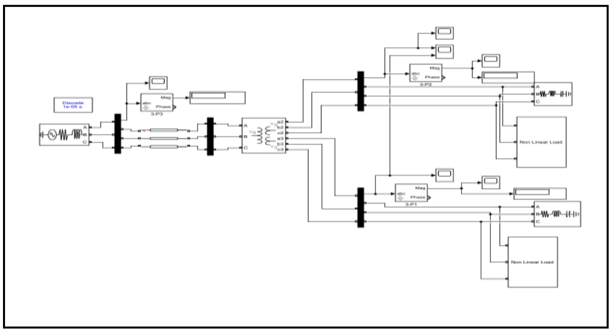

Fig. 11 Simulation model with insertion of non-linear load

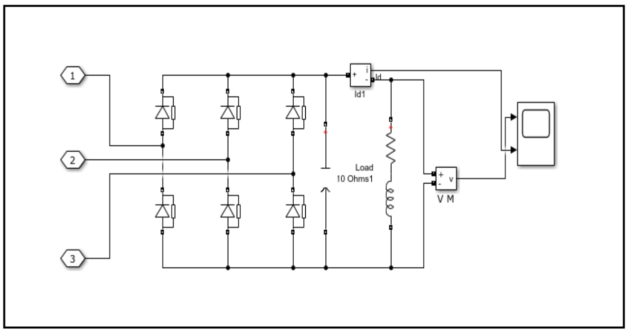

Fig. 12 Simulation model of non-linear load

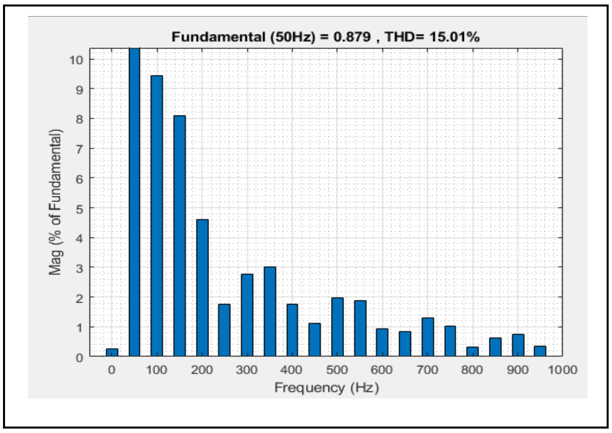

Fig. 13 THD of domestic active load

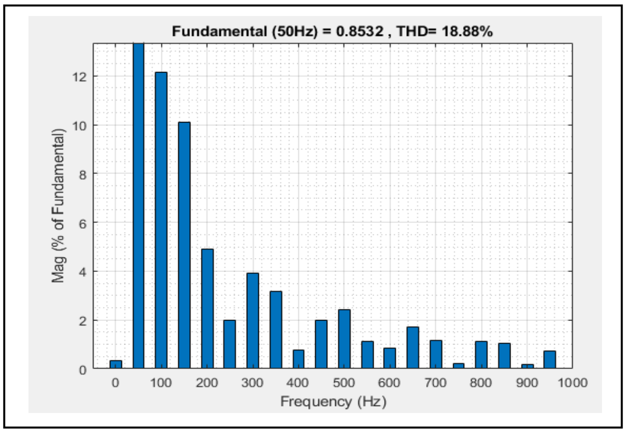

Fig. 14 THD of industrial reactive load

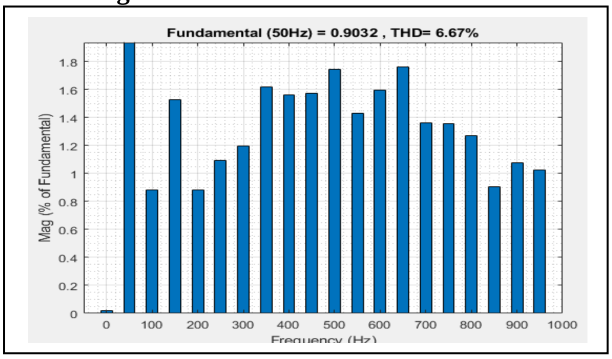

Fig. 15 THD of domestic active load

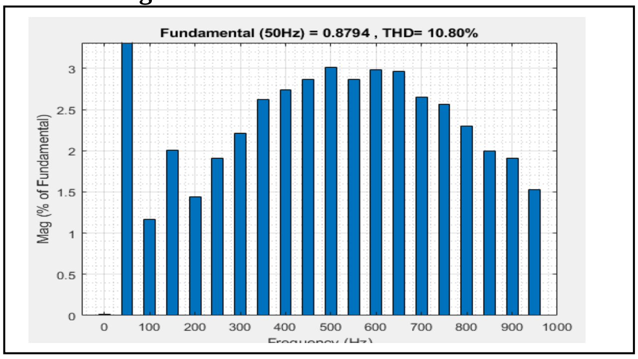

Fig. 16 THD of industrial reactive load

- The operation of DSTATCOM has been investigated for domestic load and industrial load with the insertion of non-linear load, using PI control technique for generating the switching signals.
- The swell introduced in the distribution system is mitigated by the DSTATCOM.

- The sag introduced in the distribution system is mitigated by the DSTATCOM
- The inductive load is increased and observed that analysis that DSTATCOM effectively reduces the THD in the system. The total harmonic distortion of non-linear load inserted with domestic load is 15.01%, which is reduced to 6.67% with DSTATCOM.
- The total harmonic distortion of non-linear load inserted with industrial load is 18.88%, which is reduced to 10.8% with DSTATCOM.

CONCLUSION

D-STATCOM device is used to maintain stability of power system which depends upon quality of power. There few power quality issues such as - voltage sag, voltage swell, harmonics and noise etc. These problems causes low power issue, low potency, enlarged losses in distribution lines, failure of electrical equipment and interference weakness with communication system. It is important to mitigate these issues. D-STATCOM is a three-phase shunt device employed to eliminate voltage sag and voltage swell on distribution network and reduces the THD. It is also used to improve the voltage profile even though the line length is varied and to reduce harmonics in distribution system. Different types of power quality problems example reactive power compensation, power frequency variation, power factor improvement, and increase in steady state stability with respect to real time loads can be considered. Design of different types of dynamic controllers will enhance the power quality issues of the complicated power distribution lines. Real time distribution network is having many sources including renewable, and placing the DSTATCOM in this itself is a challenge.

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