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A Novel Improved Performance of Power Distribution System using DSTATCOM under I.M Drive Scheme

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Abstract: *Electricity plays an important role in the economic development and technology advancement throughout the world. The quality and reliability of power supplies relates closely to the economic growth of a country. However, power quality disturbances such as sags, swells, flicker, harmonics, voltage imbalance etc., create a lot of problems in achieving a reliable and quality power supply. These power quality problems are very common in the electrical distribution systems. The poor voltage or reactive power compensation can be minimized or overcome by using FACTS device such as DSTATCOM. In order to maintain the power system quality the DSTATCOM will absorb and provide reactive power to mitigate voltage sag, swell, interruption and improve power factor in various conditions. The use of STATCOM for solving power quality problems due to voltage sags, flickers, swell etc., has been suggested. The purpose of STATCOM is to provide efficient voltage regulation during short duration of induction motor starting and thus prevent large voltage dips. The D-STATCOM fed with induction motor performance can be analyzed by using MATLAB /SIMULINK software.*

Key words: D-STATCOM (Distributed Static Synchronous Compensator); Induction Motor Drive Voltage Sag; Power quality.

I. INTRODUCTION

One of the most common power quality problems today is voltage dip. A voltage dip is a short time (10 ms to 1 minute) event during which a reduction in rms voltage magnitude occurs. It is often set only by two parameters, depth/magnitude and duration. The voltage dip magnitude ranges from 10% to 90% of nominal voltage (which corresponds to 90% to 10% remaining voltage) and with a duration from half a cycle to 1 min. In a three-phase system, voltage dip by nature is a three-phase phenomenon, which affects both the phase-to-ground and phase to-phase voltages. A voltage dip is caused by a fault in the utility system, a fault within the customer's facility or a large increase of the load current, like starting a motor or transformer energizing. Improved power quality is the driving force for today's modern industry. Consumer awareness regarding reliable power supply has increased tremendously in the last decade. This has lead to an additional thrust to the development of small distributed generation. Small isolated DG sets have the capability to feed local loads and thus lads to improvement in reliability of power with low capital investment. These systems are also gaining increased importance in isolated areas where transmission using overhead conductors or cables is unrealistic or prohibitive due to excessive cost. Small generation systems in hilly terrains, islands, off shore plants, power distribution in rural areas, aircrafts etc can be efficiently utilized even in developing countries.

However, these DG sets may have to be de-rated if induction motor loads are simultaneously started .One useful option is to use STATCOM in shunt configuration with the main system so that the full capacity of generating sets is efficiently utilized .STATCOM employs a voltage source converter (VSC) and generates capacitive and inductive reactive power internally. Its control is very fast and has the capability to provide adequate reactive compensation to the system. STATCOM can be effectively utilized to regulate voltage for one large rating motor or for a series of small induction motors starting simultaneously. Induction motor loads draw large starting currents (5- 6times) of the full rated current and may affect working of sensitive loads.

Thyristor based systems were initially proposed for reactive power compensation and were used for voltage flicker reduction due to arc furnace loads. However, due to disadvantages of passive devices such as large size, fixed compensation, possibility of resonance etc., the use of new compensators such as STATCOM is growing to solve power quality problems. The use of STATCOM for solving power quality problems due to voltage sags, flickers, swell etc has been suggested. The purpose of STATCOM is to provide efficient voltage regulation during short duration of induction motor starting and thus prevent large voltage dips.

II. POWER QUALITY

Power quality is defined as the concept of powering and grounding sensitive. Equipment in a matter that is suitable to the operation of that equipment.

Power quality deals with maintaining a pure sinusoidal waveform of voltage and frequency. Voltage quality concern with deviation of voltage from ideal voltage (sinusoidal) it isa single frequency sine wave at rated magnitude and frequency with no harmonics. Current quality is a complimentary term of voltage quality concern with a deviation from the ideal current. Current should be in phase with the voltage.

Equipment produces more current disturbances than it used to do both low and high power equipment is more and more powered by simple power electronic converters which produce a broad spectrum of distortion there are indications that the harmonics distortion in the power system is rising, but no conclusive results are obtained due to the lack of large scale surveys. Also energy efficient equipment is a source of power quality disturbance adjustable speed drives and energy saving lamps are both important sources of waveform distortion and are also sensitive to certain type of power quality disturbances.

According to IEEE standard 1100, “power quality is the concept of powering and grounding sensitive equipment in amanner that is suitable to the operation of that equipment”.

a) Power quality problems

There are so many problems related with quality of power. Here the main concern with the poor power quality with nonlinear loads. Non-linear loads can cause voltage and current distortion. That is it changes its shape other than sinusoidal.

b) Harmonic Distortion

Harmonic components are those waveforms which have the frequency as an integer multiple of the fundamental. Any periodic waveform which is non-sinusoidal can be divided into fundamental and non fundamental components. Everynth harmonic will have a frequency n times that of fundamental frequency.

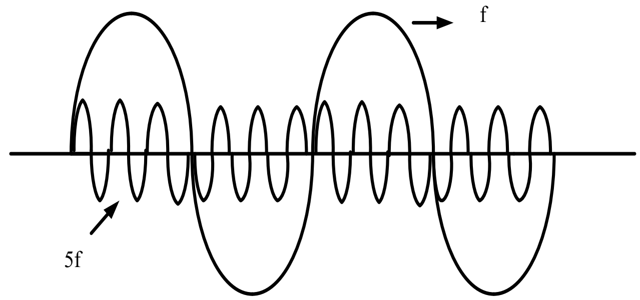

Figure.1: Fundamental component and 5th harmonic component

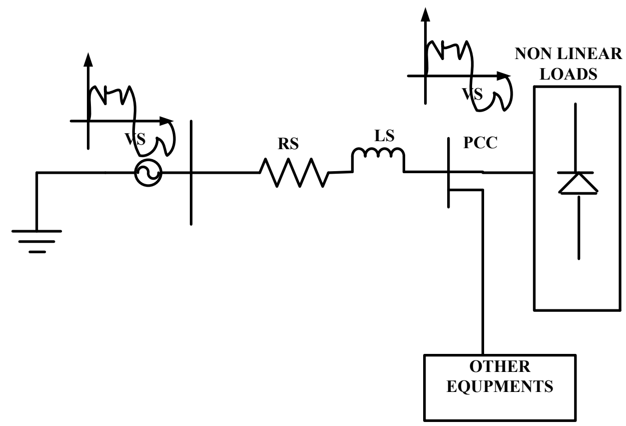

Figure.2: Power System with non-linear loads

Voltage at point of common coupling

$$V_{PCC} = V_S - L_{S1}\frac{di_s}{dt} \quad (1)$$

$$i_s = i_{s1} + \sum i_{sh} \quad (2)$$

$$V_{PCC} = \left(V_S - L_{S1}\frac{di_{s1}}{dt}\right) - (L_{S1} - \frac{di_{sh}}{dt}) \quad (3)$$

$$V_{PCC} = V_{PCC1} - V_{PCC(distortion\ )} \quad (4)$$

Where

$$V_{PCC1} = \left(V_S - L_{S1}\frac{di_{s1}}{dt}\right)$$

$$V_{PCC(distortion\ )} = (L_{S1} - \frac{di_{sh}}{dt})$$

Non-linear loads draw reactive power. So input power factoris also get poor.

Line current and Total Harmonic Distortion (THD)

$$v_s = \sqrt{2}v_s \sin\omega t \quad (5)$$

$$i_s = \sqrt{2}I_{S1}\sin(\omega_1 t - \emptyset_1) + \sum\sqrt{2}I_{sh}\sin(\omega_n t - \emptyset_h) \quad (6)$$

$$i_s = i_{s1}(t) + \sum i_{sh}(t) \quad (7)$$

$$i_s = I_{s1}^2 + \sum i_{sh}^2 \quad (8)$$

If we remove fundamental, then only ripple will be left

$$i_{distortion} = (i_s^2 - i_{s1}^2)^{\frac{1}{2}} = (\sum i_{sh}^2)^{\frac{1}{2}} \quad (9)$$

$$\%\text{THD} = I_{distortion} * \frac{100}{I_{sh}} \quad (10)$$

$$\%\text{THD} = \sqrt{(I_s^2 - I_{s1}^2)} * \frac{100}{I_{sh}} \quad (11)$$

III. PRINCIPLE OF D-STATCOM

It is shunt connected at the distribution side of the power systems. A D-STATCOM is a controlled reactive source,which includes a Voltage Source Converter (VSC) and a DClink capacitor connected in shunt, capable of generating and/or absorbing reactive power. The operating principles ofa D-STATCOM are based on the exact equivalence of the conventional rotating synchronous compensator.

The AC terminals of the VSC are connected to the Point of Common Coupling (PCC) through an inductance, which could be a filter inductance or the leakage inductance of the coupling transformer, as shown in Figure 3. The DC side of the converter is connected to capacitor, which carries the input ripple current of the converter and reactive energy storage element. This capacitor could be charged by voltage source or inverter. When AC output voltage of inverter is equal to terminal voltage, then there is no reactive power exchange. It there difference between these voltages the only reactive power exchange occurs. The control strategies studied in this paper are applied with a view to studying the performance of a D-STATCOM for reactive power compensation and harmonic mitigation.

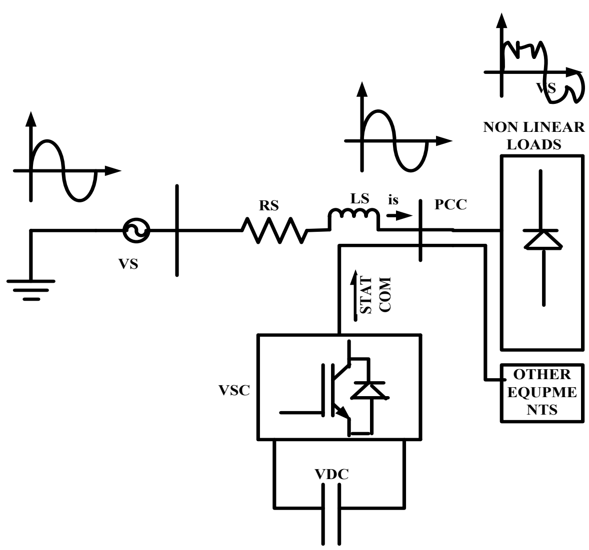

Figure.3: Power system with D-STATCOM

Configuration and operation of DSTATCOMD-STATCOM has 3-phase voltage source converter, capacitor at DC side of inverter is connected with the electrical system at the PCC. The instantaneous controllable3-phase output voltage is generated from DC voltage at fundamental frequency. The pulse is generated by the hysteresis current controllers which takes the difference of reference current and actual source current and minimizes the error and controls the current and generate 3-phase output voltage and injects capacitive or inductive current according to the nature of load.

IV. MATHEMATICAL EXPRESSION FOR SYSTEM

Total instantaneous power delivery drawn by non-linear load

$$P_L(t) = P_{s1}(t) + P_r(t) + P_{sh}(t) \quad (12)$$

Real power supplied by source-

$$P_s = P_{s1} \quad (13)$$

Reactive power supplied by source-

$$Q_S = 0 \quad (14)$$

Real power drawn by the load-

$$P_L = P_{s1} + P_{sh} \quad (15)$$

Reactive power drawn by the load-

$$Q_L = Q_{s1} + Q_{sh} \quad (16)$$

Real power supplied by the D-STATCOM-

$$P_{STATCOM} = P_{sh} - P_{LOSS} \quad (17)$$

Reactive power supplied by D-STATCOM-

$$Q_{STATCOM} = Q_{s1} + Q_{Sh} \quad (18)$$

Where P_{loss} component of STATCOM

From the single line diagram Figure 2

$$i_s = i_L(t) + i_{STATCOM}(t) \quad (19)$$

When the phase of $V_{STATCOM}$ is in quadrature with $I_{STATCOM}$ without injecting real power the D-STATCOM canachieve the voltage sag mitigation. The shunt injecting current$I_{STATCOM}$ and 5 in Figure 3 can be expressed as equation (20and 21)

$$I_{STATCOM} = I_L - I_S = I_L - \frac{v_{th} - v_L}{Z_{th}} \quad (20)$$

$$V_L = V_{th} + (I_{STATCOM} - I_L)Z_{th} \quad (21)$$

$$I_S = (V_{th} - V_L)/Z_{th} \quad (22)$$

Where

V. CONTROL STRATEGY

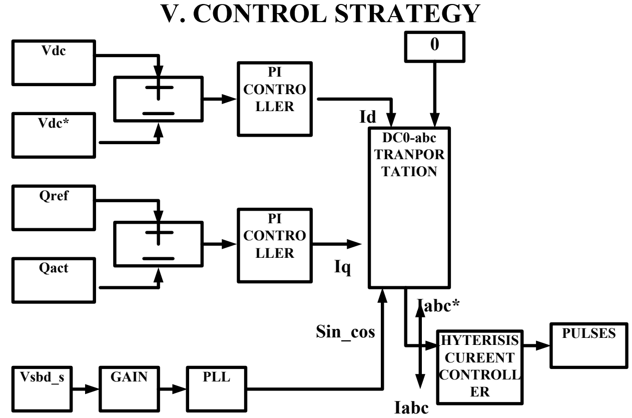

Figure.4: Control Strategy to generate pulses

VI. MATHEMATICAL MODELING

The direct and quadrature axis component of current are:

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$$I_d = \left(K_P + \frac{K_I}{S}\right) * (V_{DC}^* - V_{DC}) \quad (23)$$

$$I_q = \left(K_P + \frac{K_I}{S}\right) * (Q_{grid}^* - Q_{grid}) \quad (24)$$

a) d-q-0 to a-b-c transformation

$$\boldsymbol{x_{abc} = K^{-1} x_{dq0}}$$

$$= \sqrt{\frac{2}{3}} \begin{bmatrix} \cos\theta & -\sin\theta & \frac{1}{\sqrt{2}} \\ \cos(\theta - \frac{2\pi}{3}) & -\sin(\theta - \frac{2\pi}{3}) & \frac{1}{\sqrt{2}} \\ \cos(\theta + \frac{2\pi}{3}) & -\sin(\theta + \frac{2\pi}{3}) & \frac{1}{\sqrt{2}} \end{bmatrix}$$

b) Hysteresis Current Controller

In conventional hysteresis band (HB) current control, the switching signal is sent to the IGBT at the same arm (T1 andT4). The output of the HBC is directly connected to the transistor T1 and reverse is connected to the T4, therefore the transistor in the same leg is not simultaneously ON or OFF.IGBT are self commutated. Hysteresis Current Controller compares the actual and reference current and generates pulses for the inverter.

If

$$i \le (i^* - HB), then T1\ Is\ ON \quad (26)$$

If

$$i \ge (i^* + HB), then T4\ Is\ ON \quad (27)$$

VII. INDUCTION MOTOR DRIVE

An electrical motor is such an electromechanical device which converts electrical energy into a mechanical energy. In case of three phase AC operation, most widely used motor is three phase induction motor as this type of motor does not require any starting device or we can say they are selfstarting induction motor. For better understanding the principle of three phase induction motor, the basic constructional feature of this motor must be known to us. This Motor consists of two major parts: Stator: Stator of three phase induction motor is made up of numbers of slots to construct a 3 phase winding circuit which is connected to 3 phase AC source. The three phase winding are arranged in such a manner in the slots that they produce a rotating magnetic field after 3Ph. AC supply is given to them. Rotor: Rotor of three phase induction motor consists of cylindrical laminated core with parallel slots that can carry conductors. Conductors are heavy copper or aluminum bars which fits in each slots & they are short circuited by the end rings. The slots are not exactly made parallel to the axis of the shaft but are slotted a little skewed because this arrangement reduces magnetic humming noise & can avoid stalling of motor.

The induction motor has advantage as simple construction, reliability, raggedness and low cost has found very wide industrial appellations. Furthermore, in contrast to the commutation Dc motor, it can be used in aggressive or volatile environments since there are no problems with spark and corrosion. These advantages, however, are occupied by control problems when using induction motor in speed regulated industrial drives. These advantages, however, are occupied by control problems when using induction motor in speed regulated industrial drives. Speed control (v/f control) of induction motor requires two stage conversion (ac-dc and dc-ac), but most of the classical inverters gives poor performance.

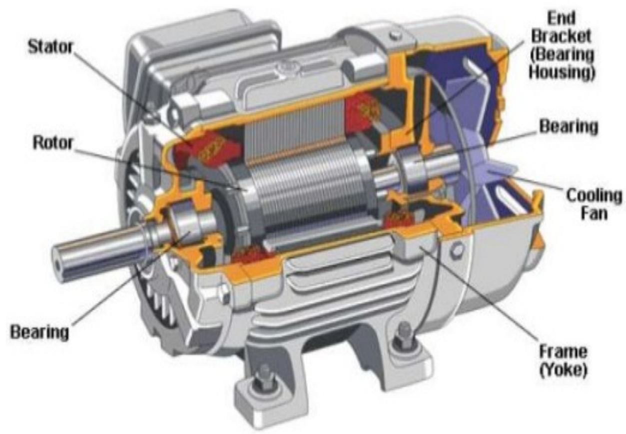

Fig.5. 3- Phase Induction motor drive

VIII. MATLAB/SIMULATION RESULTS

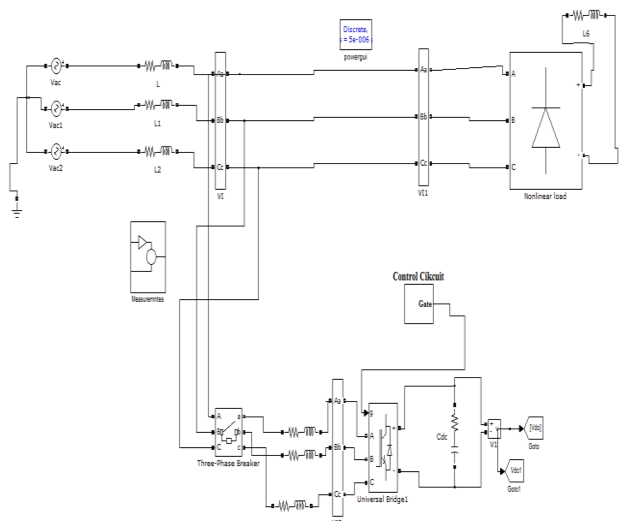

Fig.6. Matlab/Simulink circuit for Power system with D-STATCOM

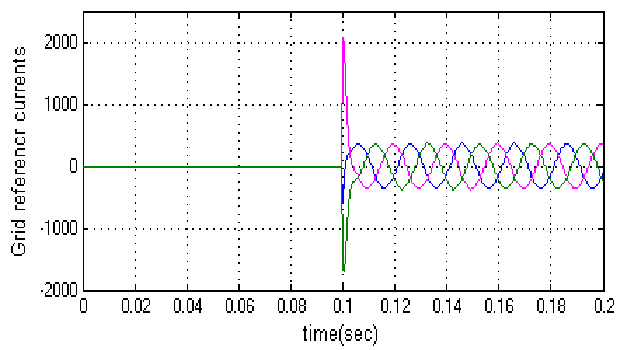

Fig.7. Simulation waveform for Grid reference current

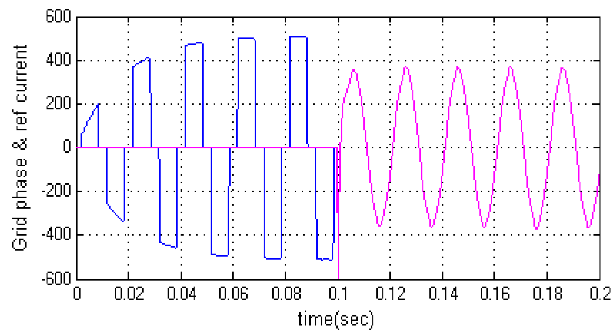

Fig.8. Simulation waveform for Grid phase and reference currents

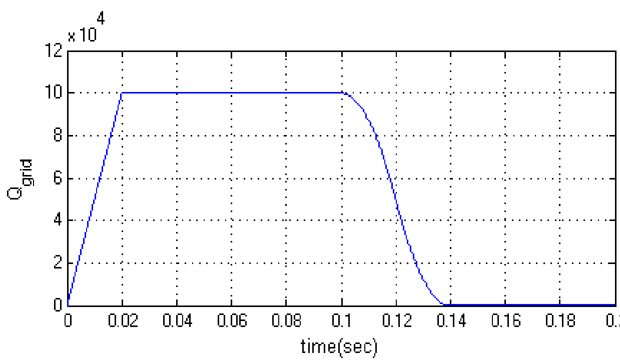

Fig.9. Reactive power generated by Grid

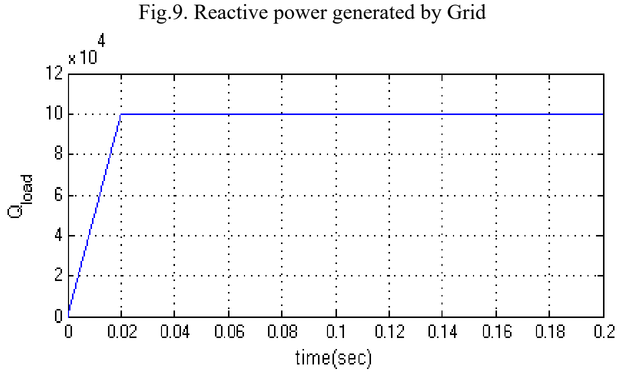

Fig.10. Reactive power demanded by load

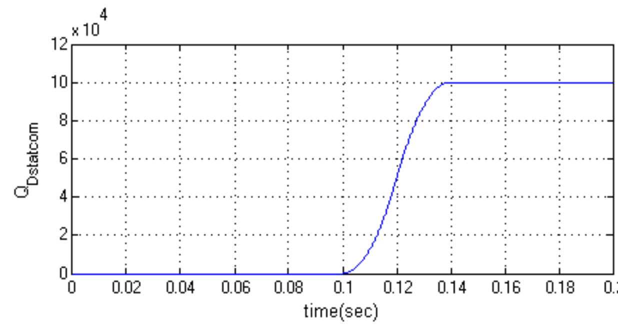

Fig.11. Reactive power supplied by D-STATCOM

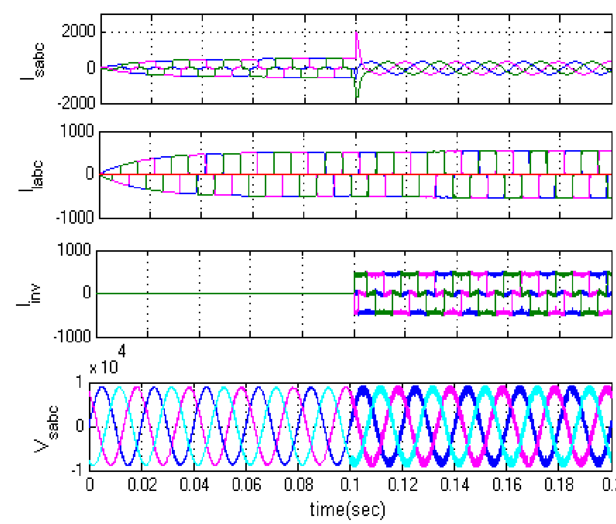

Fig.12. Source current, Load current, D-STATCOM injected harmonic current and Source voltage

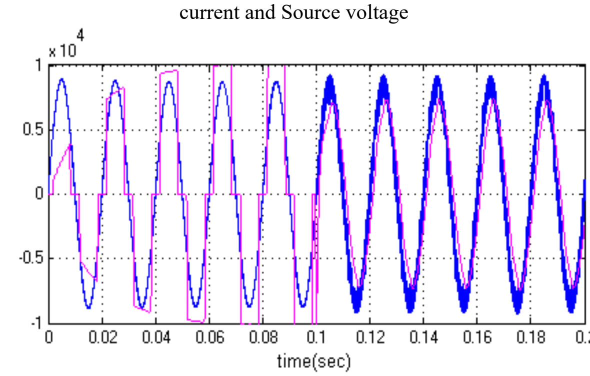

Fig.13. Power factor angle between source voltage and current

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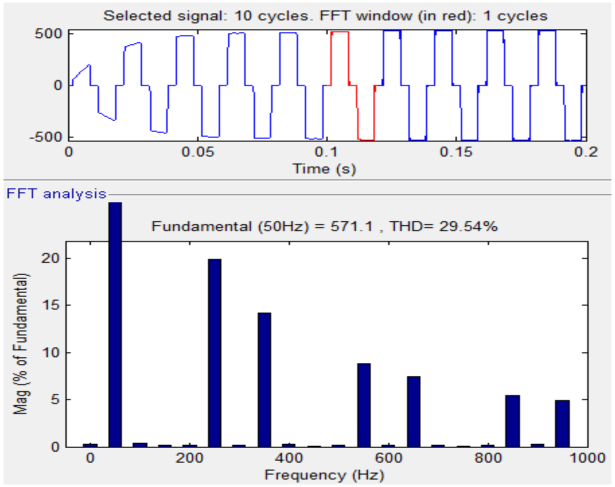


Fig.14. Load current THD

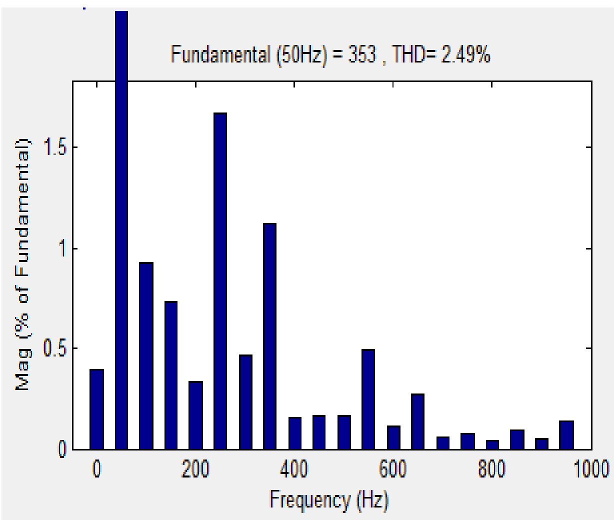


Fig.15 Source current THD

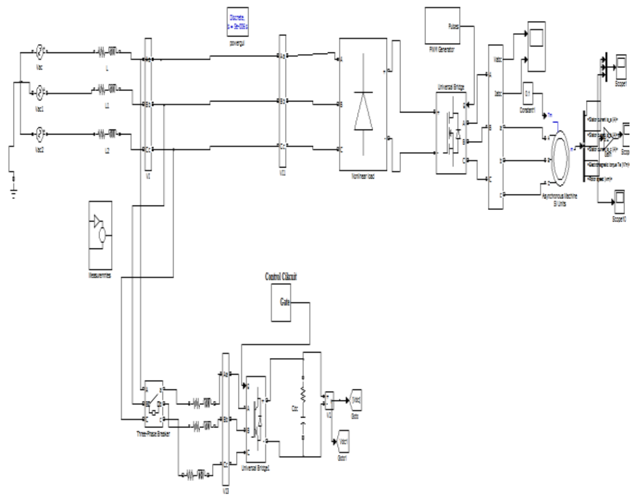
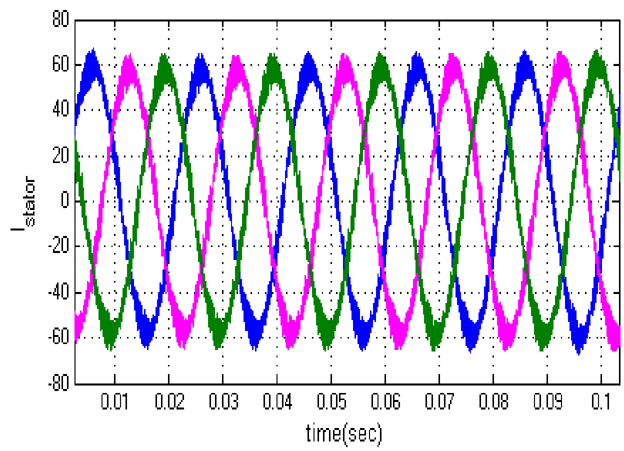
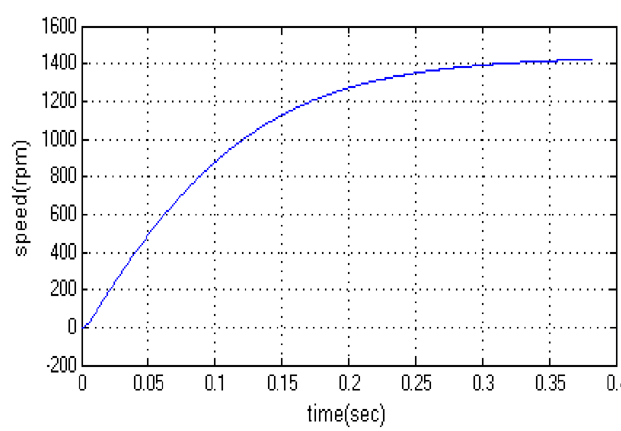


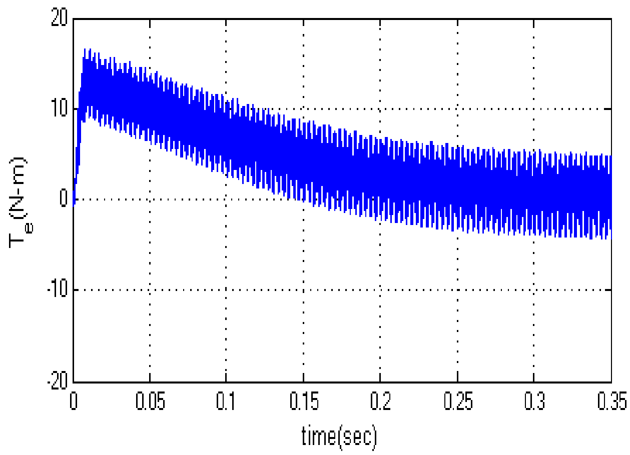
Fig.16. Matlab/Simulink circuit for Power system with D-STATCOM with Induction Motor Drive



(a) Stator Current



(b) Speed



(c) Torque

Fig.17. Simulation waveforms for Induction motor Stator current, Speed and Torque

IX. CONCLUSION

A model of three phase source feeding motor loads has been developed using Simulink tool of standard MATLAB software. Sudden application of an induction motor load results in large starting currents which results in sudden dip in ac terminal voltage at PCC The extent of voltage dip with and without STATCOM controller is compared This voltage dip is of the order of 563% without any controller. This dip is very large and it may affect the functioning of other sensitive equipment connected at PCC Model of STATCOM system applied in shunt configuration has been developed. The objective of work is to study the performance of D-statcom for mitigating voltage sag, interruption, and to improve the power quality in distribution network. The simulation results show that the performance of DSTATCOM system has been found to be satisfactory for improving the power quality at the consumer premises. DSTATCOM control algorithm is flexible and it has been observed to be capable of correcting power factor to unity, eliminate harmonics in supply currents and provide load balancing. It is also able to regulate voltage at PCC.

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