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An Improvement of Power Quality Using 4-Leg (VSC) Based DSTATCOM

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ABSTRACT: Excessive neutral current, harmonics and reactive power burden and unbalance are usually caused through Large number of single-phase linear and nonlinear loads which may be supplied from three phase ac mains with neutral conductor. A four wire DSTATCOM (distribution static compensator) is used for neutral current compensation along with reactive power compensation, harmonics elimination and load balancing. A four-leg voltage–source converter (VSC) with a dc capacitor is used as a four wire DSTATCOM. The proposed control approach is based on synchronous reference frame (SRF) theory. The switching signals for the voltage–source converter (VSC) of the DSTATCOM are derived from the estimated reference supply currents. The load balancing, harmonics elimination and the neutral current compensation are demonstrated along with unity power factor (UPF) and zero voltage regulation (ZVR) modes of operation. The DSTATCOM is able to maintain the self-supported dc bus under various disturbances. MATLAB Simulink toolbox are used to execute the simulations.

KEYWORDS:DSTATCOM, Power quality, SRF theory, ZVR, and UPF.

I.INTRODUCTION

Power quality has become one of the most inexhaustible buzzwords in the power industry since 1980s as stated in the textbook of power quality management. Both electric power utilities and end users are becoming so concerned with the quality of electric power. Paying more attention in power quality in a power system is very essential in today's scenario because of the increase in wide variety of loads that pollute the power system. Inductive loads like induction generators, induction motors, power transformers and arc furnaces, require reactive power for their magnetization and if the reactive power is consumed from the grid, a voltage dip occurs.

The distribution systems are facing severe power quality problems due to the proliferation of different types of linear and non-linear loads such as solid-state controllers, which draw harmonics and reactive currents from ac mains . Similarly, the single-phase linear and non-linear loads in the three-phase four wire distribution systems may lead to unbalance and excessive neutral current resulting in low power factor and increased loss. Moreover, it may lead to poor power quality at AC source such as sag, swell, notch, flicker, unbalance, etc. Because of such severity of power quality problems, several standards have been developed and are being enforced on consumers and utilities. The last decade has seen a marked increase on the deployment of end-user equipment that is highly sensitive to poor quality controlled electricity supply. Several large industrial users are reported to have experienced large financial losses as a result of even minor lapse in the quality of electricity supply. Efforts have been made to remedy the situation, where solutions based on the use of the latest power electronic technologies prominently. Indeed, custom power technology, the low- voltage counterpart of the more widely known flexible ac transmission system (FACTS) technology, aimed at high -voltage power transmission applications, has emerged as a credible solution to solve manyproblems relating to continuity of supply at the end-user level. Both the FACTS and custom power concepts may be directly credited to EPRI (Electric Power Research Institute).

Specifically, among these customs devices emphasis is mainly on the distribution static compensators (DSTATCOM), dynamic voltage restorer (DVR) and unified power quality conditioner (UPQC).

The performance of the DSTATCOM depends on the control algorithm i.e. the extraction of the current components. For this purpose there are many control schemes which are reported in the literature and some of these are instantaneous reactive power (IRP) theory, instantaneouscompensation, instantaneous symmetrical

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components, synchronous reference frame (SRF) theory, computation based on per phase basis, and scheme based on neural network. Among these control schemes instantaneous reactive powertheory and synchronous rotating reference frame are most widely used and is also selected on this research work.

II.LITERATURE SURVEY

Some of the survey literature related to this research reports includes 'Three-Leg VSC and a Transformer Based Three-Phase Four-Wire DSTATCOM for Distribution Systems' and the research have demonstrated the performance of a new topology of three-phase fourwire DSTATCOM consisting of three-leg VSC with a star/delta transformer for neutral current compensation along with reactive power compensation, harmonic elimination and load balancing and also 'Reactive Power Compensation by Controlling the DSTATCOM. Lastly but not the list is 'Comparison of Three leg and Four Leg VSC DSTATCOM for Power Quality Assessment'this shows the comparison of the two different topologies in term of their performances for reactive power compensation, harmonic elimination, load balancing and mitigating circulating power flows in interconnected utilities

III.POWER QUALITY ISSUES

Power quality is ultimately a consumer-driven issue, and the end user's point reference takes priority. Therefore, the following definition of power quality problem is use:

Any power problem manifested voltage, current, or frequency deviations that result in failure or malfunction of customer equipment.

Power quality and reliability cost the industry large amounts due to mainly sags and short-term interruptions. Here we define the reliability as the continuity of supply. The problem of distribution lines is divided into two major categories i.e. power quality, and power reliability. First group consists of harmonic distortions, impulses and swells. Second group consists of voltage sags and outages. Voltage sags is much more serious and can cause a large amount of damage. If exceeds a few cycle, motors, robots, servo drives and machine tools cannot maintain control of process. voltage swell is defined as a sudden drop in the root mean square (R.M.S) voltage and is usually characterized by the remaining (retained) voltage.

Voltage Swell is defined by IEEE 1159 as the increase in the RMS voltage level to 110% - 180% of nominal, at the power frequency for durations of ½ cycles to one (1) minute. It is classified as a short duration voltage variation phenomena, which is one of the general categories of power quality problems

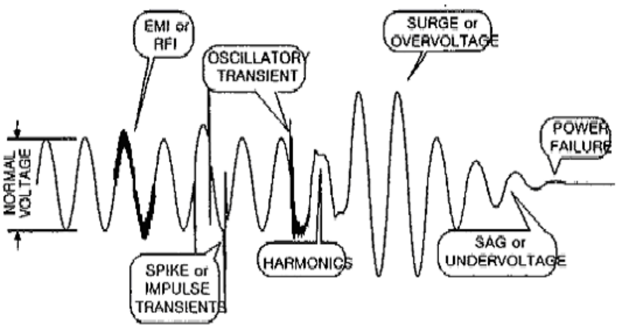

Fig.1. power quality and reliability

For example, a consumer that is connected to the same bus that supplies a large motor load may have to face a severe dip in his supply voltage every time the motor load is switched on. There are also sensitive loads such as hospitals (life support, operation theatre, and patient database system), processing plants, air traffic control, financial institutions and numerous other data processing and service providers that require clean and uninterrupted power. Thus in this scenario in which consumers increasingly demand the quality power, the term power quality (PQ) attains increased significance.

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IV.DISTRIBUTED STATIC COMPENSATOR (DSTATCOM)

D-STATCOM is the most important controller for distribution networks. It has been widely used since 1990s to precisely regulate system voltage, improve voltage profile, reduce voltage harmonics, reduce transient voltage disturbances and load compensation. It is a voltage source inverter based static compensator (similar in many respects to the DVR) that is used for the correction of bus voltage sags.

Distribution Static Compensator (D-STATCOM) otherwise known as shunt voltage controller comprises of a two level voltage source converter (VSC), a dc energy storage device, a coupling transformer connected in shunt to the distribution network and associated control circuit as depicted fig below. The VSC converts the dc voltage across the storage device into a set of three phase ac output voltages. These voltages are in phase and coupled with theac system via the reactance of the coupling transformer. Good setting or adjustment of the phase and magnitude of the D-STATCOM output voltages yield effective control of real andreactive power exchangesbetween the D-STATCOM and ac system. Such configuration provides and permit the device to absorb or generate controllable real and reactive power.

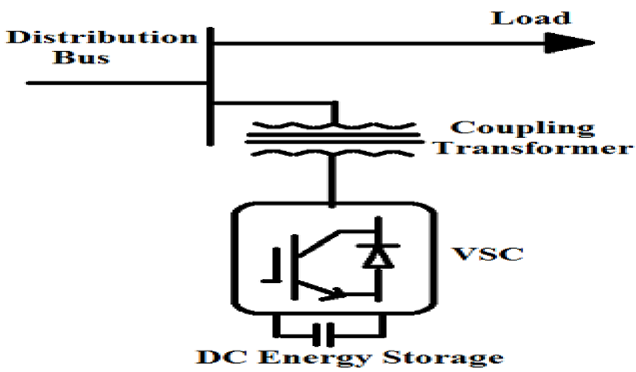

Figure 2. Basic Structure of D-STATCOM

Figure 2. shows the VSC connected in shunt with the ac system and this provides a multifunctional topology which can be used for up to three quite distinct purposes.
a) Correction of power factor.
b) Voltage regulation and compensation of reactive power.
c) Elimination of current harmonics.

V.CONTROL VSC OF DSTATCOM

There are several control approaches available for the generation of reference source currents for the control of VSC of DSTATCOM for three-phase four-wire system such as instantaneous reactive power theory (IRPT), synchronous reference frame theory (SRFT), unity power factor (UPF) based, instantaneous symmetrical components based, etc. The SRFT is used in this investigation for the control of the DSTATCOM. A block diagram of the control scheme is shown in Fig. 3. The load currents (iLa, iLb, iLc), the PCC voltages (VSa, VSb, VSc), and dc bus voltage (Vdc) of DSTATCOM are sensed as feedback signals. Synchronous reference frame is based on the point that the load currents from the a –b–c frame are first of all transformed or converted to the α–β–o frame and then to the d–q–o frame using matrix below

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$$\begin{bmatrix} i_{ld} \\ i_{lq} \\ i_{lo} \end{bmatrix} = 2/3 \begin{pmatrix} \cos\theta & -\sin\theta & \frac{1}{2} \\ \cos(\theta - 120^0) & -\sin(\theta - 120^0) & \frac{1}{2} \\ \cos(\theta + 120^0) & \sin(\theta + 120^0) & \frac{1}{2} \end{pmatrix} \begin{bmatrix} i_{la} \\ i_{lb} \\ i_c \end{bmatrix} \quad (1)$$

This can further be simplified as

$$\begin{bmatrix} i_{ld} \\ i_{lq} \\ i_{lo} \end{bmatrix} = \frac{2}{3} \begin{pmatrix} \cos\theta & -\sin\theta & \frac{1}{2} \\ \cos\left(\theta - \frac{2\pi}{3}\right) & -\sin\left(\theta - \frac{2\pi}{3}\right) & \frac{1}{2} \\ \cos\left(\theta + \frac{2\pi}{3}\right) & -\sin\left(\theta + \frac{2\pi}{3}\right) & \frac{1}{2} \end{pmatrix} \begin{bmatrix} i_{la} \\ i_{lb} \\ i_{lc} \end{bmatrix} \quad (2)$$

Where cos θ and sin θ are obtained using a three-phase phase-locked loop (PLL). A PLL signal is obtained from terminal voltages for generation of fundamental unit vectors for conversion of sensed currents to the d–q–o reference frame. The SRF controller extracts dc quantities using a low-pass filter, and also, the non-dc quantities (harmonics) are separated from the reference signal. The direct-axis and quadrature-axis currents consist of fundamental and harmonic components as

$$i_{Ld} = i_{ddc} + i_{dac} \quad (3)$$

$$i_{Lq} = i_{qdc+} l_{qac} \quad (4)$$

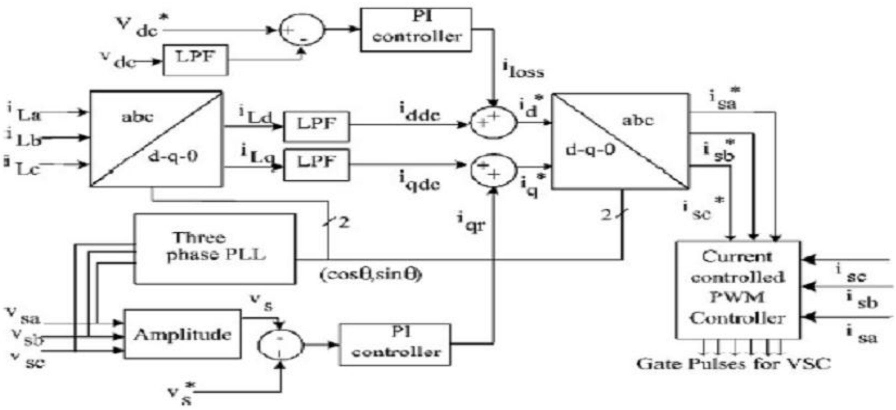

Figure 3. Control algorithm for the three leg VSC based DSTATCOM in a three phase four –wire system.

This figure illustrate the control algorithm of synchronous reference frame in respect of the DSTATCOM with four-legs VSC based.

VI. UNITY POWER FACTOR (UPF) OPERATION OF DSTATCOM

In compensating method for reactive power compensation for UPF operation considers that, the source must deliver the mean value of the direct-axis component of the load current along with the active power component current for maintaining the dc bus and meeting the losses(iloss) in DSTATCOM. The output of PI controller at the dc bus voltage of DSTATCOM is considered as the current (iloss) for meeting its losses.

$$i_{loss(n)} = i_{loss(n-1)} + k_{pd}\left(v_{de_{(n)}} - v_{de_{(n-1)}}\right) + k_{id} v_{de_{(n)}} \quad (5)$$

Where $v_{de_{(n)}} = v_{dc^*} - v_{dc_{(n)}}$ is the error between the reference (v_{dc^*}) and sense to dc voltage at the nth sampling instant. Kpd and Kid are the proportional and theintegral gains of the dc bus voltage PI controller. The reference source current is therefore as,

$$i_{d^*} = i_{d\,dc} + i_{loss} \quad (6)$$

Consequently, the reference source current must be in phase with the voltage at the PCC but with no zero-sequence component. It is therefore obtained by the following reverse Park's transformation with the id* as in (6) and iq*and i0*as zero.

VII.ZERO VOLTAGE REGULATION (ZVR) OPERATION OF DSTATCOM

Similarly the compensating strategy for ZVR operation considers that the source must deliver the same direct axis component, id* along with the sum of quadrature axis current (iqdc) and the component obtained from the PI controller (iqr) used for regulating the voltage at PCC. The amplitude of ac terminal voltage (VS) at the PCC is controlled to its reference voltage (VS*) using the PI controller. The output of PI controller is considered as the reactive component of current (iqr) for zero voltage regulation of ac voltage at PCC. The amplitude of AC voltage (VS) at PCC is calculated from the ac voltages (vsa,vsb, vsc) as,

$$v_s = (2/3)^{1/2}\left(v_{sa}^{\ 2} + v_{sb}^{\ 2} + v_{sc}^{\ 2}\right)^{1/2} \quad (9)$$

Then, a PI controller is used to regulate this voltage to a reference value as,

$$i_{qr_{(n)}} = i_{qr_{(n-1)}} + k_{pq}\left(v_{te(n)} - v_{te(n-1)}\right) k_{iq} v_{te(n)} \quad (7)$$

Where, denotes the error between reference (v_s^*) and actual $(v_{s(n)})$ terminal voltage amplitude at the nth sampling instant. Kpq and Kiq are the proportional and the integral gains of the dc bus voltage PI controller. The reference supply quadrature axis current is as

$$i_q^{\ *} = i_{qdc} + i_{qr} \quad (8)$$

The reference source current is obtained by the following reverse Park's transformation with the id*as iq* and i0*as zero

VIII.CURRENT CONTROLLED PWM GENERATOR

While in a current controller, the sensed and reference supply currents are compared and a proportional controller is used for amplifying current error in each phase before comparing with a triangular carrier signal to generate the gating signals for six IGBT switches of VSC of DSTATCOM

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IX.SIMULATION RESULTS

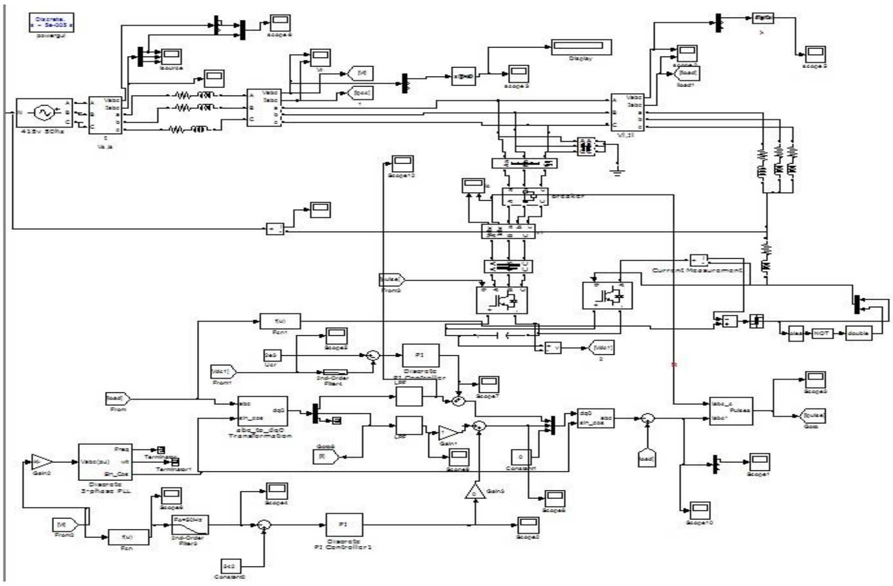

Figure 4 four- leg VSC Based DSTATCOM

Figure 4shows the 4-legs VSC based DSTATCOM for mitigating power quality problems like UPF, ZVR,Load balancing in three phase four wire distribution netwrk.

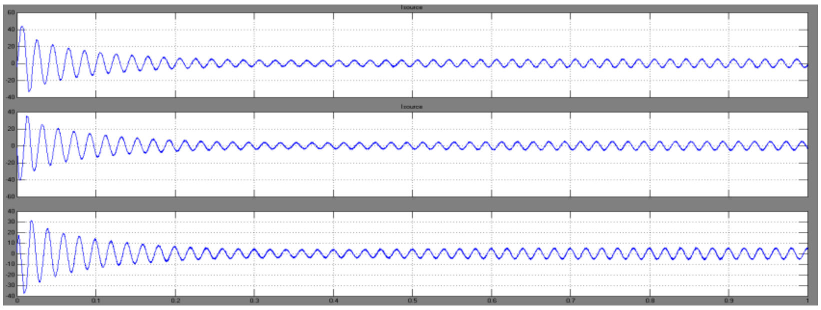

Figure 4.2 source current(amps) vs Time (sec)

This figure illustrate the three source current Ia,Ib,Ic magnitude vs the time in (sec) in the transformation of SRF controller.

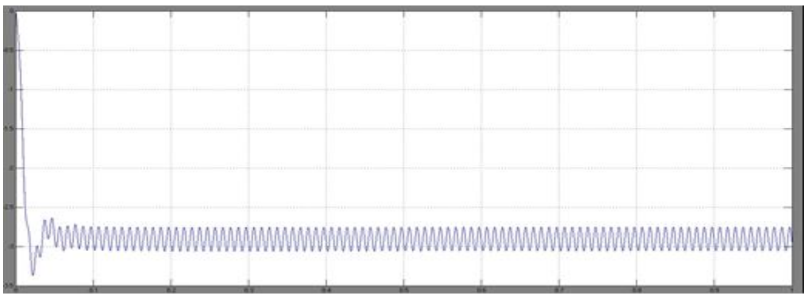

Figure 4.5 voltage and current at pcc vs Time (sec)

This is the terminal voltage and current in the point of common coupling against the Time (sec).

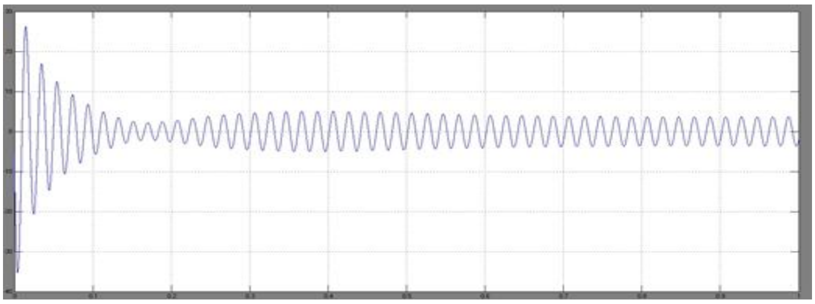

Figure 4.4 Load current vs Time (sec)

This is the wave form behavior of the load connected current or load current versus the time.

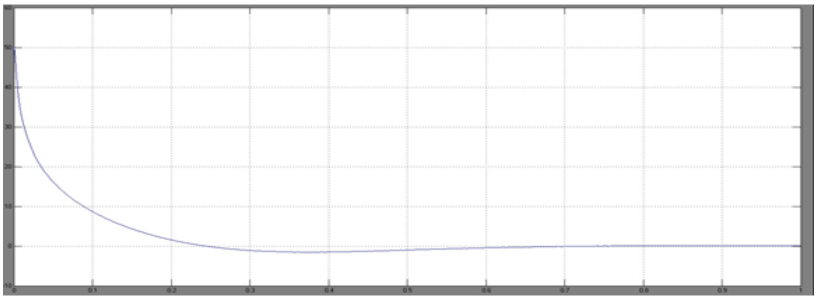

Figure 4.5 Loss current vs Time (sec)

This is the loss current before inclusion of the custom power device DSTATCOM against the time or in respect with time.

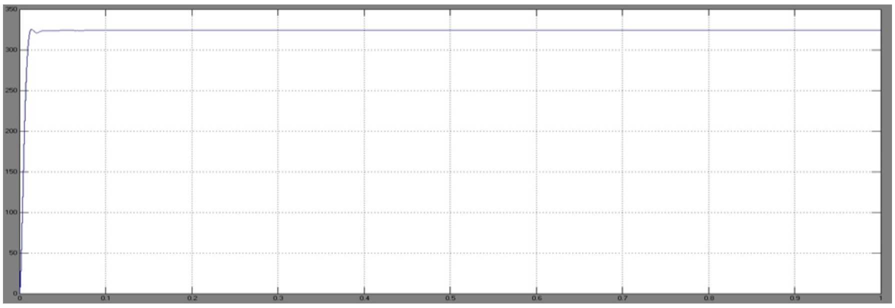

Figure 4.6 Voltage response with PF improvement vs Time (sec)

This figure shows the response of the system power factor after connecting of DSTATCOM to the circuit vs tme (sec)

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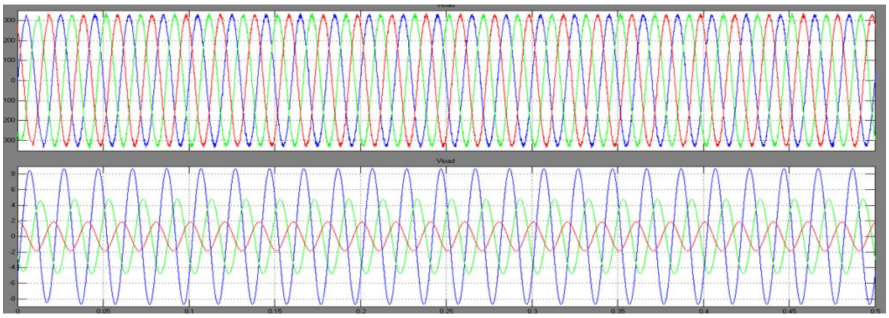

Figure 4.7 final load voltage vs Time (sec)

After inclusion of the DSATCOM to wipe away all the problems in the system the performance of the SRF controller, the final load voltage wave form becomes so functional as it is shown in the above figure.

VIII.CONCLUSION

The performance of a new topology of four-leg VSC DSTATCOM has been demonstrated for reactive power compensation, harmonic elimination, load balancing and mitigating circulating power flows in interconnected utilities. The voltage regulation and power factor correction modes of operation of the DSTATCOM have been observed as expected ones. The dc bus voltage of the DSTATCOM has been regulated to the reference dc bus voltage under varying loads .

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BIOGRAPHY

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