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IMPROVEMENT OF POWER QUALITY IN TRANSMISSION LINE BY USING DSTATCOM

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ABSTRACT

In this paper, a static distribution compensator (DSTATCOM) is implemented to control a distributed power generation system using a control technique based on the proposed composite observer. The problem of power quality is a phenomenon that manifests itself as a non-standard voltage, current, or frequency that causes a malfunction or malfunction of the end-user's equipment. Public utility distribution networks, sensitive industrial loads and critical business operations suffer from various types of interruptions and outages that can lead to significant financial losses. The proposed control technique is used for extracting fundamental components from deformed load currents. These extracted components are used to estimate the currents of the reference source to generate gate signals from DSTATCOM. The proposed control technique is implemented to reduce reactive power, harmonic distortion and load distribution under linear / non-linear loads. The performances of DSTATCOM are considered satisfactory for these consumption loads with a regulated generator voltage at the common coupling point and a self-supporting DC connection of the DSTATCOM voltage generator.

Keywords: DSTATCOM, reactive power compensation, voltage unbalance, weights, harmonic elimination, loadbalancing.

I. INTRODUCTION

The concept of static compensator (STATCOM) is based on the device derivation Flexible AC Transmission System (FACTS) [1] which allows to control the voltage of the line at the point of common coupling (PCC), the balance of loads can compensate or The reactive power of the load can compensate by producing the desired amplitude and phase of the output voltage of the inverter connected to a DC capacitor (energy storage device). The STATCOM connected to the distributed system is called DSTATCOM. There are many possible configurations of Voltage Source Inverter (VSI) and therefore there are many different DSTATCOM configurations

available. There are many different strategies, such as integral proportional controller, sliding mode controller, and nonlinear controller to control DSTATCOM [2-3]. Due to the nonlinear operation of DSTATCOM, the nonlinear controller is preferred over the linear method. The dynamics of the system can be improved by reducing and adjusting the DC voltage of the capacitor in DSTATCOM. The nonlinear arrangement is based on an exact feedback linearization [4]. There is a PI regulator in this control system to control the DC voltage. In addition, some selected PI parameter sets may not be suitable for all operating ranges, and searching for these values is time consuming and complex. Vector-controlled techniques [5] are used to control transducer currents, which results in control with high reactive current. In the nonlinear controller, the generalized averaged method [6] is used to determine the nonlinear invariant continuous model of the system. This technique is particularly interesting because it converts a non-linear system into a linear system [7] in terms of input-output relationship. Only Q axis current should be documented, but it should be noted that, unlike other shunt compensator, a high power storage device, with almost constant voltage, DSTATCOM makes it more robust and also improves reaction speed. This is why control objectives have been implemented in DSTATCOM. First there is the current of the axis q and the second is the voltage of the capacitor in the DC connection. Fortunately, the q-axis detects the perfect matching reference value, but the capacitor voltage is not ideal for reference, due to the presence of a proportional-integral regulator between the current reference number axis error. DC link voltage In other words, the performance indices (sedimentation time, rise time and overshoot) are remarkable values. Therefore, the optimized and accurate determination of the P1 gains can lead to a reduction of the system reaction interruptions.

STATCOM solutions are often used in the transmission system. When used in the distribution system, it is called D-STATCOM (STATCOM in the distribution system). D-STATCOM is an important FACTS controller and uses power electronics to solve many food quality problems that are often faced with distribution systems [8]. Possible D-STATCOM applications include power factor correction, voltage control, load balancing and harmonic reduction. Compared to SVC, the D-STATCOM has a faster reaction time and a compact structure. It is expected that the D-STATCOM in the near future is to

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replace the rolls of SVC and STATCOM are different in terms of structure and function, while choosing the control strategy is related to the main circuit structure and function compensators [9], D-STATCOM and STATCOM use a different control strategy. At present, the use of STATCOM is broad and the strategy is mature, while the introduction of D-STATCOM is rarely mentioned. Numerous control techniques are reported, such as the instantaneous reactive power theory (Akagi et al., 1984), the energy equilibrium theory, and so on. This article is an indirect technique of current control (Singh et al., 2000a, b) used to obtain a port. Signals for isolated gate bipolar transistor inverter (IGBT) devices used in the controlled voltage source current (CC-VSI) that functions as a DSTATCOM. DSTATCOM model was developed using MATLAB to study the transient analysis of the distribution system under symmetric / asymmetric linear phase and single-phase non-linear loads (diode rectifier with R and R charge-C). The results of the simulation will be presented during equilibrium.

The causes of power quality problems are generally complex and difficult to detect. Technically speaking, the ideal AC line supply by the utility system should be a pure sine wave of fundamental frequency (50/60Hz). Different power quality problems, their characterization methods and possible causes are discussed above and which are responsible for the lack of quality power which affects the customer in many ways. We can therefore conclude that the lack of quality power can cause loss of production, damage of equipment or appliances or can even be detrimental to human health. It is therefore imperative that a high standard of power quality is maintained [5].

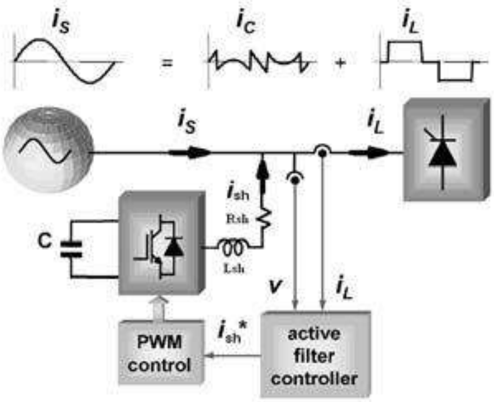

Fig. 1:- System configuration of DSTATCOM

When the STATCOM is applied in distribution system is called DSTACOM (Distribution-STACOM) and its configuration is the same, or with small modifications, oriented to a possible future amplification of its possibilities in the distribution network at low and medium voltage, implementing the function so that we can describe as flicker damping, harmonic filtering and short interruption compensation.

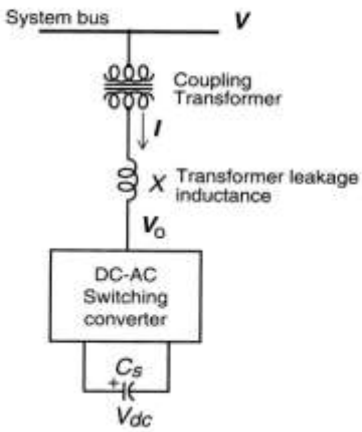

Fig 2:- Reactive power generation by a rotating a voltage-sourced switching converter.

Distribution STATCOM (DSTATCOM) exhibits high speed control of reactive power to provide voltage stabilization, flicker suppression, and other types of system control. The DSTATCOM utilizes a design consisting of a GTO- or IGBT-based voltage sourced converter connected to the power system via a multi-stage converter transformer. The DSTATCOM protects the utility transmission or distribution system from voltage sags and/or flicker caused by rapidly varying reactive current demand. In utility applications, a DSTATCOM provides leading or lagging reactive power to achieve system stability during transient conditions. The DSTATCOM can also be applied to industrial facilities to compensate for voltage sag and flicker caused by non-linear dynamic loads, enabling such problem loads to co-exist on the same feeder as more

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sensitive loads. The DSTATCOM instantaneously exchanges reactive power with the distribution system without the use of bulky capacitors or reactors.

A static inverter generator (var) comprises a plurality of gate-controlled power semiconductor switches (GTO thyristor). The port assignments for these devices are generated by the internal control converter (which is part of the actual var generator) in response to the demand for reactive and / or actual power reference signals. The reference signals are provided by controllable VAR generation methods, the controller or the external system, operating instructions and system variables, which determine the functional activity of the STATCOM. Internal control is an integral part of the converter. Its main function is to control the power switches of the inverter to generate a fundamental waveform of the output voltage with the magnitude angle and phase required in synchronism with the AC system.

II. SYSTEM CONFIGURATION

Fig.1 shows the basic circuit diagram of a D-STATCOM system with non -linear load connected three phase three wire distribution system. A nonlinear load is realized by using a three phase full bridge diode rectifier. A three phase voltage source converter (VSC) working as a D-STATCOM is realized using six insulated gate bipolar transistor (IGBTs) with anti-parallel diodes. At ac side, the interfacing inductors are used to filter high frequency components of compensating currents. The first harmonic load currents of positive sequence are transformed to DC quantities. The first harmonic load currents of negative sequence and all the harmonics are transformed to non-DC quantities and undergo a frequency shift in the spectrum. The voltage regulator in the converter DC side is performed by a proportional –integral (P-I) controller. Its input is the capacitor voltage error vdcref-vdc and through the regulation of the first harmonic active current of positive sequence. It is possible to control the active power flow in the VSI and thus the capacitor voltage vdc. The dynamics of each VSC are modeled by solving differential equations governing two modes of the inverter. The switching of the inverter is done by monitoring the reference and actual currents and comparison of error with the hysteresis band of hysteresis current controller [10].

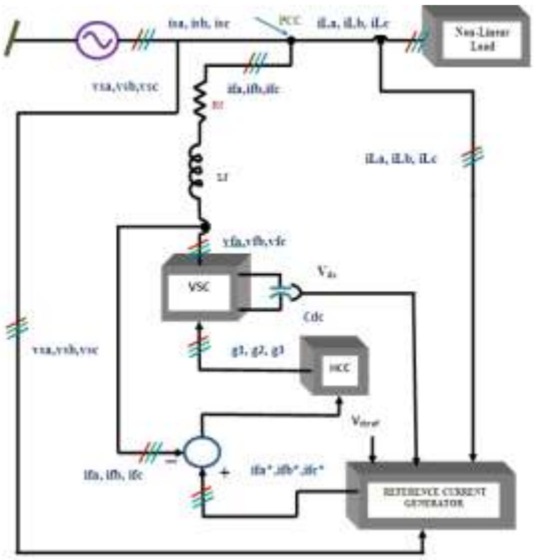

Fig 3:- System Design of D-STATCOM

III. CONTROL ALGORITHM

Instantaneous p-q Theory was initially proposed by Akagi. This theory is based on the transformation of three phase quantities to two phase quantities in α-β frame and the Instantaneous active and reactive power is calculated in this frame. Sensed inputs V_{sa}, V_{sb} and V_{sc} & i_{La} , i_{Lb} and i_{Lc} are fed to the p-q controller shown in fig.2 and these quantities are processed to generate reference commands(i^*_{fa} , i^*_{fb} , i^*_{fc}) which are fed to a hysteresis based PWM current controller to generate switching pulses for D- STATCOM.

The system terminal voltages are given as

$$V_{sa} = V_m \sin wt$$
$$V_{sa} = V_m \sin(wt - 120^0)$$
$$V_{sa} = V_m \sin(wt - 240^0) \quad (1)$$

and the respective load current are given as

$$i_{La} = \sum I_{Lan} \sin\{n(wt) - \theta_{an}\}$$
$$i_{Lb} = \sum I_{Lbn} \sin\{n((wt) - 120^0) - \theta_{an}\}$$
$$i_{Lc} = \sum I_{Lbn} \sin\{n((wt) - 240^0) - \theta_{bn}\} \quad (2)$$

In a, b and c coordinates a, b and c axes are fixed on the same plane apart from each other by 2π/3. These phasors can be transformed into α-β coordinates using Clarke's transformation as follows.

$$\begin{bmatrix} V_\alpha \\ V_\beta \end{bmatrix} = \sqrt{2/3}\begin{bmatrix} 1 & \frac{-1}{2} & \frac{-1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix}\begin{bmatrix} V_{sa} \\ V_{sb} \\ V_{sc} \end{bmatrix} \quad (3)$$

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \sqrt{2/3}\begin{bmatrix} 1 & \frac{-1}{2} & \frac{-1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix}\begin{bmatrix} i_{La} \\ i_{Lb} \\ i_{Lc} \end{bmatrix} \quad (4)$$

Where α and β axes are the orthogonal coordinates. Conventional instantaneous power for three phase circuit can be defined as

$$p = v_\alpha i_\alpha + v_\beta i_\beta \quad (5)$$

Where p is equal to conventional equation

$$p = v_{sa} i_{sa} + v_{sb} i_{sb} + v_{sc} i_{sc} \quad (6)$$

Similarly the instantaneous reactive power is defined as

$$q = v_\beta i_\alpha - v_\alpha i_\beta \quad (7)$$

Therefore in matrix form, instantaneous real and reactive power are given as

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} v_\alpha & v_\beta \\ v_\beta & -v_\alpha \end{bmatrix}\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} \quad (8)$$

The α-β currents can be obtained as

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \frac{1}{\mathrm{V}}\begin{bmatrix} v_\alpha & v_\beta \\ v_\beta & -v_\alpha \end{bmatrix}\begin{bmatrix} p \\ q \end{bmatrix} \quad (9)$$

where $\mathrm{V} = v_\alpha^2 + v_\beta^2$

Instantaneous active and reactive powers p and q can be decomposed into an average (dc) and oscillatory

$$p = \bar{p} + \mathring{p}$$
$$q = \bar{q} + \mathring{q} \quad (10)$$

Where and are the average dc part and are the oscillatory (ac) part of these real and reactive instantaneous power. Reference currents are calculated to compensate the instantaneous reactive and the oscillatory component of the instantaneous active power. Therefore the reference compensating currents and in α-β coordinate can be expressed as

$$\begin{bmatrix} i_{f\alpha}^* \\ i_{f b}^* \end{bmatrix} = \frac{1}{\mathrm{V}}\begin{bmatrix} v_\alpha & v_\beta \\ v_\beta & v_\alpha \end{bmatrix}\begin{bmatrix} \pm p \\ q \end{bmatrix} \quad (11)$$

The oscillatory part of real power p is obtained by using 4th order low pass Butterworth filter of cut-off frequency 25 Hz. These currents can be transformed in abc quantities to find reference currents in a-b-c coordinates using reverse Clarke's transformation.

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$$\begin{bmatrix} i_{fa}^* \\ i_{fa}^* \\ i_{fa}^* \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ -1/2 & \frac{\sqrt{3}}{2} \\ -1/2 & \frac{-\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_{f\alpha}^* \\ i_{f\beta}^* \end{bmatrix} \quad (12)$$

IV. PERFORMANCE INDICES

Total harmonic distortion

The total harmonic distortion (THD) is a measurement of the harmonic distortion present in a signal and is defined as the ratio of the sum of the powers of all harmonic components to the power of the fundamental frequency. It is expressed as a percent of the fundamental and is defined as

$$THD(current) = \sqrt{\sum_{h=2}^{50} I_H^2} \; / \; I$$

Total harmonic distortion (THD) is an important aspect in power systems and it should be kept as low as possible. Lower THD in power systems means higher power factor, lower peak currents, and higher efficiency. Low THD is such an important feature in power systems that international standards such as IEC 61000-3-2 set limits on the harmonic currents of various classes of power equipment.

V. RESULTS AND DISCUSSION

To investigate the performance of the D-STATCOM for p-q control algorithm, simulations are performed on MATLABplatform. A three phase three wire distribution system with parameters given below is considered for simulation. The performance of the control algorithm is evaluated based on two different cases.

System Parameters:

Supply voltage:400Vrms (L-N), 50Hz, three phasebalanced, Sourceimpedance's=0.01Ω,Ls=.0005mH, Nonlinear load: Three phase full bridge diode rectifier with load (L=10mH,RL=20Ω) DC storage Capacitor Cdc=500μF Interface inductor Lf=2.2mH, Rf=0.1Ω, DC Link voltage Vdc=1000V

MATLAB with SIMULINK and Sim Power System tool boxes is used for the development of the simulation model of a DSTATCOM and its control algorithm. The performance of the control algorithm is observed under non linear loads.

The control scheme is implemented using MATLAB software. In this work, the performance of VSC based power devices acting as a voltage controller is investigated. Moreover, it is assumed that the converter is directly controlled (i.e., both the angular position and the magnitude of the output voltage are controllable by appropriate on/off signals) for this it requires measurement of the rms voltage and current at the load point.

The DSTATCOM is commonly used for voltage sags mitigation and harmonic elimination at the point of connection. The VSC generates a three-phase ac output current which is controllable in phase and magnitude. These currents are injected into the ac distribution system in order to maintain the load voltage at the desired voltage reference.

D-STATCOM, based on voltage-source converter (VSC), has been improving the power factor of the load locally by injecting suitable reactive power in the power distribution line. The amplitude of the output voltage of the D-STATCOM is made greater than the system voltage for the purpose of controlling the VAR generation. Thus it can internally generate capacitive reactive power to be used for shunt compensation.

Table1 Thd &Power Factor

Control strategy	**THD (in %)**	**Power Factor**
After Compensation	6.22	0.998
Before Compensation	9.32	0.863

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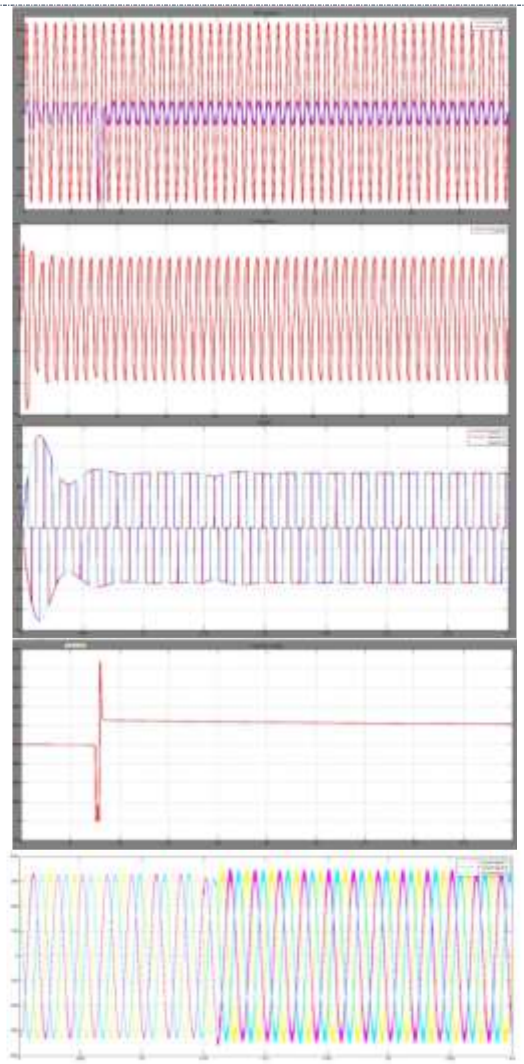

Fig 4:- (a) UPF operation ,(b) load current , (c) shunt reactive current (d) capacitor voltage and (e) load voltage

VI. CONCLUSION

In this work, a fast and cost effective DistributionSTATCOM (DSTATCOM) is proposed for mitigating theproblem of harmonic elimination, load balancing and reactivepower compensation is done in order to mitigate powerquality problems. A controller which is based on Proportional controller technique is used which utilizes the error signalwhich is the difference between the reference current andactual measured load current to trigger the switches of aninverter using a Pulse Width Modulation (PWM) scheme. It isclear from the results that the power quality of the system withRL load as in IEEE data can be compensated effectively usingthe control algorithm and DSTATCOM.

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