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Reducing of THD using DSTATCOM in Distribution Network against Non-Linear Loads

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ABSTRACT: Power Quality in electrical networks is one of today's most concerned areas of electric power system. It has become the most productive concepts in the power industry. The problem is an occurrence manifested as a non-standard voltage, interruptions, unbalances, harmonics, etc., that result in a failure or mis-operation of the equipment. This paper shows the effectiveness of DSTATCOM (Distribution STATic COMpensation) in the reduction of harmonics in the distribution network, connected to the non-linear loads, here DSTATCOM is used to correct the line currents and minimize the THD(Total Harmonic Distortion) value by using IRP(Instantaneous reactive power)theory as the control. The validity of proposed method and achievement of desired compensation are confirmed by the results of the simulation in MATLAB/SIMULINK.

KEYWORDS: Power quality, THD, DSTATCOM, IRP control, VSC.

I.INTRODUCTION

Power quality may be defined as the "Degree to which both the utilization and delivery of electric power affects the performance of electrical equipment. " The vigorous use of power electronic converters and non-linear loads resulted in the deterioration of power quality. This also includes high reactive power burden, harmonic currents, voltage flicker, voltage regulation, sag and swell, load unbalances etc. This paper deals with the harmonics posed into the power system due to non-linear loads, this loads deviate the sinusoidal voltage and current waveform to non-sinusoidal. This distortion in waveform due to harmonics is called as harmonic distortion, which is measured in terms of index-THD (Total Harmonic Distortion)[2][3]. It can be expressed as theRatio of the square root of the sum of squares of the rms value of harmonic component to the rms value of the fundamental component is defined as Total Harmonic Distortion.Harmonic distortion is load sensitive, devices that draw the non-sinusoidal current from sinusoidal voltage sources cause it. If the harmonics are increased to an extent then the whole system will be out of sequence. In this paper the effort is made to reduce the THD[2] value to least minimum value. So, that the power quality is improved. This can be done by using the custom power device DSTATCOM[1] which is a voltage source converter VSC based power electronic device on the distribution network. Usually this device is supported by short term energy stored in a dc capacitor [3]. The control technique used for the DSTATCOM control is Instantaneous reactive power theory (IRP)

II.DISTRIBUTION STATIC COMPENSATOR

A Static compensator is a flexible ac-transmission system (FACTS)[1] controller, which can either absorb or deliver reactive power to a power system. DSTATCOM is proposed for compensation of reactive power and unbalances caused by various non-linear loads in distribution system. The DSTATCOM is based on the principle of voltage source converter VSC[4], in this paper we use it for the correction of line currents. DSTATCOM is an effective measure to maintain the stability and to improve power quality[3] of distribution grid. It is a shunt controller used to regulate voltage by generating or absorbing reactive power. It is capable of generating continuously variable inductive or capacitive shunt compensation at a level up its maximum MVA rating. Basically, the DSTATCOM system is comprised of three main parts: a VSC, a set of

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coupling reactors and a controller. The basic principle of a D-STATCOM installed in a power system is the generation of a controllable ac voltage source by a voltage source converter (VSC) connected to a dc capacitor (energy storage device). The ac voltage source, in general, appears behind a transformer leakage reactance. The active and reactive power transfer between the power system and the D-STATCOM is caused by the voltage difference across this reactance. The D-STATCOM is connected in shunt with the power networks at customer side, where the power quality problem is a concern. All required voltages and currents are measured and are fed into the controller to be compared with the commands. The controller then performs feedback control and outputs a set of switching signals to drive the main semiconductor switches (IGBT's, which are used at the distribution level) of the power converter accordingly. Therefore DSTATCOM checks the line waveform with respect to the reference ac signals and provide correct amount of leading or lagging reactive current compensation. In this paper the dstatcom is used for elimination of harmonics in distribution network and thereby reduce the THD value.

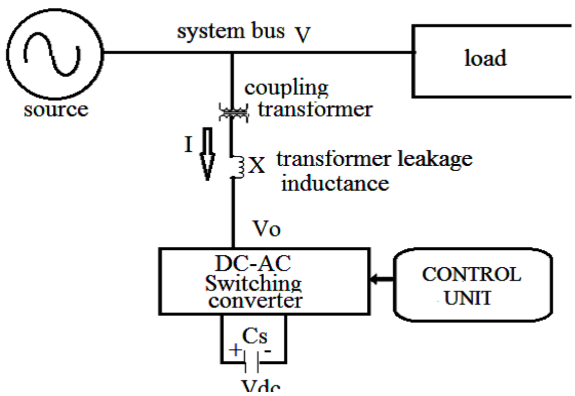

Fig. 1 Single-line diagram of D-STATCOM

III.VOLTAGE SOURCE CONVERTER

Three phase Voltage Source Converter (VSC) is heart of most new FACTS and custom power[5] equipment. It may be employed as a series or shunt element or combination of both. A voltage-source converter is a power electronic device,which can generate a sinusoidal voltage with any required magnitude, frequency and phase angle. Voltage source converters are widely used in adjustable- speed drives, but can also be used to eliminate harmonics, mitigate voltage dips etc. The converter is normally based on some kind of energy storage, which will supply the converter with a DC voltage. The solid-state electronics in the converter is then switched to get the desired output voltage. Normally the VSC is used for power quality issues like harmonics, voltage dip mitigation and flicker etc., Voltage source converters (VSC) are commonly used to transfer power between a dc system and an ac system or back to back connection for ac systems with different frequencies, Depending on the converter rating, series-connected IGBT valves are arranged in either a three-phase two-level or three-level bridge. A basic VSC structure is shown in Fig.3 where Rs and Ls represent the resistance and inductance between the converter ac voltage (VC) and the ac system voltage (Vs) and Is is the current injected into the grid. A dc capacitor is connected on the dc side to produce a smooth dc voltage. The switches in the circuit represent controllable semiconductors, such as IGBT or power transistors. 6-pulse D-STATCOM configuration with the IGBT's used as power devices. The IGBTs are connected anti parallel with diodes for commutation purposes and charging of the DC capacitor .For converter the most important part is the sequences of operation of the IGBTs. The IGBTs signals are referred to the Pulse Width Modulation (PWM) that will generate the pulses for the firing of the IGBTs. IGBTs are used in this simulation because it is easy to control the switch on and off of their gates and suitable for the D-STATCOM.[6]

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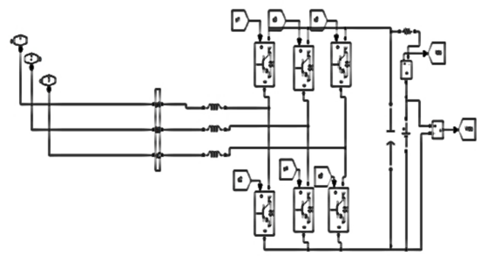

Fig. 2 Matlab model of dstatcom

IV.IRP CONTROL OF DSTATCOM

A theory based on instantaneous values in three-phase power systems with or without neutral wire, and is valid for steady-state or transitory operations, as well as for generic voltage and current waveforms called as Instantaneous Reactive Power(p-q) theory[9][8] which consists of an algebraic transformation (Clarke transformation) of the three-phase voltages in the *a-b-c* coordinates to the α-β-*0* coordinates, it is then followed by the calculation of the p-q theory instantaneous power components. The mathematical computation of control technique is shown below.

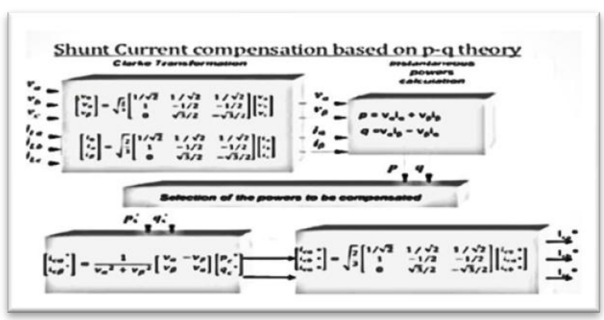

Fig.3 Block diagram of IRP control

From the fig.3.where v_a v_b v_c are the phase voltages, i_a i_b i_c are the phase currents. The instantaneous three phase power is given by

$$P_{3\emptyset}(t)= v_a\, i_a + v_b\, i_b + v_c\, i_c = v_\alpha\, i_\alpha + v_\beta\, i_\beta + v_0\, i_0 = p_a(t)+p_b(t)+p_c(t)= p_\alpha(t)+p_\beta(t)+p_0(t)= p(t)+p_0(t) \quad (1)$$

Where $p = p_\alpha + p_\beta$ is instantaneous real power, and $p_0(t)=v_0 i_0$ is the instantaneous zero sequence power.There is an advantage of using the transformation of α-β-0 is to separate the zero sequence component of the system. The real and the reactive power measurement can be given by[9]

$$P(t)=i_\alpha v_\alpha + i_\beta v_\beta \quad (2)$$

$$Q(t)=v_\alpha i_\beta - v_\beta i_\alpha \quad (3)$$

the reactive power written in terms of a-b-c components as

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$q=-[(v_a-v_b)i_c+(v_b-v_c)i_a+(v_c-v_a)i_b]/\sqrt{3}$ (4)

the powers p and q can be rewritten as

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} v_\alpha & v_\beta \\ -v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} \quad (5)$$

From this matrix equation ,

$$\Delta = v_\alpha^2 + v_\beta^2 \quad (6)$$

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \frac{1}{\Delta} \begin{bmatrix} v_\alpha & -v_\beta \\ v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} p \\ q \end{bmatrix} \quad (7)$$

Separating the active and reactive parts the current components are

$i_{\alpha p}=v_\alpha p/\Delta$, $i_{\alpha q}=-v_\beta q/\Delta$, $i_{\beta p}=v_\beta p/\Delta$, $i_{\beta q}=v_\alpha q/\Delta$

power in phases α and β can be separated and we get the power components as

$p_{\alpha p}= v_\alpha i_{\alpha p} = v_\alpha^2 p/\Delta$ (8)

$p_{\alpha q}= v_\alpha i_{\alpha q}= -v_\alpha v_\beta q/\Delta$ (9)

$p_{\beta p}= v_\beta i_{\beta p} = v_\beta^2 p/\Delta$ (10)

$p_{\beta q}= v_\beta i_{\beta q}= v_\alpha v_\beta q/\Delta$ (11)

Therefore, the three phase active power can be rewritten as

$P_3\emptyset(t)= p_\alpha+ p_\beta + p_0 = p_{\alpha p} + p_{\alpha q} + p_{\beta p} + p_{\beta q} + p_0 = p_{\alpha p}+ p_{\beta p}+p_0$ (12)

from equations (9) and (11)

$p_{\alpha q} +p_{\beta q} = 0$

$p_{\alpha p}$ -α axis instantaneous active power.

$p_{\beta p}$ -β axis instantaneous active power.

$p_{\alpha q}$ -α axis instantaneous reactive power.

$p_{\beta q}$ -βaxis instantaneous reactive power.

It is observed that the reactive power corresponds to the parts of instantaneous power, which is dependent on the instantaneous imaginary power *q*, in each independent phase and vanishes when added$p_{\alpha q} +p_{\beta q} = 0$, in a two- phase(α-β)system. Instantaneous real power *p*, gives the net energy per second being transported from source to load and vice-versa at any time, which is dependent only on the voltage and currents in phases α and β and has no zero-sequence present.

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V.MODELLING OF CONTROL

The reactive and harmonic compensation is carried by injecting appropriate currents into the circuit through a compensator ie., DSTATCOM. Firstly, the three phase voltages and current are transformed from a-b-c coordinates to the α-β-0 coordinates, and p, q , Δ ,p_0 are designed as shown in Fig.4. Then the real power is calculated using α-β coordinates.

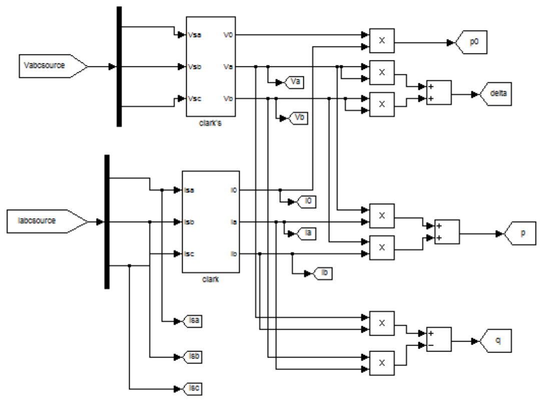

Fig.4 Clarks transformation

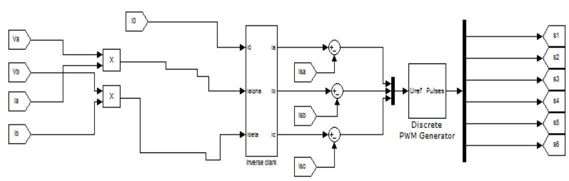

Fig.5 Inverse clarks transformation

Next is the calculation of current injected into the system The current computed in this way is done by the two coordinates. So it is required for the transformation of two coordinates (α-β) into the a-b-c coordinates as the system will take three phase currents. This is accomplished by using inverse Clarke transformation in fig.5. Then this current is injected into the power system with the help of pulse generators as the IGBTs accepted the signals in the form of pulses. The computation of current in α-β coordinates and a-b-c coordinates.

VI.SIMULINK BASED MODELS

As discussed before, the DSTATCOM is connected in shunt to the distribution network via coupling transformer, the effort is made to minimize the harmonics and reduce the THD value. The harmonics produced in the system should be in permissible limits otherwise it leads to malfunctions which results in discontinuity of supply to the customers. DSTATCOM is connected with six pulse generators which provides gating signals to six IGBT/diode with a delay time. By connecting the DSTATCOM in shunt and using the IRP control to it, the THD value has been reduced to some extent by improving the power quality. The models are done in Simulink, with dstatcom and without dstatcom when connected to the non-linear loads, here DTC induction motor drive, and DC motor. In the fig.6.the DTC induction motor drive is given without dstatcom,.

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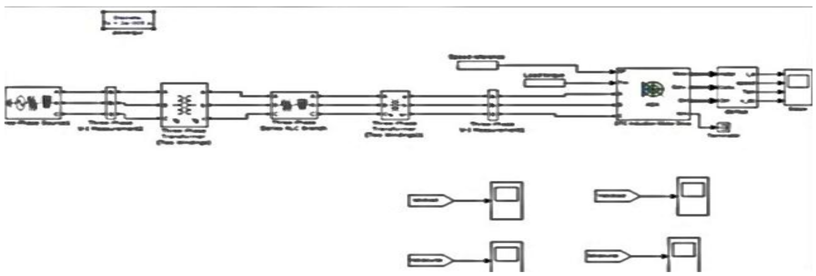

Fig.6 DTC Induction motor drive without dstatcom

The results of above model are simulated and the thd value is shown in the below fig.7.

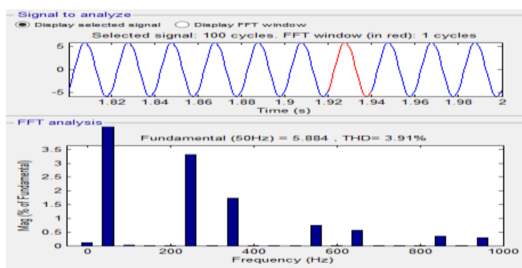

Fig.7 Thd of the DTC induction motor drive without dstatcom

The fig.8. shows the simulation of the DTC induction motor with dstatcom andcan observe the changes of the load before and after connecting the dstatcom the thd value varies for both.

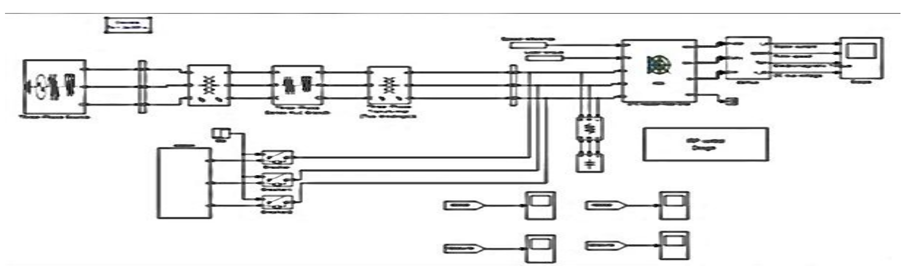

Fig.8 DTC Induction motor drive without dstatcom

After simulating the DTC induction motor drive with dstatcom the thd value is low when compared to the model without connecting dstatcom .the results are shown in the fig.9.

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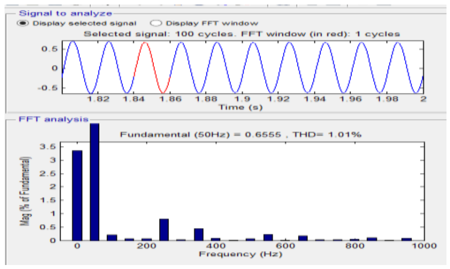

Fig.9 Thd of the DTC induction motor drive without dstatcom

If the non- linear load hereDC MOTOR, is connected to the dstatcom.It is observed that THD value is more when not compensated, but after connecting to the dstatcom the THD value is minimized. The Simulink model of the DC motor is shown in the fig .10, and the results before and after the step time are clearly mentioned.

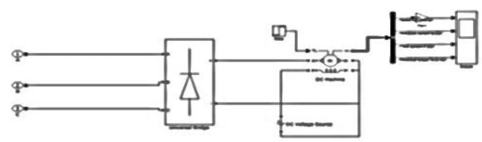

Fig.10 Model of dc motor in Simulink

Fig.11. shows the results when dc motor acts as the load when not connected to dstatcom.

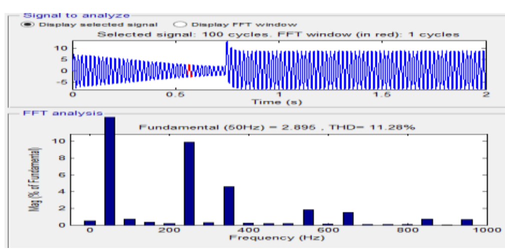

Fig.11 DCmotor without dstatcom

The fig.12 shows the results of the dc motor when connected to the dstatcom , the thd value can be observed to be reduced after connecting dstatcom.

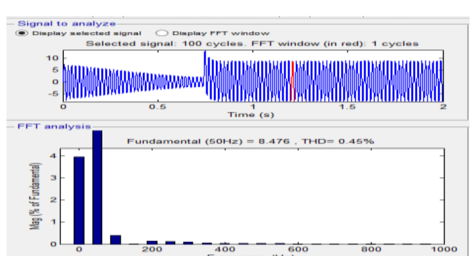

Fig.12 DCmotor with dstatcom

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VII.PARAMETERS

Non-linear loads are considered in the proposed models and the distribution static compensator control is modeled in such a way that the harmonics distortion in the current is mitigated. Given the basic parameters to both the loads. As shown in the tabular coloumn. Thus, by the implementation of the DTSATCOM at the point of common coupling, the THD values have been minimized to the least according to the standards.

S. No.	System quantities	Standards
1	Source	3 phase, 11kV,50 Hz
2	Source resistance and inductance	0.8929 ohms, 16.58mH
3	Three winding transformer	250 MVA, 50Hz
	Winding 1	11kV,0.002pu, 0.08pu
	Winding 2	132kV,0.002pu, 0.08pu
	Winding 3	132kV,0.002pu, 0.08pu
4	Two Winding Transformer	250MVA, 50 Hz
	Winding 1	132kV,0.002pu, 0.08pu
	Winding 2	11kV,0.002pu, 0.08pu
5	IGBT Diode	6 no.
6	Capacitor	1microfarad, 100V
7	DC volatge source	20000V
8	Induction motor power	12865VA
9	No. of poles	4
10	Inertia	0.089kg*m^2

Tabular column showing the results of loads before and after connecting the DSTATCOM with both the DTC induction motor drive and DC motor.

NAME OF LOAD	DSTATCOM	THD%
DTC INDUCTION MOTOR DRIVE	NO	3.91
	YES	1.01
DC MOTOR	NO(0.74)	9.91
	YES(after 0.74)	0.45

VIII.CONCLUSION

The paper presented the study and simulation model of custom power equipment, namely D-STATCOM. and applied them for power quality problem such as elimination of harmonics and minimization of THD. The highly develop graphic facilities available in MATLAB is used to conduct all the aspect of model implementation and to carry out extensive simulation studies. A new control technique which transforms the three phase voltages and currents in the a-b-c coordinates to α-β-*0* coordinates is used. The simulated results shows good accuracy as per the reported index journals. DSTATCOM shows the effectiveness in mitigating the current harmonics.

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