IMPACTS OF THE DISTRIBUTED GENERATOR AND DSTATCOM DEVICES ON POWER QUALITY OF UTILITY CONNECTED GRID

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***Abstract*: This paper proposes two schemes to meet the different power quality challenges in the utility connected grid due to micro-grid applications in distribution networks by using of three phase distributed Generators (DG) and distribution static compensator (DSTATCOM). The impacts of these devices in stability and protection system of a utility connected grid system to achieve an enhancement of both quality of power within micro-grid and quality of currents flowing between the micro-grid and utility system. The devices are used to compensate the active & reactive power in the utility connected grid and reduction of total harmonics distortion (THD) of the system connected the simulations are carried out using MATLAB**

***Keywords*: Distributed Generation, micro-grid, power quality, DSTATCOM, THD.**

I. INTRODUCTION

A power system is an interconnected system composed of generation stations, which convert fuel energy into electrical energy, sub-station that distribute electrical power to loads or consumers and transmission lines that tie the generating station and distribution substation together. According to the voltage levels, an electrical power system can be viewed as consisting of a generating station, a transmission system and a distribution system.

Today's due to industrial civilization in the world the numerous industries are establish all around the world causing Environmental Pollution. Day to day power consumption requirements are increasing widely to meet the requirements adding to new generation capacity, our traditional power generation methods of burning the primary fossil fuels such as coal, oil, natural gas etc. the cumulative effect of all this will cause Green house effect .to reduce this effect the development of distributed generation (DG) systems became significant for both consumers and power utilities. By development of DG systems increases generation and efficiency, reduce greenhouse gas emissions, improve power quality and system stability, cut energy costs and capital expenditures, and alleviate the bottleneck caused by distribution lines [1-3].

DG systems are usually small modular devices close to electricity users including wind turbines, solar energy systems, fuel cells, micro gas turbines and small hydro systems as well as the relevant controlling/managing and energy storage systems. [3]. Micro-grids can generally be viewed as a cluster of micro generators connected to the mains utility grid, usually through some voltage source converters(VSCs) based interfaces. Concerning the interfacing of a micro-grid to the utility system, an important area of study is to investigate the impact of unbalanced utility grid voltages (usually caused by unbalanced systems faults or connected loads) on the overall system performance. Loads are of linear and non-linear loads are connected to micro-grid the cumulative effect of all this will causes power quality problem at the utility side. Subjecting the micro-grid to sustained unbalanced voltages at the point of common coupling (PCC), if no compensating action is taken. Such an unbalance in voltages can cause increased loss3es in motor loads and abnormal operation of sensitive equipment [.however large unbalanced currents can flow between the unbalanced utility grid and micro-grid due to the very low line impedance interfacing both grids. This flow of large unbalanced currents can over stress semiconductor devices within the interfacing inverters and system components such as overhead lines and feeder cables [5].

To mitigate the above-mentioned complications, this paper proposes two schemes in the first scheme using three phase distribution generator (DG) connected at the PCC which share both real and reactive power with the utility compensates the unbalanced voltages and currents and second scheme Distribution static compensator (DSTATCOM) is connected at the point of common coupling (PCC) to compensate the unbalance and nonlinear nature of the total load current and nonlinear nature of the total load current and to provide the reactive power. Hence the technique has proposed to control the power fed into grid at the desired value by which the harmonics are reduced. The simulation carried out using MATLAB .

II. SYSTEM STRUCTURE

The structure of the system studied in this paper is shown in Fig.1. The utility is connected to PCC through an impedance of primary feeder with Rs, Ls. The supply side contains three single phase DGs and one three phase DG or DSTATCOM. The single phases DGs are connected through secondary feeders to the PCC. Here the three single phases DGs are connected to PCC are of different capacity. Six single phase loads are connected to secondary feeder to the single phase DGs are denoted by Ld_1 to Ld_6 the output voltages are denoted of DGs by $E_i\angle\delta_i$,i=1, 2. &3.an induction motor is connected at the PCC to study the impact of poor power quality on its operation [1].

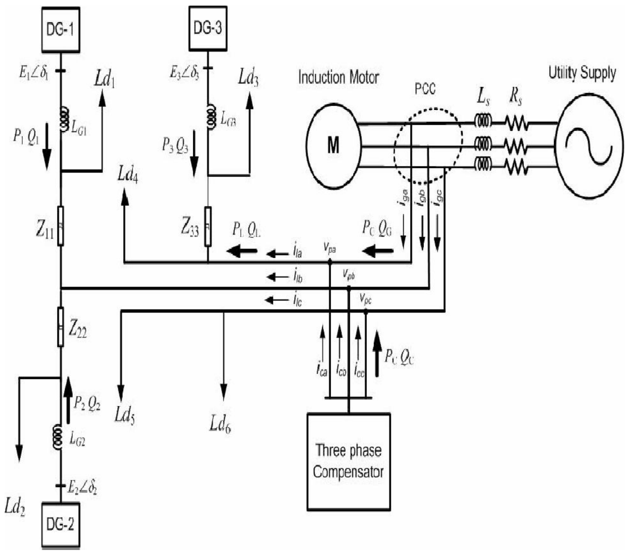

Fig. 1. Structure of the grid system under consideration

System parameters:

System frequency = 50Hz
Feeder impedances = 1.03+j4.7 Ω
Load rating
Load 1, 2, 4, 7=4.2KW and 3.2KVAr
Load 3, 5, 6=4.2KW and 3.2KVAr
DG ratings
DG-1=5.2KW
DG-2=7.5KW
DG-3=3.0KW
Output inductances=7.5mH.

III. POWERQUALITY ISSUES

Power quality determines the fitness of electrical power to consumer devices. Synchronization of the voltage frequency and phase allows electrical systems to function in their intended manner without significant loss of performance or life.

Here the most common power supply problems and their likely effect on sensitive equipment

A. *Power surges:*

A power surge takes place when the voltage is 110% or more above normal. The most common cause is heavy electrical equipment being turned off. Under these conditions, computer systems and other high tech equipment can experience flickering lights, equipment shutoff, errors or memory loss

B. High voltage spikes:

High-voltage spikes occur when there is a sudden voltage peak of up to 6,000 volts. These spikes are usually the result of nearby lightning strikes, but there can be other causes as well. The effects on vulnerable electronic systems can include loss of data and burned circuit boards.

C. Transients:

Transients are potentially the most damaging type of power quality disturbance that you may encounter. Transients fall into 2 categories.
Impulsive
Oscillatory

D. Frequency variation:

A frequency variation involves a change in frequency from the normally stable utility frequency of 50 or 60 Hz, depending on your geographic location. This may be caused by erratic operation of emergency generators or unstable frequency power sources. For sensitive equipment, the results can be data loss, program failure, equipment lock-up or complete shut down

E. Power sag:

Sag is the reduction of AC Voltage at a given frequency for the duration of 0.5 cycles to 1 minute's time. Sages are usually caused by system faults, and often the result of switching on loads with high demand startup currents

F. Electrical line noise:

Electrical line noise is defined as Radio Frequency Interference (RFI) and Electromagnetic Interference (EMI) and causes unwanted effects in the circuits of computer systems. Sources of the problems include motors, relays, motor control devices, broadcast transmissions, microwave radiation, and distant electrical storms. RFI, EMI and other frequency problems can cause equipment to lock-up, and data error or loss.

Power quality is assessed based on a number of parameters (presence of faults) that are measured in the grid. The most common parameters are voltage dips, voltage swells, harmonics, transients, unbalance, flicker, frequency deviations and RVCs.

Measures of Electric power quality:

1. *Total Harmonic Distortion* (THD) :

For periodic wave, THD is defined as:

i= order of harmonics

V (i) = Amplitude of i^{th} harmonic components of voltage

$$THD = \frac{\sqrt{\sum_{i=2}^{i=\infty} V^{(i)^2}}}{V^{(1)}}$$

2. *Distortion index(DIN):*

$$DIN = \frac{THD}{\sqrt{1 + THD^2}}$$

3. *Fickler factor (F) :*

Vm cos(wf t) may be considered as being modulated by the signal Vf cos(wOt) where Vf is the flicker amplitude. Thus flicker component of bus voltage in

Vf(t)= Vf cos(wft). Vm cos(wOt)
And the total bus voltage is V(t)= Vm cos (wOt) +Vf(t)=(1+Vfcos(wft))Vm cos(wot)

IV. CONVERTER STRUCTURE AND DSTATCOM CONTROL

A. Converter structure .three phase voltage converter the main aim of the compensator is to cancel the effects of unbalanced and harmonic components of the load [2].

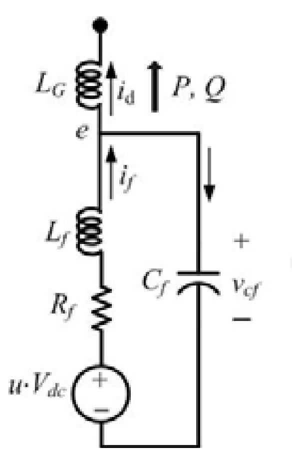

Fig.2. Three phase convertor structure

$u.V_{dc}$ represents the converter output voltage, where u is the switching function that can take on values ± 1.The main aim of the converter control is to generate u. from the circuit Fig. 2. The state space description of the system can be given as

$$x = A_x + B_1 u_c + B_2 v_{pcc}\ (k). \qquad (1)$$

Where u_c is the continuous time control input.

DSTATCOM

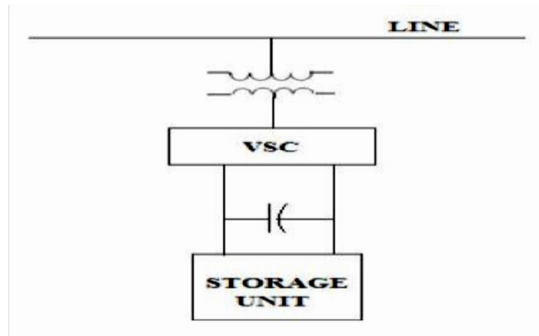

Fig.3. Basic circuit diagram of DSTATCOM

DSTATCOM is shunt connected custom power device specially designed for power factor correction, current harmonics filtering and load balancing. It can also be used for voltage regulation at a distribution bus. It is often referred to as a shunt or parallel active filter. It operates as current controlled voltage source and compensates current harmonics by injecting the harmonics components generated by the load but phase shifted by 180 degrees. With an appropriate control scheme, the DSTATCOM can also compensate for poor load power factor.

Here the main aim of compensator is to cancel the effects of unbalanced and harmonic components of the load. If proper compensation is achived.the currents i_g and i_l will be balanced and so will be the voltage v_p provided that v_c is balanced
Let us denoted the three phases by the subscripts *a, b* and *c.* Consider the circuit of Fig.1 in which the current entering the distribution system from PCC is denoted by i_g and the current supplied to the distribution system is denoted by i_l . the compensator current is denoted by i_c such that the Kirchoff's current law (KCL) at the compensator coupling point is given by

$$ick + igk = ilk\ ,\ k = a,b,c \qquad (2)$$

Since it is desired that the supplied currents are balanced, we have

$$iga + igb + igc = 0 \qquad (3)$$

Therefore combining (2) and (3) by adding the currents of the all the three phases together,
we get

$$ica + icb + icc = ila + ilb + ilc \quad (4)$$

Since i_g is balanced due to the action of the Compensator. The voltage v_p will also become Balanced provided that the supply voltage is balanced. Hence the instantaneous real powers P_G will be equal to its average components. Therefore we can write

$$V_{pa}i_{ga} + V_{pb}i_{gb} + V_{pc}i_{gc} = P_G \quad (5)$$

From the KCL of (2), (5) can be written as

$$vpa\ (ila - ica) + vpb\ (ilb - icb) + vpc(\ ilc - icc) = PG \quad (6)$$

Similarly the reactive powers Q_G and Q_C will be equal to their instantaneous components .therefore we can write

$$(v_{pb} - v_{pc})\, i_{ga} + (v_{pc} - v_{pa}) i_{gb} + (v_{pa} - v_{pb}) i_{gc} = \sqrt{3} \text{ x } Q_G \quad (7)$$

Using the KCL of (2), (7) can be written as

$$(v_{pb} - v_{pc})(\ i_{ia} - i_{ca}) + (v_{pc} - v_{pa})(i_{lb} - i_{cb}) + (v_{pa} - v_{pb})(i_{lc} - i_{cc}) = \sqrt{3} \text{ x } Q_G \quad (8)$$

After computing

$$\begin{bmatrix} i_{ca} \\ i_{cb} \\ i_{cc} \end{bmatrix} = \begin{bmatrix} i_{la} \\ i_{lb} \\ i_{lc} \end{bmatrix} + \frac{1}{|A|} \begin{bmatrix} 3P_G v_{pa} + \sqrt{3} Q_G (v_{pb} - v_{pc}) \\ 3P_G v_{pb} + \sqrt{3} Q_G (v_{pc} - v_{pa}) \\ 3P_G v_{pc} + \sqrt{3} Q_G (v_{pa} - v_{pb}) \end{bmatrix} \quad (9)$$

Now let us consider that the utility supplies P_G that is λ_p times the average power P_{Lav} supplied to the λ_p times the average power P_{Lav} supplied to the distribution system and Q_G which is λ_q times the average reactive power Q_{Lav} supplied to the distribution system. This is given by the following two relations

$$P_G = \lambda_p \text{ x } P_{Lav}$$
$$Q_G = \lambda_q \text{ x } Q_{Lav} \quad (10)$$

Substituting (10) in(9) the reference currents are given by

$$\begin{bmatrix} i_{ca} \\ i_{cb} \\ i_{cc} \end{bmatrix} = \begin{bmatrix} i_{la} \\ i_{lb} \\ i_{lc} \end{bmatrix} + \frac{1}{|A|} \begin{bmatrix} 3\lambda_p P_{Lav} v_{pa} + \sqrt{3}\lambda_q Q_{Lav} (v_{pb} - v_{pc}) \\ 3\lambda_p P_{Lav} v_{pb} + \sqrt{3}\lambda_q Q_{Lav} (v_{pc} - v_{pa}) \\ 3\lambda_p P_{Lav} v_{pc} + \sqrt{3}\lambda_q Q_{Lav} (v_{pa} - v_{pb}) \end{bmatrix} \quad (11)$$

This is a modification of the method presented in [7].once the reference currents are obtained, the references of the voltage v_p and filter capacitor currents are obtained in the same manner as discussed in the previous sub-section[1].

V. SIMULATION STUDY

Simulation studies are carried out in MATLAB. The DGs are connected as inertia-less dc sources supplied through the VSCs

Case.1: without compensator

It is assumed that all the single phase DGs are able to supply their maximum rated power. The total load demand is more than the total maximum generation. Thus the rest of the power requirement has to be supplied from the utility. It is assume that the system is operating in the steady state in which DG-2 is supplying 3 KW and load Ld_1 is not connected. Suddenly at 0.45s, the power output of DG-2 increase to 7KW. Furthermore, at 0.7s, the load Ld_1 gets connected drawing real and reactive power of 4.2KW and 3.2 KVAr respectively. It can be seen that the maximum power supply by DG-2 increase, while the load change due to the imbalance in the three phases. At 0.45s the utility power decreases as the power generation in DG-2 is increased, while at 0.7s the utility supply is increased to supply the load change in phase b

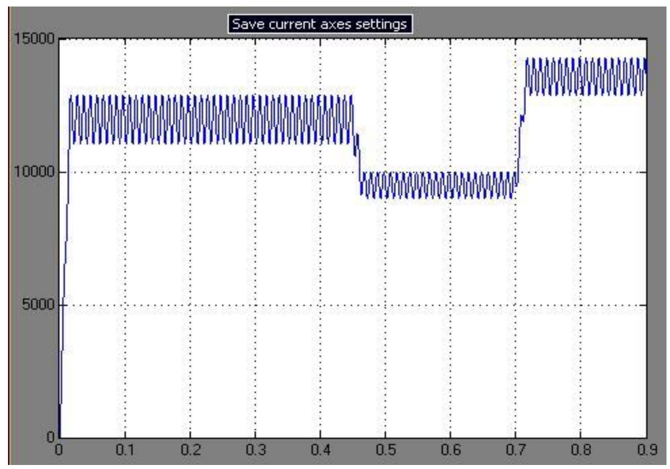

Fig.4 Reactive Power in the Utility Grid

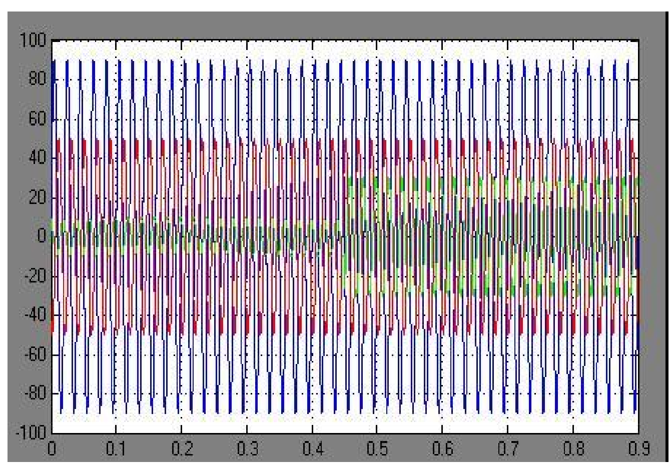

Fig.5 Three Phase Current in the Utility Grid

Fig. 4 and Fig. 5 shows the unbalanced utility currents in the three phases and the reactive power in the utilty

Case-2: DSTATCOM connected at PCC

To compensate the imbalance among the phases, at first a DSTATCOM is connected as a three phase compensator. As discussed before, DSTATCOM can share the reactive power requirement with utility in a pre-specified ratio. With the initial starting condition as in Case-1, the DSTATCOM is connected to the system at 0.05s and it is desired that DSTATCOM supply the 70% of the reactive power while balancing the utility currents.

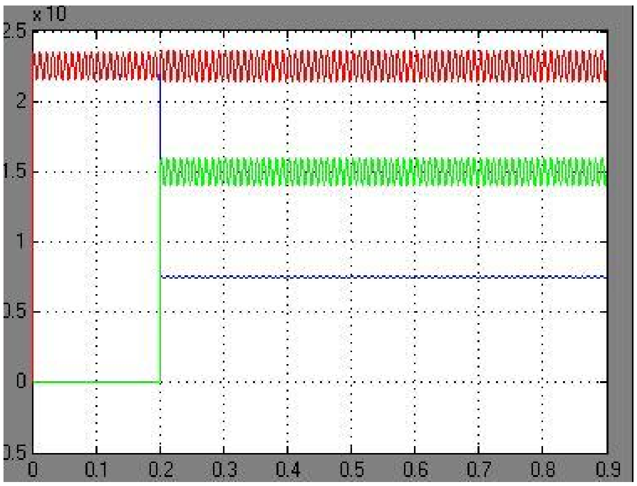

Fig. 6 Reactive Power due to DSTATCOM

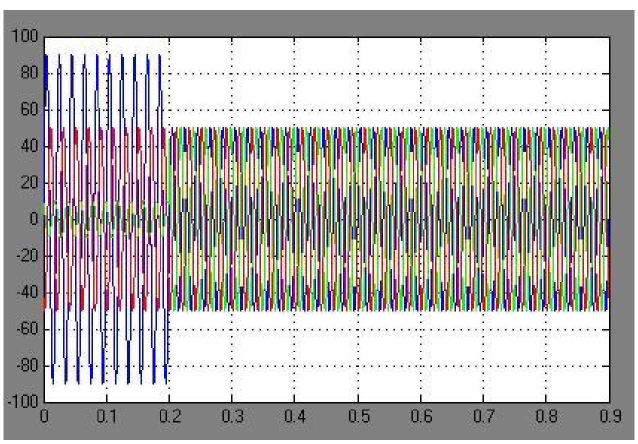

Fig.7 Three phase currents due to DSTATCOM

From the results, it is been observed that the required reactive power is been supplied by the DSTATCOM. The green color line in the waveform shows how much reactive power is been injected by the DSTATCOM. Fig.6 and Fig.& shows the compensating current of the DSTATCOM. The disturbances in the current from the utility is also been compensated.

Case-3: DG-Compensator Connected at PCC

While the DSTATCOM can only provide the required power, a compensator connected with DG can also share the real power burden of the utility. Let us assume that the DG-compensator supplies 30% of real and reactive power demand (P_L, Q_L), when it gets connected to the system at 0.45s

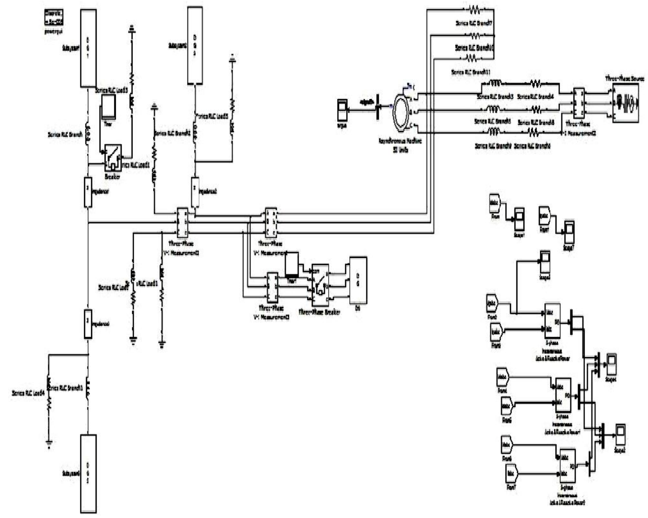

Fig.8 Utility Grid Connected With DG

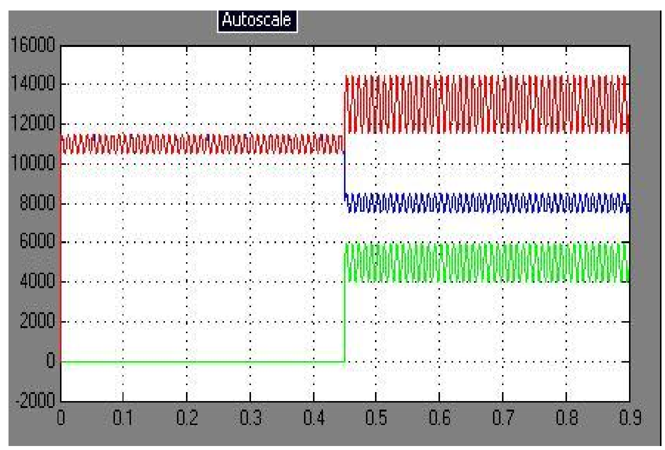

Fig. 9. Real Power Injected due to 3phase DG

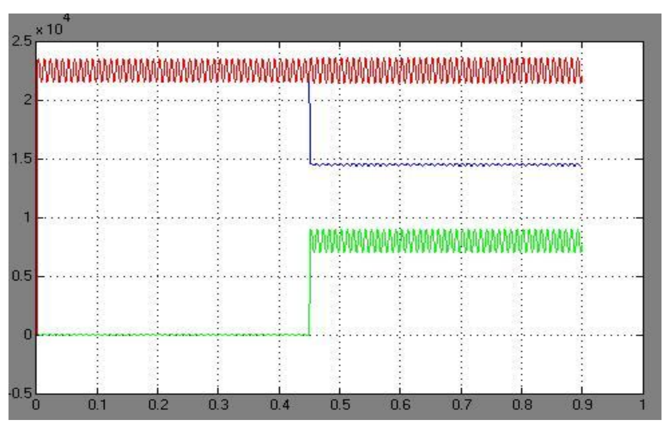

Fig.10 Reactive Power injected due to 3phase DG

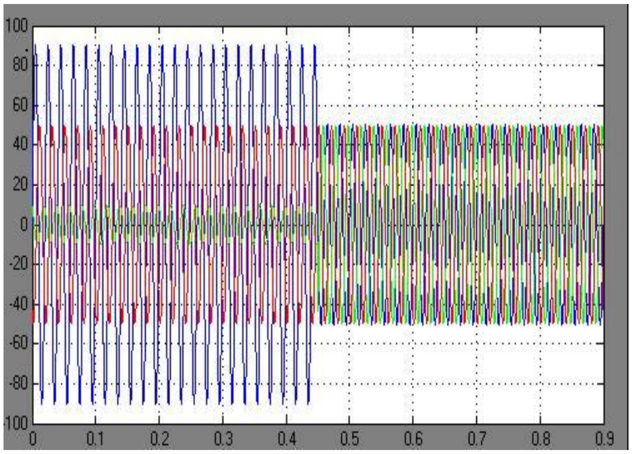

Fig. 11 Three phase compensator current due to 3 phase DG three phase current

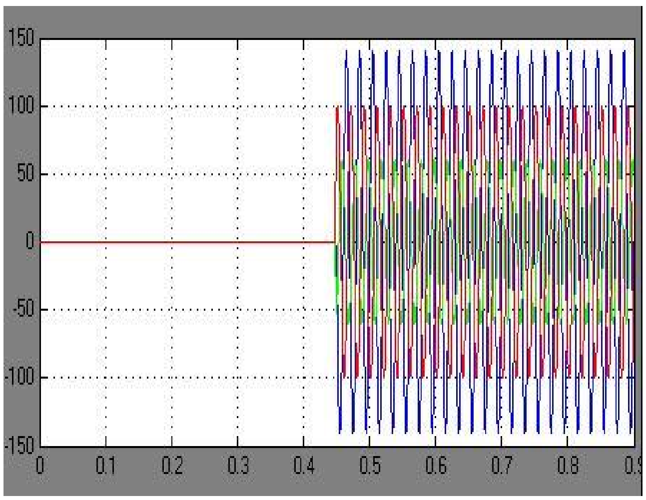

Fig.12 Three Phase Compensator Current due to 3 phase DG

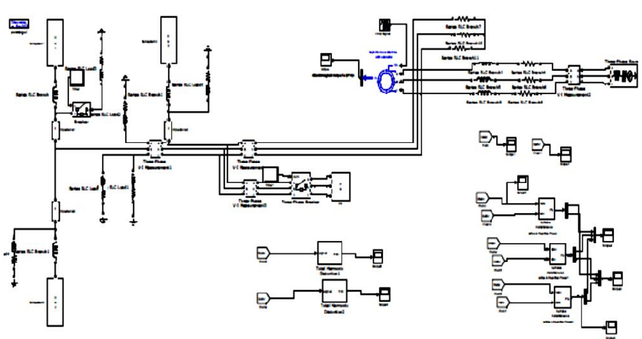

Fig.13 Utility Grid Connected with DG-Compensator

The Fig.13 shows the utility connected grid with DG-compensator along with Total harmonic distortion (THD) module by which the THD is computed, here the current harmonic of a single phase non-linear loads simulations have been performed for this case. The THD of the grid voltage is about 10% and the negative and zero sequence components are around 5% of the positive sequence component before DG-compensator connected .these are then reduced such that the THD becomes less than 0.5%, where as negative and zero sequence components of the voltages remain below 0.02% once the DG compensator is connected

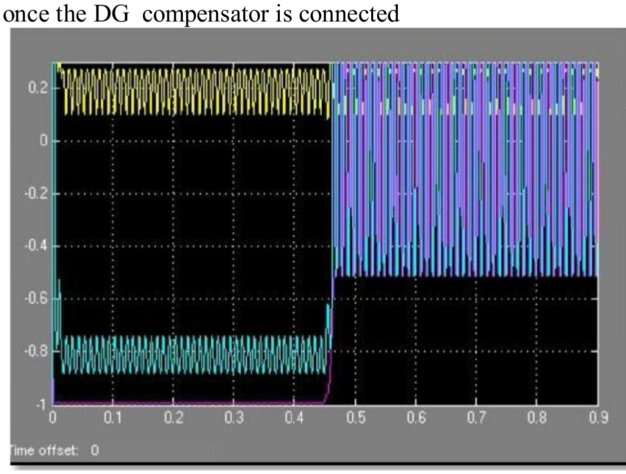

Fig.14 THD of Three Phase Current

VI. CONCLUSION

In this paper the control of micro grid sources (single phase DG) are connected in a three-phase utility connected grid. The imbalances in voltages due switching phenomena, faults or due to the linear and non-linear loads connected to the utility connected system

This cumulative effects are compensated by using three phase DG-compensator and DSTATCOM

The performance of the proposed schemes was investigated for output power fluctuations due to the single phase distribution generation at the distribution side. In addition the THD of the utility is computed using simulation in MATLAB it is concluded from the simulation and experimental results that the voltage imbalances and necessity of active and reactive powers by utility for serving the load requirements can be obtained by using DSTATCOM and DG-Compensator by which the power Quality is maintained.

The impacts of these devices in stability and protection system of a utility connected grid system to achieve an enhancement of both quality of power within micro-grid and quality of currents flowing between the micro-grid and utility system.

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