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Combined operation of UPQC with Distributed Generation to Enhance The Power Quality in Power Grid using PSCAD

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***Abstract*—this paper presents analysis of power quality issues like voltage sag, swell, voltage imbalance and DC offset occurrence in the power distribution side. The proposed system integrates operation of the Unified Power Quality Conditioner (UPQC) with distributed generation. Power quality issues are becoming more and more significant in these days because of the increasing number of power electronic devices that behave as nonlinear loads. Thus to enhance the quality of power supply UPQC-DG is proposed. The UPQC combines the operation of series active filter and shunt active filter. The results are discussed in PSCAD/EMTDC under the condition of before and after compensation of different power quality issues by UPQC-DG.**

Keywords—Power quality, voltage sag and swell, voltage unbalance, DC offset, Unified Power Quality Conditioner, distributed generation (DG).

I. INTRODUCTION

Unified Power-Quality Conditioner was widely studied by many researchers as an ultimate method to improve power quality [1]. The function of Unified Power-Quality Conditioner (UPQC) is to mitigate the disturbance that affects the performance of the critical load. The UPQC, which has two inverters that share one dc link capacitor, can compensate the voltage sag and swell, the harmonic current and voltage, and control the power flow and voltage stability. However, UPQC cannot compensate the voltage interruption because it has no energy storage in the dc link. In other words, the UPQC has the capability of improving power quality at the point of installation on power distribution systems or industrial power systems. The UPQC, therefore, is expected to be one of the most powerful solutions to large capacity loads sensitive to supply voltage flicker/imbalance.

DG (Distributed generation) sources are developing in the power system because of their remarkable advantages such as increasing security, reducing transmission losses and costs of high voltage equipment's. Some recent researches have considered the integration of Dynamic Voltage Restoration (DVR) and Distributed static synchronous compensator (DSTATCOM) with DG sources. The UPQC is the combination of DVR and DSTATCOM which are series and shunt controller respectively. The series component of the UPQC regulates the voltage so as to maintain the voltage at the load terminals balanced and free of distortion.

The shunt component of the UPQC injects current in the AC system such that the currents entering the bus to which the UPQC is connected are balanced sinusoids. Electric Power Quality (EPQ) is a term that refers to maintaining the near sinusoidal waveform of power distribution bus voltages and currents at rated magnitude and frequency. Both electric utilities and end users of electric power are becoming increasingly concerned about the quality of electric power. A utility may define power quality as reliability and show statistics demonstrating that its system is 99.98 percent reliable. Criteria established by regulatory agencies are usually in this vein. A manufacturer of load equipment may define power quality as those characteristics of the power supply that enable the equipment to work properly. These characteristics can be very different for different criteria. Power quality is ultimately a consumer driven issue, and the end user's point of reference takes precedence.

Today, both power suppliers and consumers are obliged to comply with various Power Quality (PQ) standards proposed by international bodies such as IEEE and IEC worldwide. The number of vulnerable loads which are very sensitive to PQ problems have increased in the modern power system and at the same time the number of PQ polluting factors has also escalated. The increased penetration of distributed generation sources in to the power system has further contributed to existing PQ complexities. These distributed generation sites are often fuelled by renewable energy sources such as wind and solar. The random nature of these energy sources poses a reliability threat to the power system. Need for assessment of electric power quality it is common experience that electric power of poor quality has detrimental effects on health of different equipment and systems. Moreover, power system stability, continuity and reliability fall with the degradation of quality of electric power.

II. SYSTEM CONFIGUEATION

The single line diagram of the proposed AC grid system with UPQC-DG is shown in Fig.1. The system comprises of a 230 kV, 50 Hz transmission system, feeding into the primary side of a 2-winding transformer [2]. The load is connected to the 13.5 kV secondary side of the transformer. Then the

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different loads are connected to the grid at different time and exist for different time duration which creates different power quality issues. In the proposed system voltage sag and swell are caused due to over voltage and under voltage respectively. Similarly voltage unbalance and DC offset are caused due to the single phase loads connected in three phase circuit and rectifier load respectively. The proposed system is tested under two conditions. i) One is without UPQC-DG; and ii) with UPQC-DG.

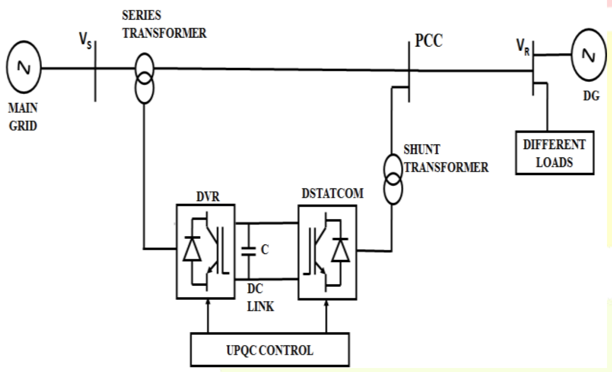

Fig 1.Proposed UPQC system with DG.

The Unified Power-Quality Conditioner is mainly used for power quality enhancement in power grid. In the proposed system Sinusoidal PWM-based control scheme is used for the gate pulse production in the voltage source controllers of the UPQC.

III. POWER QUALITY PROBLEMS

Power quality determines the fitness of electric 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. The power quality issues analysed in the proposed system are listed by,

- Voltage sag
- Voltage swell
- Voltage unbalance
- DC offset

Power quality is ultimately a consumer-driven issue, and the end user's point of reference takes precedence. Any power problem manifested in voltage, current, or frequency deviations that results in failure or maloperation of customer equipment.

A. *Voltage sag*

A voltage "dip" or a "sag" can be defined as when RMS voltage is below the nominal voltage by 10 to 90% for 0.5 cycle to 1 minute.

B. *Voltage swell*

A voltage "swell" can be defined as 'When the RMS voltage exceeds the nominal voltage by 10 to 80% for 0.5 cycle to 1 minute.

C. *Voltage unbalance*

Voltage "imbalance" (also called voltage unbalance) is sometimes defined as the maximum deviation from the average of the three-phase voltages or currents, divided by the average of the three-phase voltages or currents, expressed in percent.

D. *DC offset*

The presence of a dc voltage or current in an ac power system is termed dc offset. This can occur as the result of a geomagnetic disturbance or asymmetry of electronic power converters. Incandescent light bulb life extenders, for example, may consist of diodes that reduce the rms voltage supplied to the light bulb by half-wave rectification.

IV. UPQC CONFIGURATION

The FACTS concepts applied in distribution systems has resulted in a new generation of compensating devices. A UPQC is the extension of the UPFC concept at the distribution level. It has two voltage source inverters (VSIs) that are connected to a common dc energy storage capacitor. UPQC combines the operations of a DSTATCOM and a DVR together [1]. One of these two VSI's is connected in series with the ac line while the other is connected in shunt with the same line. A UPQC is employed in a power distribution system to perform shunt and series compensation at the same time.

UPQC is the integration of Series APF and shunt APF, active power filters, connected back-to-back on the dc side, sharing a common DC capacitor. The series component of the UPQC is responsible for mitigation of the supply side disturbances: voltage sags/swells, flicker, voltage unbalance and harmonics. It inserts voltages so as to maintain the load voltages at a desired level; balanced and distortion free [3]. The shunt component is responsible for mitigating the current quality problems caused by the consumer: poor power factor, load harmonic currents, load unbalance etc. It injects currents in the ac system such that the source currents become balanced sinusoids and in phase with the source voltages.

UPQC has shunt and series voltage source inverters which are 3-phase 3-wire shunt inverters connected to point of common coupling (PCC) by shunt transformer. The series inverter stands between source and coupling as current source and it operates as voltage source.

The equations for real and reactive power through the line are as follows:

$$P = \underline{V_S V_R}\ \sin(\delta_1 - \delta_2) \quad (1)$$

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These equations is given by neglecting the resistance of the line. UPQC is able to compensate current harmonics, to

The overall function of UPQC mainly depends on the series and shunt APF controller. Let us first assume that the combination of an ideal series voltage source and an ideal shunt current source represents the UPQC. There are two possible ways of connecting this device at the point of common coupling (PCC). They are shown below.

A. Right-Shunt

The right-shunt UPQC operates in a zero power injection/absorption mode [1]. It can make the power factor unity at the load terminal.

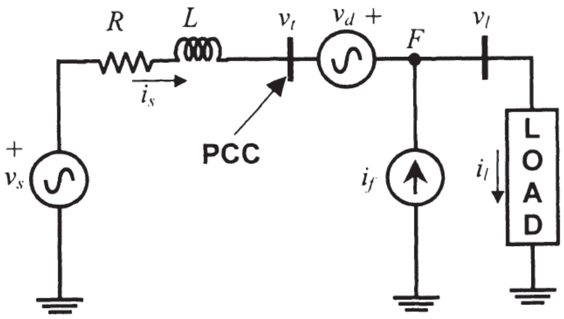

Fig 2. The right-shunt UPQC compensation configuration.

The shunt compensator in the right-shunt UPQC can supply the entire requirement of the reactive power by the

compensate reactive power, voltage distortions and control load flow but cannot compensate voltage interruption because of non-availability of sources

load. The single line diagram of right-shunt UPQC compensation configuration is shown in Fig 2.

B. Left-Shunt

The left-shunt UPQC cannot operate in a zero power injection/absorption mode [1]. The power factor at the load terminal depends on the load. The shunt compensator in the left-shunt UPQC can only supply the mean of the load reactive power. The single line diagram of left-shunt UPQC compensation configuration is shown in Fig 3.

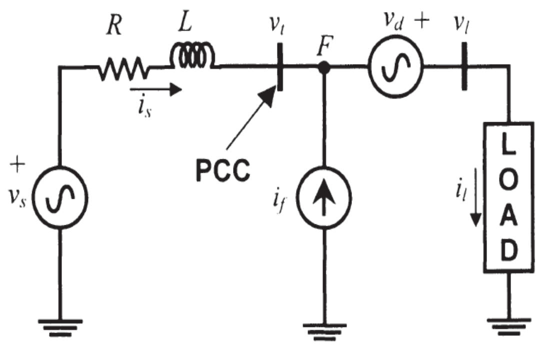

Fig 3. The left-shunt UPQC compensation configuration

V. PSCAD SIMULATION OF PROPOSED SYSTEM

a) Without UPQC-DG

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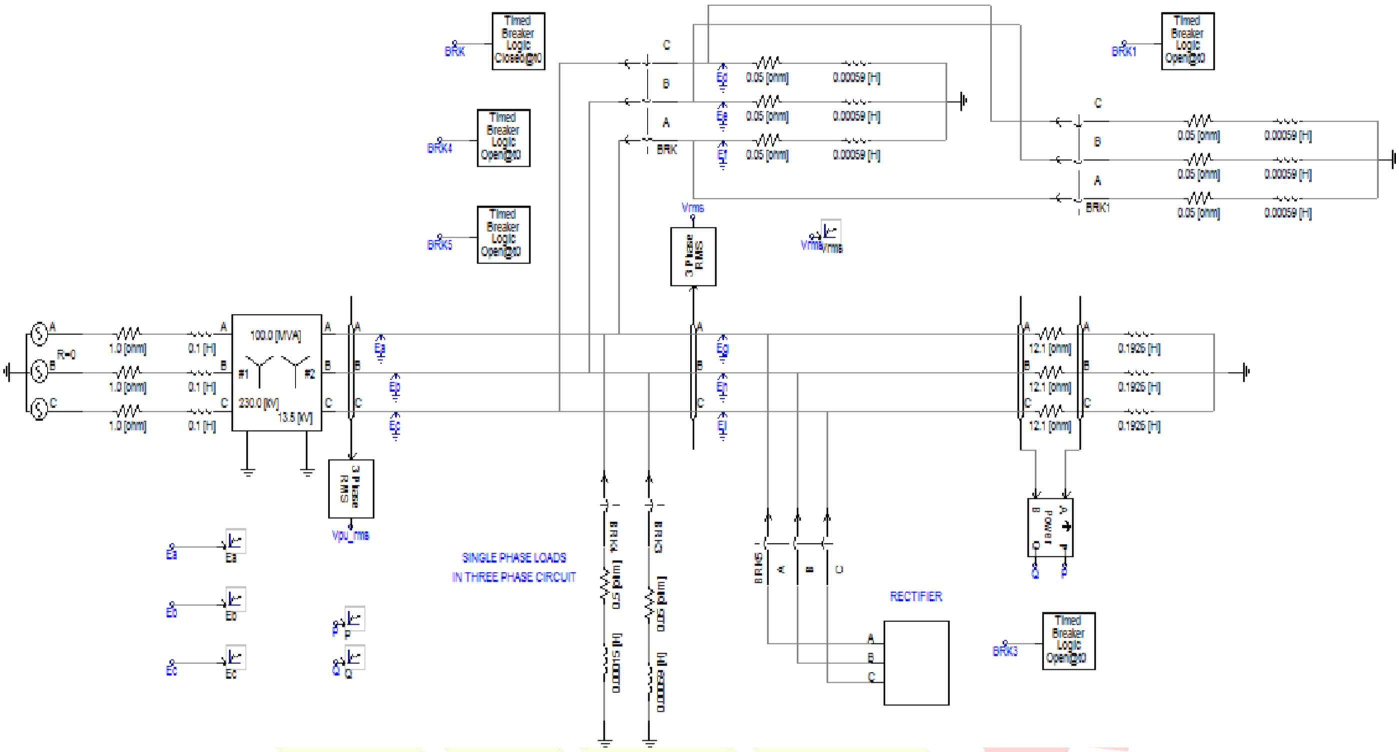

Fig 4.Proposed system without UPQC and DG

The proposed system is described by 100 MVA, 230 KV 50 HZ transmission system feeding the different loads through step down transformer of 230 KV/13.5 KV. The power quality problems are occurred due to the different loading condition. The voltage sag and swell are caused due to over voltage and under voltage process respectively. In the same way the voltage imbalance and DC offsets are caused due to single phase loads connected in the three phase circuit and switching on of rectifier loads respectively.

All the above mentioned loads are switched on at particular time period and exist for few cycles or seconds. The RMS voltage at the load terminal was measured and shown in graph. The overall proposed system PSCAD simulation model without UPQC and DG is shown in Fig 4.

b) With UPQC-DG

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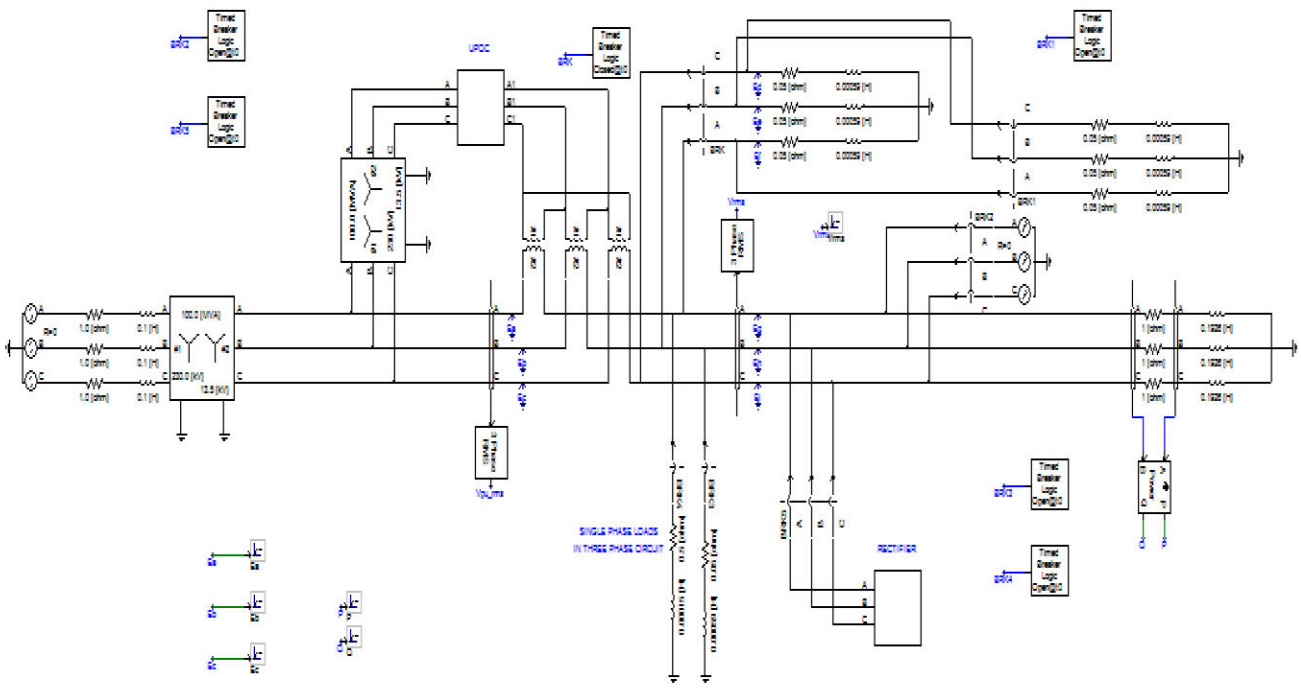

Fig 5.Proposed system with UPQC and DG

A power transmission line generally operates in a balanced, distortion (harmonic) free environment. But in power distribution system, on the other hand, may contain unbalance, distortion and even DC components. Therefore a UPQC must operate under this environment while providing shunt or series compensation. Thus UPQC can also operate even though the system is under disturbance. The PSCAD simulation with UPQC and DG is shown in Fig 5.

In the consumer side most of the loads are sensitive to the quality of the power supply. Therefore to improve the power quality UPQC is used in the proposed system. The Distributed Generator is used to provide uninterrupted power supply even though the system is under fault condition or under disturbance. Distributed generation (DG) generally refers to small-scale (typically 1 kW – 50 MW) electric power generators that produce electricity at a site close to customers or that are tied to an electric distribution system. In the proposed system DG is rated as 100 MVA, 5.5 KV, 50 HZ.

Distributed generation (DG) refers to power generation at the point of consumption. Generating power on-site, rather than centrally, eliminates the cost, complexity, interdependencies, and inefficiencies associated with transmission and distribution. Like distributed computing (i.e. the PC) and distributed telephony (i.e. the mobile phone), distributed generation shifts control to the consumer. Although the primary task of UPQC is to minimize grid voltage and load current disturbances along with reactive and harmonic power compensation, additional functionalities such as compensation of voltage interruption and active power transfer to the load and grid have also been identified.

VI. RESULTS AND DISCUSSION

The simulation results of proposed system without UPQC-DG in PSCAD is shown in figure. The load voltage and V_{rms} in pu is shown in graph under the condition of with and without UPQC-DG. At the time of 0.2 sec the consumer load is increased and exist for the duration of 0.2 sec. Thus the sag is occurred from 0.2 to 0.4 sec due to the overloading process. Voltage swell is occurred due to the unloading process starts at 0.6 sec with the duration of 0.2 sec. Thus the swell is shown from 0.6 to 0.8 sec.

The next one is voltage imbalance. This is caused due to the single phase loads connected in the three phase circuits. These kinds of loads are switched ON at 1 sec with the duration of 0.1 sec. Thus the voltage imbalance shown in graph Fig 6. from 1 to 1.1sec.

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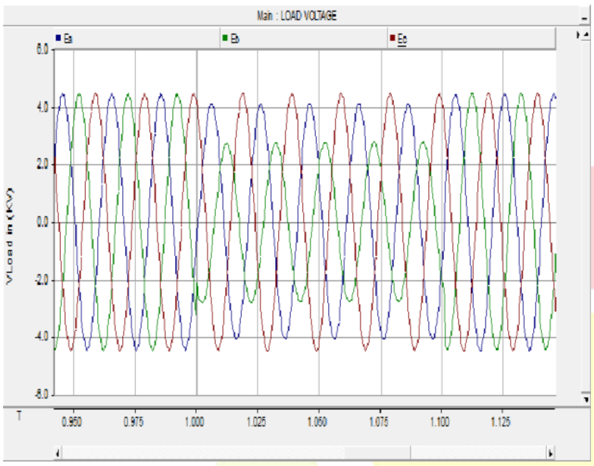

Fig 6. Voltage unbalance

The final power quality problem shown in this paper is DC offset. In this paper DC offset is caused due to the switching process of rectifier loads which switched on at 1.4 sec and exist at the duration of 0.1 sec. DC offset was shown in graph Fig 7. from 1.4 to 1.5 sec.

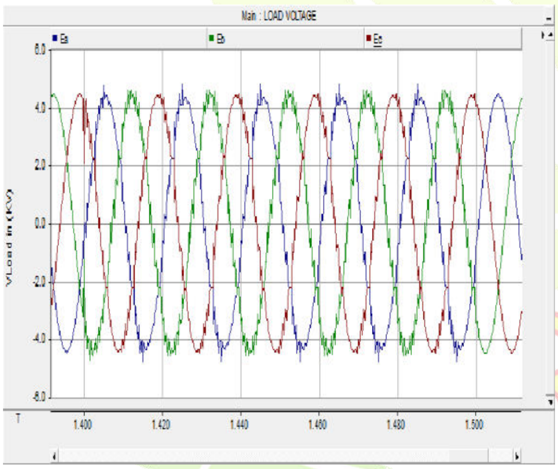

Fig 7. DC offset

The following Fig 8. shows the load voltage in V_{rms} pu with the power quality problems. Here the UPQC and DG are not connected. The graph clearly shows variations in the per unit RMS load voltage magnitude corresponding to type of power quality problem.

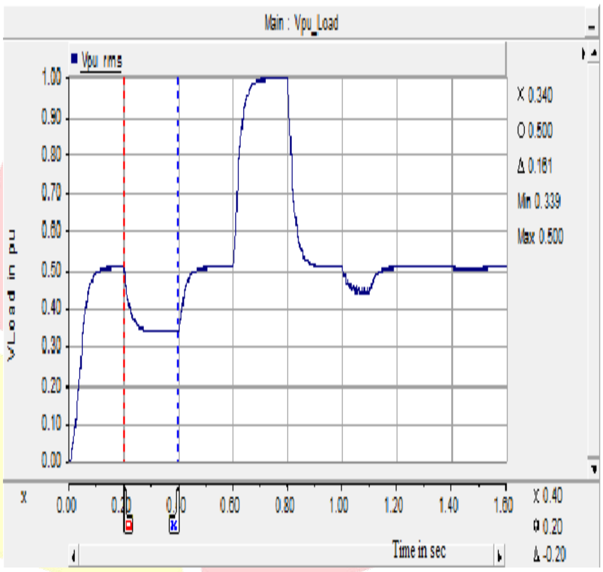

Fig 8. Load voltage V_{rms} in pu without UPQC-DG

Therefore to compensate the power quality problems Unified Power Quality Conditioner and DG are implemented. Thus the pu RMS load voltage magnitude is maintained at 0.5pu by the use of UPQC and DG which is shown in Fig 9.

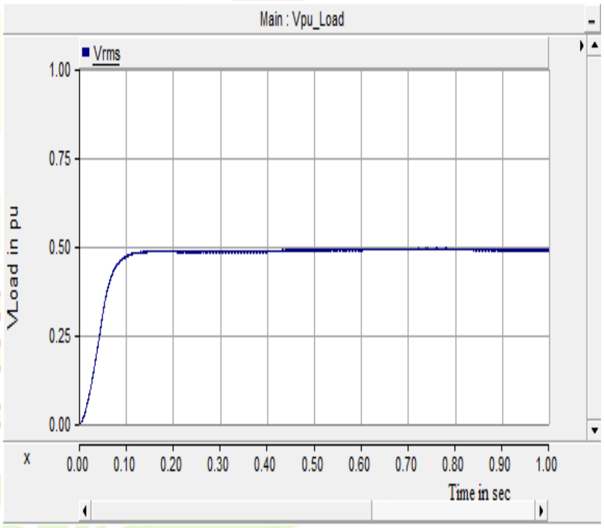

Fig 9. Load voltage V_{rms} in pu with UPQC-DG

The overall simulation of the load voltage without UPQC-DG are shown in Fig 10. In this variation of load voltage magnitude for different kinds of disturbances in the proposed system is shown.

The next Fig 11. indicate the load voltage after compensation by UPQC and DG the waveform distortion is completely eliminated and the load voltage is maintained constant by Distributed Generator.

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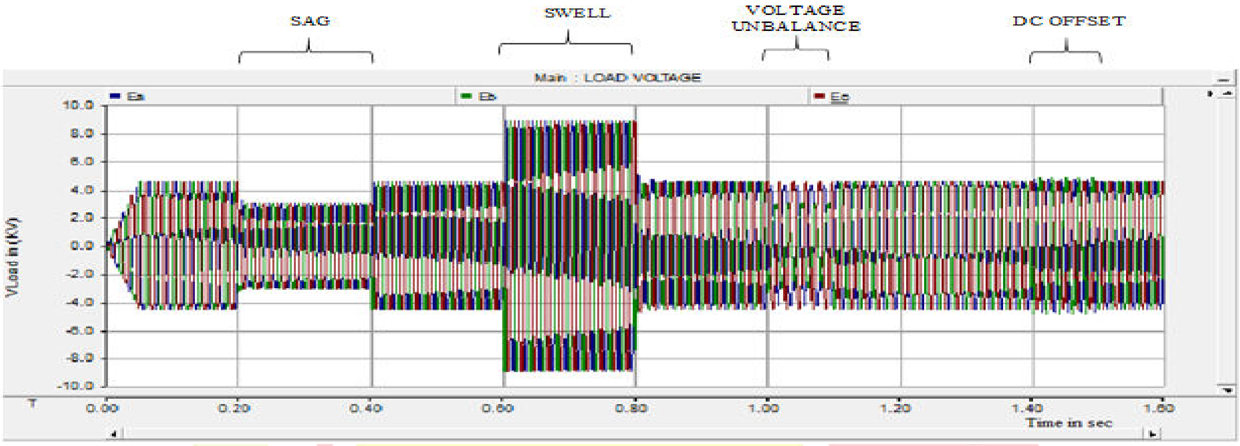

Fig 10. Load voltage without UPQC and DG

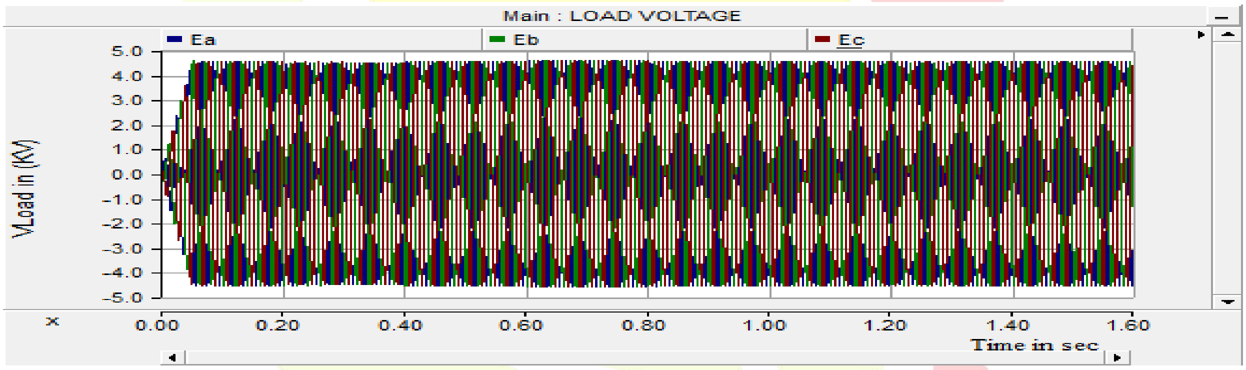

Fig 11. Load voltage with UPQC and DG

VII. CONCLOSION

This paper analyses various power quality issues that are caused due to the different kinds of loads. The system having sag- sell, voltage imbalance and DC offset which are caused by over loading-unloading process, connecting single phase loads to the three phase AC system and switching ON the rectifier load. The proposed system is tested with before and after voltage compensation by UPQC and DG. Hence the power quality of the proposed system is enhanced by implementing the UPQC and Distributed Generator.

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