Power Quality Improvement by Upqc With Real Power Injected Micro Turbine

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Abstract

Power Quality is one of the major concerns in the present system. Due to the rapid growth of non-linear loads, major power quality problems such as harmonics, unbalance operation and voltage deficiencies (i.e., sag and swell) arise. This paper proposes MTG based Unified Power Quality controller (UPQC) to get better the power quality troubles like voltage sag, current unbalance in the LV residential feeders which performs both the series and shunt operation. In this paper, Micro Turbine Generator (MTG) system is proposed to improve the efficiency and environmental benefits. The proposed system consists of two types, single shaft and split shaft MTG system. Among these two types, single shaft system is used which is simple in structure and easy to implement. The output of MTG system is connected to the DC link of UPQC. This proposed system reduces the THD content in the source voltage and load current of the system. The presentation of the projected system is imitation using the MATLAB / SIMULINK.

Keywords: Unified power quality conditioner (UPQC), micro turbine generator (MTG), single shaft, split shaft, voltage sag, swell, power quality problems.

1. Introduction

Distributed Generation (DG) refers to miniature level up to 50kw electric influence generators that create electricity at a spot close to regulars or that are joined to an electric allotment system [1-2]. MTs are at present deployed as miniature-scale on-site DGs for Micro grids & Smart grids. general off-line and actual time investigate are working for analyzing the load subsequent concert of MTs beneath is land and grid-associated modes of process at sharing voltage level [3].Based on the investigation of voltage-power individuality of the distributed power supply system, it proposes the methods of by means of super capacitor energy luggage compartment and micro turbine to smooth the fluctuations of DG to progress the voltage excellence respectively. This method make certain the general production power of DG and super capacitor energy storage steady, thus ensuring the power impartial and voltage steady in the circulated power supply scheme [4].Major difficulty with the grid tied micro turbine is harmonization and unpredictability. Due to this difficulty the stability of obtainable grid gets condensed. The steadiness can be achieved by output control of the turbine [5].Now days gas turbines for power manufacture has make bigger in current years and is probable to keep on to increase. The quantity for power generation using cooperative heat and power is also growing regularly due to effectiveness development and emerald benefits. Micro turbine system offers more compensation compare to other technologies for small scale power generation [6]. Micro turbine

Generation (MTG) system is appropriate for isolated as well as grid-associated process in micro grid networks. The MTG system consisting of PMSG coupled with a MT is fitting for stability study in smart grid networks [7]. The active presentation of split shaft MTG and diesel engine system are also examined when they are related together to assure the load demand and transient behavior during active power injection [8]. UPQC is utilized to determine various types of intensity quality issues like responsive power remuneration, intrusions and music [9].Performance of the electric power framework has been enhanced with the utilization of DGs. Another method based Time Changing Quickening Coefficients to distinguish islanding conditions has been actualized for small scale turbine as dissemination age [10]. A small scale gas turbine was worked with and biodiesel brings together. Motor power age and discharges execution were resolved. The outcomes uncover that as bio-diesel content in the fuel blend expanded, the fuel pour rate expanded to manage the consistent speed activity and comparability proportion lessened [11]. Upgrade the speed senator with the end goal to limit the fuel use and flitting reaction of lasting magnet generator. This MT show has been added to a cross breed Smaller scale framework to examine its impacts on recurrence reaction of the framework [12].The MTG framework utilizes the turbine speed to control the miniaturized scale turbine yield control in correlation with the reference speed and shaft speed. The created air conditioning power is changed over to DC utilizing a uninvolved rectifier and this DC control is upset back to air conditioning capacity to network recurrence. While conveying the DC connect capacity to the matrix and islanding load, the particular Dynamic, Receptive

Power quality and Voltage Recurrence control techniques are utilized for inverter activity [13]. To relieve the voltage unbalance issue caused by the high entrance of photovoltaic frameworks into the low voltage dissemination systems utilizing a solitary stage vitality stockpiling framework [14]. In this proposed framework, control quality issues, for example, droop and swell can be alleviated utilizing UPQC with Smaller scale turbine Generator (MTG) framework. With the end goal to enhance the viability of the proposed framework, Gas turbine is executed in this framework.

2. Unified power quality conditioner

The UPQC is the power quality custom power device that consists of two converters, one is shunt and other is series which are connected through a common DC link capacitor. Supply voltage harmonics and voltage unbalances are compensated with the help of series converter, that can also act as a harmonic overcrowding filter and damps power system oscillations.
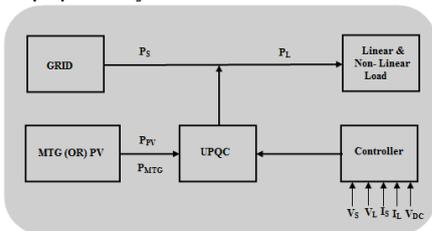

Figure 1: Block diagram of proposed system

Load current unbalances, reactive power and load current harmonics are compensated with the help of shunt converter. Also, it regulates the DC link capacitor voltage. Distribution Static Compensator (DSTATCOM) and Dynamic Voltage Restorer (DVR) operation can be done using the UPQC. In the voltage control mode, voltage profile can be maintained at the source end. In the current control mode, current profile can be maintained at the load end. Figure.1. shows the block diagram of the proposed system where UPQC is the main part of the proposed system.

3. Compensation strategy of UPQC

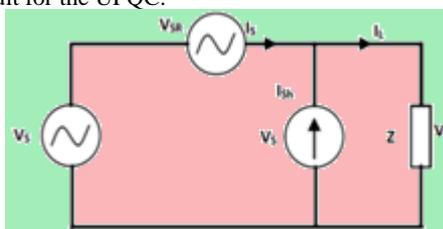Think about the alike circuit of the UPQC.Figure.2. Shows the same circuit for the UPQC.

Figure 2: Equivalent circuit of UPQC

In this circuit,
V_S - Voltage at power supply
V_{SR} - Voltage compensation,
V_L - Load voltage
I_{Sh} - shunt current
Due to the voltage Distortion, the system may contain negative phase sequence and harmonic components. In general, the source voltage in Figure can be expressed as:

$$V_{Source} + V_{Shunt} \ V_{Load} \tag{1}$$

Balance sinusoidal load voltage with fixed amplitude V, can be obtained by the given expression;

$$V_{SR} = (V - V_P)\sin(\omega t + \theta_{1P}) - V_n - \sum_{k=2}^{\infty} V_k(t) \tag{2}$$

Where,
V_P - positive sequence voltage amplitude
$\Theta_{1P\text{ - initial}}$ phase of voltage
V_n - negative sequence component
The shunt-APF acts as a controlled current source and its output components should include harmonic, reactive and negative-sequence components in order to compensate these quantities in the load current, when the output current of shunt APF I_{sh} is kept to be equal to the component of the load as given in the following equation:

$$I_L = I_p \cos(\omega t + \theta_P)\sin\varphi + I_n + \sum_{k=2}^{\infty} I_k \tag{3}$$

$$\emptyset_P = \varphi_P - \theta_P \tag{4}$$

Where,
φ_P - initial phase of current for positive sequence
As seen from the on top of equations that the harmonic, reactive and negative succession current is not smooth into the power source. Therefore, the incurable source current is harmonic free sinusoid and has the same phase angle as the phase voltage at the load terminal

$$I_{Souce} = I_{Load} - I_{shunt} \tag{5}$$
$$= I_p \sin(\omega t - \theta_p)\cos\varphi_p \tag{6}$$

3.1. Shunt converter

The three stage air conditioning side is related transversely the three stage air conditioning transport bar at the situation of widespread coupling through a voltage transformer and an arrangement reactor as appeared in Figure 1.The Graetz connect converter shunt converter is a three stage with a DC plane and a three stage air conditioning side. A PWM generator creating fit exchanging beats switch the six switches of the three leg shunt converter. The targets of the shunt convertor can be accomplished by reasonably providing the exchanging beats. The age of the exchanging beats is represented by the three stage reference flag that is formed by the giving of two controllers. The control targets of the two controllers weight the age of the introduction flag and this prompts the capacity of the convertor tradition out its necessities. There are two controllers related with the shunt converter. A square figure demonstrating the area of the controllers close to with their info and yield signals are appeared in Figure 2.

3.2. Series converter

The grouping converter is otherwise called the Static Synchronous Arrangement Compensator (SSSC). It is a three leg three stages Graetz connect converter with a DC side and a three stage air conditioning side. The three stage air conditioning side is related corner to corner one side of a three stage transformer and the helper side of this transformer is in arrangement with the three stage air conditioning transport bar as appeared in Figure 1.The destinations of the SSSC are to put in an arrangement voltage hence supply to the air conditioner transport bar. This arrangement incorporation of voltage at appropriate stage and sum can oversee remunerate list or swell in the transport voltage. Voltage list and swell can be kept up by the SSSC with the end goal that the voltage over the heap is essentially consistent. The motions in voltage over the heap can destructively influence the power conveyed to the dynamic load. . Incorporation of the remunerating arrangement voltage can be acknowledged out just from a genuine power source and, in that capacity, the DC side of the SSSC ought to be related over a DC interface where there is a prospect of illustration genuine power. Under stipulations of voltage droop and swell spread from the source side, the duty of safeguarding of dependability of voltage over the heap and in this manner the arrival of the fundamental capacity to the heap rests with the

SSSC. On account of UPQC the DC voltage is kept up at favored DC potential and the vitality put away in the DC interface is upheld up by the STATCOM in transmission framework [5]. The control aims of the two controllers control the age of the introduction flag and this prompts the activity of the SSSC gathering out its necessities.

4. Neural network controller

In this work, a talented ANN is utilized to discover the yield infused voltage reference voltage for the dynamic framework. ANN display comprises of neurons in three layers are input, covered up and yield layers. ANN is the portrayal of the human mind that endeavors to copy its learning technique. It is a versatile and astute framework that changes its structure dependent on info and yield in arrangement. The ANN is utilized to instructed figure the best reference voltage progressively, which coordinate ups to most extreme power at some random info misshapening voltage. The info layer is enacted by outside data, while the yield layer drives data to an outer gadget. The private ANN arrangement is a multilayer-perceptron structure mutually with an information layer, a concealed layer and yield layer. The info layer gathered of two hubs in the information that are; the dc capacitor voltage and source voltage the shrouded layer is aloof of 25 hubs whose activity is initiated sigmoid. The informational collection (2000) used to prepare the ANN is gotten from impersonation results. The activity of this procedure is clarified in the square chart and game plan in Figure 3. The yield layer is orchestrating of one hub that is the most ideal door control flag.
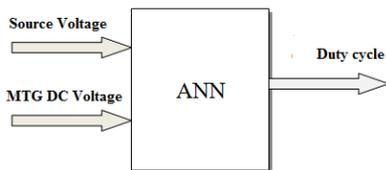
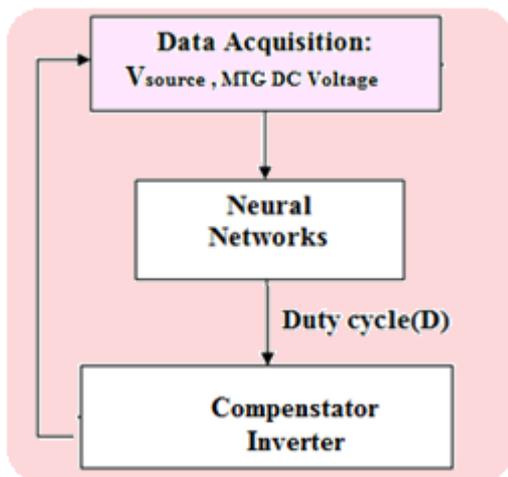**Figure 3:** Block diagram of ANN

Figure 4: ANN systems

Figure 4 ANN UPQC arrangement of PV framework. In this work, informational index comprises of 2500 examples of framework voltage and D.C capacitor voltage, which have separated into two sub-databases, 85%, of the examples are utilized to prepare the ANN, and the rest 35% are second-hand to test and approve the system. The introduction is estimated by computing the mean-square blunder as appeared in Condition (7).

$$ e = \frac{1}{p} \sum_{i=1}^{p} \left\| y^{(i)} - v^{(i)} \right\|^2 \tag{7} $$

Where, p= number of preparing information sections; y = ANN yield vector; v = wanted yield .For an arrangement of info insolation and temperature, an all around prepared ANN would give as a yield, the reference voltage that is near the coveted esteem, giving a mistake right around zero. Every neuron aj registers a weighted entirety of its n inputs Vk, k = 1, 2. . . n, and creates a yield as appeared in Condition (8).

$$ a_j = \tan sig\left(\sum_{k=1}^{n} w_k v_k + bias \right) \tag{8} $$

The tan sigmoid significance of the noteworthy weighted total that consistently has an inclination associated with it that can be considered as an advantageous information gives the yield. In Condition (8), wk speaks to the neurotransmitter weight connected with every last one of the n inputs. These preparation sets select to cover all the unmistakable information space with the end goal to get great introduction.

5. Micro turbine generator system (MTGS)

The building square outline anticipated MTGS-UPQC. The displaying of a MTGS plot comprises of three sections; the smaller scale turbine, rectifier circuit and perpetual magnet synchronous machine. The model comprises of fuel control, temperature control and speed representative and quickening control squares. There are two sorts of turbine plans existing dependent on circumstance of generator turbine and blower. Figure 5 indicates single shaft plan with blower and mounted on a similar shaft the length of with the PMSG. The generator delivers the power at high recurrence going from 1500 to 4000 Hz. The high recurrence voltage is first corrected and afterward altered to a standard air conditioning power at 50 or 60 Hz. The miniaturized scale turbines are much minor in physical measurement than a preservationist gas turbine. The length of each piece of modestly minute and the gas moves decently snappy speed inside the miniaturized scale turbine segment consequently every constituent of smaller scale turbine has a little thermodynamic time perpetual. Consequently any adjustment in the contribution of fuel or wind current of a small scale turbine influences its yield mechanical power in short point in time. In this manner, thermodynamics of miniaturized scale turbine ought to be estimated in the examination of a dynamic execution of the MTG and information mechanical capacity to the generator can't be careful as steady an incentive through electro-mechanical elements of generator.
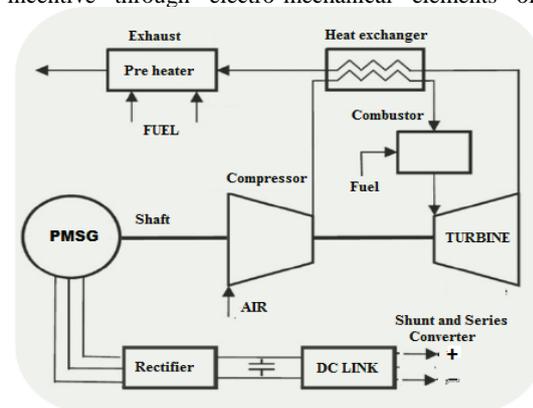

Figure 5: Single shaft MTG system

Here Permanent Magnet Synchronous Generator (PMSG) is used for energy conversion because it has the advantage of super high speed operation with small unit size of the machine which is directly proportional to the increase in speed. Super high speed PMSG is an important component of Single shaft MTG System.

6. Simulation results

The effects of load currents, load voltages and neutral current are analyzed by modeling the 1000 watts distribution system with diode bridge rectifier loads. The various system parameters considered for the simulation compare with conventional dc link and MTGS dc link are shown in Table 1. To demonstrate the effectiveness of the ANN control proposed system, UPQC is simulated using MATLAB/SIMULINK for the system harmonic disturbances. The results are shown for source and load parameter such as voltage, current and corresponding THD%. Two conditions are carried out in this system which is before and after connecting the MTGS-UPQC in the feeder with sag and swell condition.
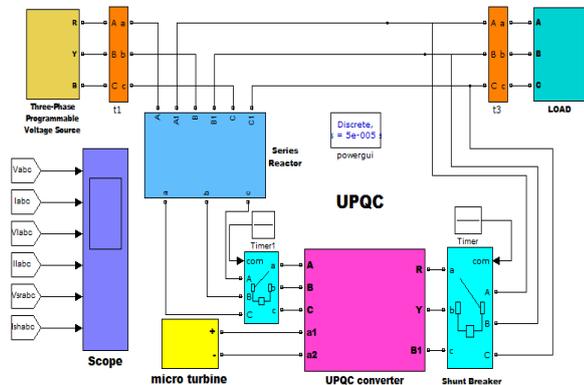
Figure 6: Simulation UPQC with micro turbine
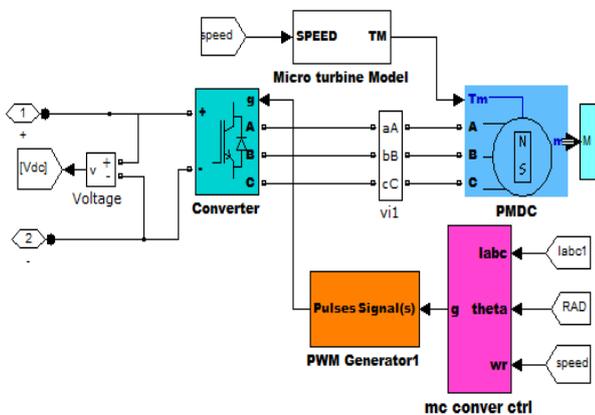
Figure 7: Micro turbine simulation

Table 1: Simulation Parameters of 1000 Watts Distribution System

System parameters	Values
Three phase source voltage VLN	100
Supply Frequency	60hz
Leakage Reactance of the Transformer	0.1e-3 H

6.1. Case 1: conventional DC LINK

To validate the effect of ANN controller, a MATLAB simulink model of the proposed system is simulated and is shown in Figure 6, masked micro turbine shown in Figure 7. The parameters of the simulation are supply voltage Vs=100V, supply frequency=60Hz, dc-link capacitor voltage (V_{dc})= 230V, dc-link capacitance C=5000μF, filter inductance Lf =0.3mH, filter resistance R_{cf}= 0.1 switching frequencies f_s=20 KHz values are the same as in table and dc link voltage shown Figure 8.
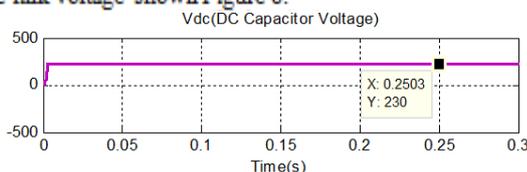
Figure 8: Conventional dc link voltage
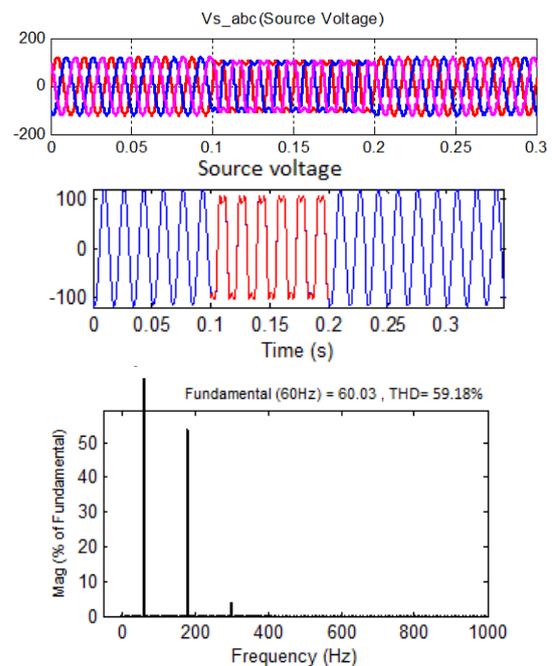
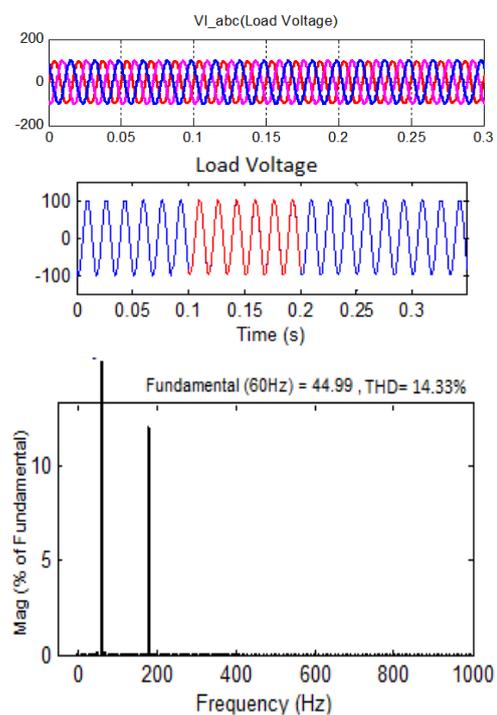
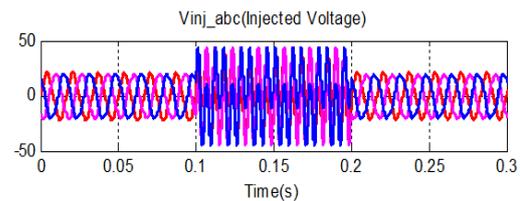**Figure 9:** Source voltage and harmonic spectrum

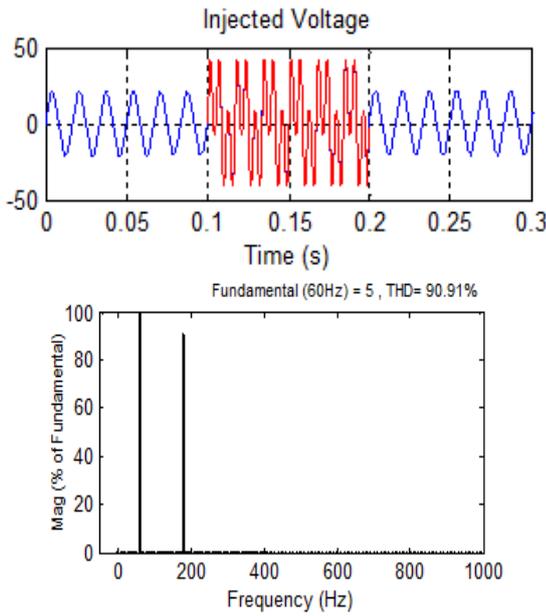**Figure 10:** Load voltage and harmonic spectrum

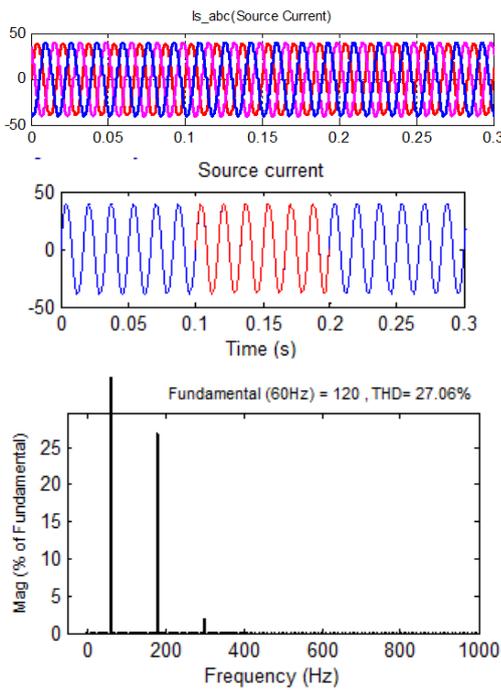**Figure 11:** Injected voltage and harmonic spectrum

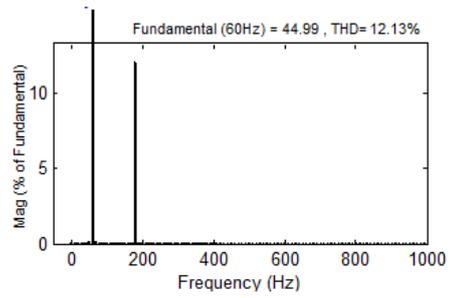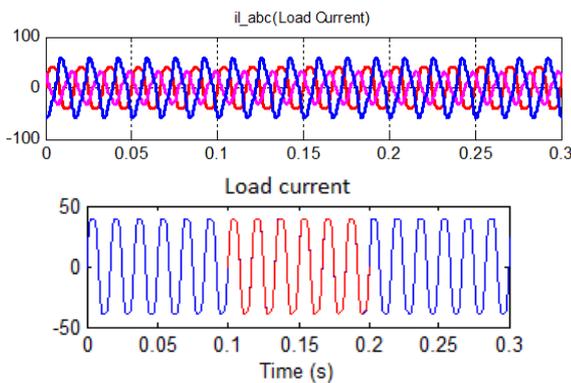**Figure 12**: Source current and harmonic spectrum

Figure 13: Load current and harmonic spectrum

The waveform of the harmonic generated source, load and injected voltages after compensation are shown in Figure 9-11 source and load currents are shown in Figure 12-13 conventional DC link compensation. The distortions in the load voltages and current are reduced. The THD values of load voltages are reduced from 59.18% to 2.98% .Similarly, the distortion in the load currents are reduced and the THD values are reduced from 12.13% to 2.31% respectively.

6.2. Case 2: Sag with MTG DC voltage

The MATLAB simulation of distribution system with non-linear and unbalanced loads injected by MTG is done and the waveforms of load voltages, load currents and neutral current are analyzed system sag condition compensation. The dc voltage injected by the MTGS as shown in Figure 14. It is found that the effects of harmonics with sag on the source, load and injected voltage and load currents are very high which lead to greater THD values. The THD values of source, load and injected voltages are 54.125, 2.29% and 83.23% as shown in Figure 15-17. Similarly, the THD values of source and load currents are 12.13% and 2.31% shown Figure 18-19. To improve the performance of the distribution system, UPQC is modeled and simulated. The load compensation voltages and currents are extracted using ANN controller.
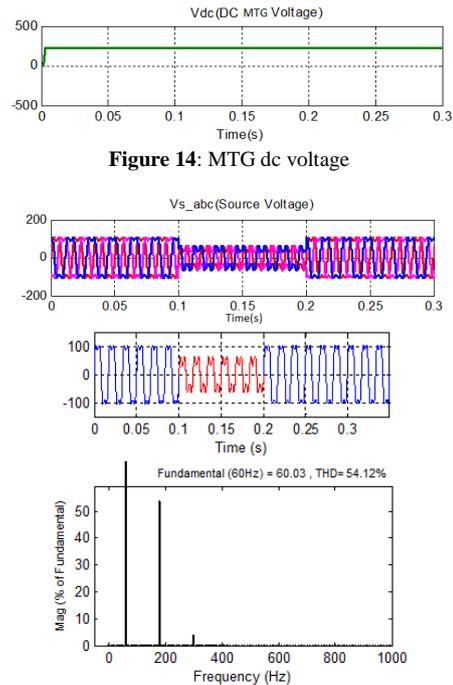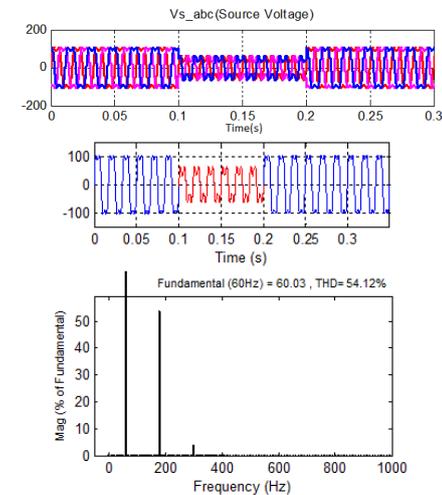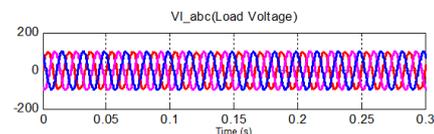

Figure 14: MTG dc voltage

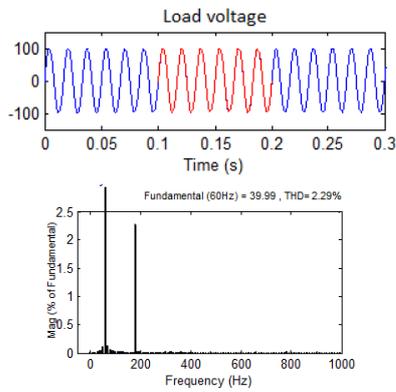**Figure 15:** Source voltage and harmonic spectrum

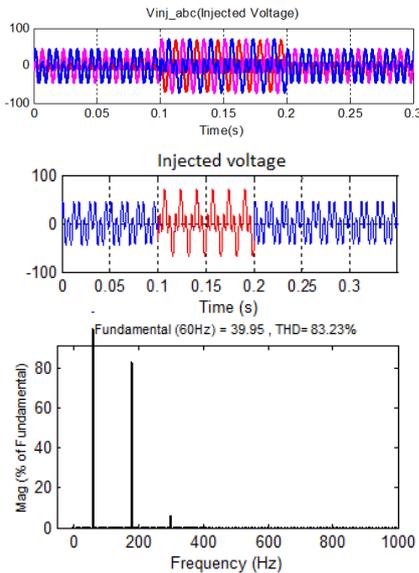**Figure 16:** Load voltage and harmonic spectrum

Figure 17: Injected voltage and harmonic spectrum
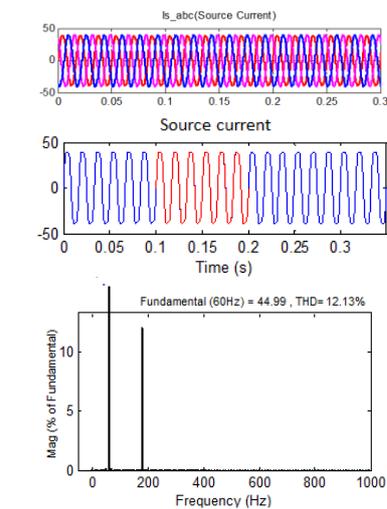

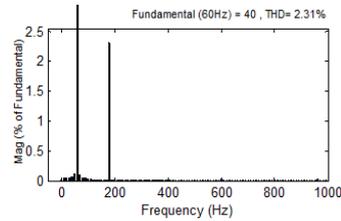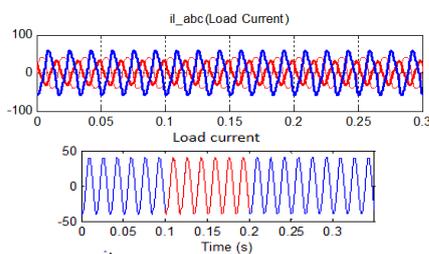**Figure 18:** Source current and harmonic spectrum

Figure 19: Load current and harmonic spectrum

6.3. Swell with MTG injected DC voltage

The simulation results show that the load voltages and load currents are sinusoidal and the distortion due to the effects of harmonics is completely reduced. Also the load currents become nearly balanced with the RMS values. The THD values of the load voltages are reduced from 41.54% to 2.33% and the load current THD values are reduced from 18.03% to 2.33% respectively. The waveform of neutral current and voltage across the capacitor are shown in Figures 18-20 and Figure 21-22 respectively. The voltage across the capacitor is also maintained constant by which enhances the power quality in the distribution system. After Connecting the MTGS-UPQC in the feeder, the voltage and current values can be improved. The series injection voltage maintains the voltage profile and the shunt injection current maintains the current profile of the system.
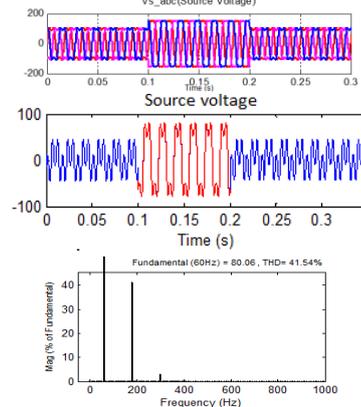

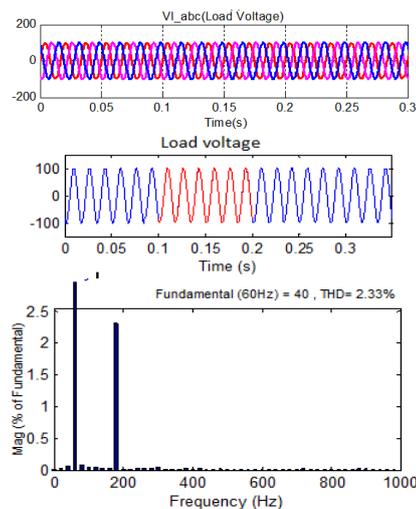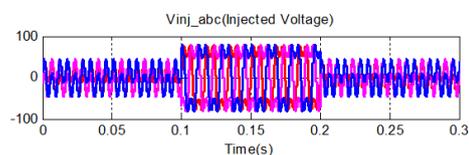**Figure 19:** Source voltage harmonic spectrum
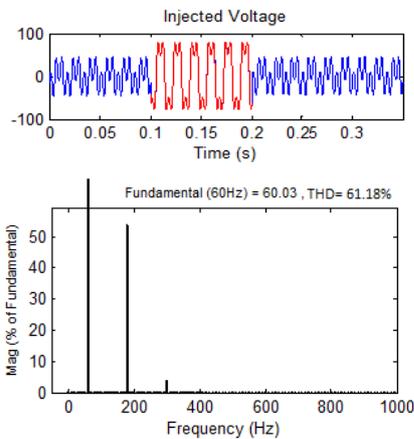

Figure 20: Load voltage and Harmonic spectrum

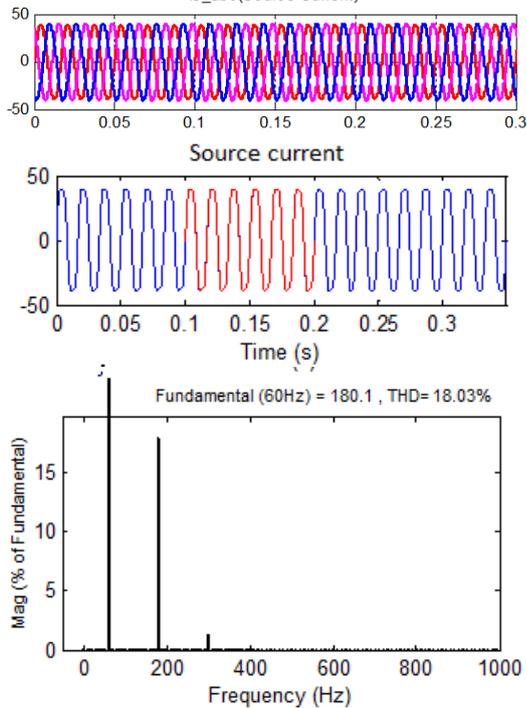**Figure 21:** Injected voltage and spectrum

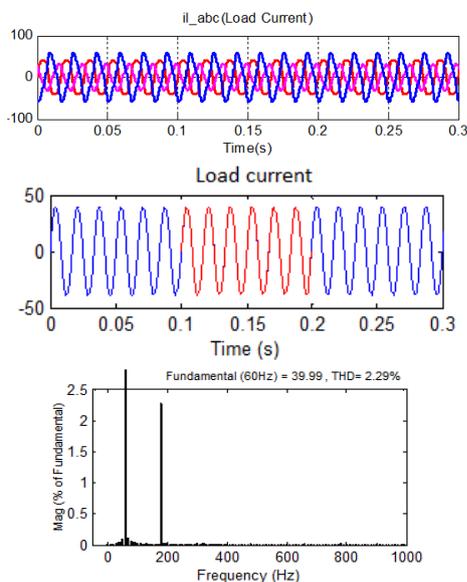**Figure 22**: Source current and harmonic spectrum

Figure 23: Load current and harmonics

The %THD content in the source voltage and load current after remuneration is appeared in Fig.13 and Fig.14. In the wake of

interfacing the MTGS-UPQC, the symphonious substance present in voltage and current gets lessened. THD esteem is appeared in the figures made reference to above. From the above waveforms it is seen that the source voltage and load flows are adjusted, sinusoidal and in-stage. So the UPQC can repay the unbalance in source voltage and load current. The correlation table for THD examination is appeared in the table I. Fig.14 demonstrates the graph for THD investigation.

Table I: Comparison Table

%THD	Conventional DC link	Sag With MTG-UPQC	Swell with MTG-UPQC
Voltage THD (%)	14.33	2.29	2.33
Current THD (%)	12.13	2.31	2.29

7. Conclusion

This paper presents the design of the Unified Power Quality Conditioner with Micro turbine Generator (MTGS) system. The UPQC is configured taking right shunt topology into account. A compensation strategy has been developed. A Micro turbine Generator (MTGS) System is also connected with UPQC in order to increase the voltage level of the three phase line. In previous work Conventional DC link is connected with UPQC to increase the voltage level, now Micro turbine is connected which gives more efficiency, more reliability to the system. The developed MTGS-UPQC provides a significant improvement in the unbalances and distortions due to linear and non-linear loads.

References

[1] Mallikarjuna N, Muqthiarali S & Padma Lalitha M, "Improvement of voltage quality of micro turbine generator with matrix converter & venturini techniques", *International Journal of Engineering Research*, Vol.9, No.8, (2014), pp.41-49.
[2] Gaonkar DN & Nayak S, "Modeling and Performance Analysis of Microturbine Based Distributed Generation System-A review", *Institute of Electrical & Electronics Engineering (IEEE)*, (2011), pp. 1-5.
[3] Saha AK, Chowdhury S, Chowdhury SP & Crossley PA, "Microturbine Based Distributed Generator in smart grid application", *CIRED Seminar*, (2008), pp.1-4.
[4] Gang W, Qui-nan C, Wan-lu W & Xin Z, "Effective utilisation of unified power quality conditioner for interconnecting PV modules with grid using power angle control method", *China International Conference Electricity Distribution (CICED)*, (2014), pp.317-323.
[5] Tiwari K & Harinarayana T, "Increasing the Efficiency of Grid Tied Micro Wind Turbines in Low Wind Speed Regimes", *Smart Grid and Renewable Energy*, Vol.5, No.10, (2014), pp.249-257.
[6] Pilavachi PA, "Mini and micro-gas turbines for combined heat and power", *Applied Thermal Engineering*, (2002), pp.2003–2004.
[7] Khorshidi A, Zolfaghari M & Hejazi MA, "Dynamic Modeling and Simulation of Microturbine Generating System for stability Analysis in Microgrid Netwoks", *International Journal of Basic Sciences & Applied Research*, Vol.3, No.9, (2014), pp. 663-670.
[8] Das B & Das D, "Dynamic Performance of Split-Shaft Microturbine Generator(MTG) and Diesel Generator as Distributed Energy Resources", *International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering*, Vol.2, No.10, (2014), pp.2131-2137.
[9] Kalaipriya K & Jeyachitra S, "Power Quality Improvement using UPQC", *Elsevier Journal of Engineering Research and Applications*, Vol.4, No.5, (2014), pp. 1-4.
[10] Dincer MS, Tezcan SS & Korjani S, "Using TV-ACPSO for Islanding detection and controlling Based Microturbine Network System", *International Journal on Technical and Physical Problems on Engineering*, Vol.6, No.20, (2006), pp.145-152.
[11] Dülger Z, Aslan S, Arıcı , Catori C, Karabay H, Polat N, Akşit İM, Saraç Hİ & Gökalp B, "Performance and Emissions of a Micro-Turbine Fueled With JP8-Canola Biodiesel Mixtures", *ASME Turbo Expo 2014: Turbine Technical Conference and Exposition*, (2014).

[12] Keshtkar H, Solanki J & Solanki SK, "Dynamic modeling, control and stability analysis of microturbine in a microgrid", *IEEE PES T&D Conference and Exposition,* (2014), pp.1-9.

[13] Nayak SK & Gaonkar DN, "Distributed Generation & Alternative Energy", *International Journal of Science, Engineering and Technology Research*, Vol.29, No.1, (2014), pp.61-80.

[14] Pal Y, Swarup A & Singh B, "A Comparitive analysis of different magnetics supported three-phase four-wire unified power quality conditioners–A simulation study", *International Journal of Electrical Power & Energy Systems*, Vol.47, (2013), pp.436-447.

[15] Emayavaramban G & Amudha A, "Recognition of sEMG for Prosthetic Control using Static and Dynamic Neural Networks", *International Journal of Control Theory and Applications*, Vol.2, No.6, (2016), pp.155-165.

[16] Emayavaramban G & Amudha A, "Identifying Hand Gestures using sEMG for Human Machine Interaction", *ARPN Journal of Engineering and Applied Sciences*, Vol.11, No.21,(2016), pp.12777-12785.

[17] Ramkumar S, Sathesh Kumar K & Emayavaramban G, "EOG Signal Classification using Neural Network for Human Computer Interaction", *International Journal of Control Theory and Applications*, Vol.9, No.24, (2016), pp. 223-231.

[18] Ramkumar S & Hema CR, "Recognition of Eye Movement Electrooculogram Signals Using Dynamic Neural Networks", *KJCS*, Vol.6, (2013), pp.12-20.

[19] Ramkumar S, Sathesh Kumar K & Emayavaramban G, "EOG Signal Classification Using Neural Network for Human Computer Interaction", *International Journal of Computer Theory and Applications*, Vol.2, No.6, (2016), pp.1-11.

[20] Ramkumar S, Satheshkumar K & Emayavaramban G, "Nine States HCI using Electrooculogram and Neural Networks", *IJET*, Vol. 8, No.6, (2017), pp.3056-3064.

[21] Ramkumar S, Sathesh Kumar K & Emayavaramban G, "A Feasibility Study On Eye Movements Using Electrooculogram Based HCI", *IEEE-International Conference on Intelligent Sustainable Systems*, (2017), pp.384-388.

[22] Emayavaramban G, Ramkumar S, Amudha A & Sathesh Kumar K, "Classification of Hand Gestures Using FFNN and TDNN Networks", *International Journal of Pure and Applied Mathematics*, Vol.118, No.8, (2018), pp.27-32.

[23] Ramesh T, Mayurinathan SK, Saravanan R & Emayavaramban G, "Enhancing Power Quality of ANN Controller Based Photovoltaic Source Injected DVR", *International Journal of Engineering & Technology*, Vol.7, (2018), (2018), pp.155-160.

[24] Ramesh T, Dharunprasath L, Kaliappan S & Emayavaramban G, "Performance of Solar PV-Fuel Cell (FC) Hybrid System for Stand-Alone Applications", *International Journal of Engineering & Technology*, Vol.7, (2018), pp.272-276.