Role of upqc in microgrid to mitigate Voltage sag/swell

AmarnadhReddy.N,M.Tech(PTPG)-EPE
Department of EEE ,JNTUCEH
HYDERABAD,500072, INDIA
Email: **amarnadhreddy_n@vnrvjiet.in**

Dr.A.Raghuram
Department of EEE ,JNTUCEH
HYDERABAD,500072, INDIA
Email: **Raghuram_a@yahoo.co.in**

Abstract— A microgrid (MG) is a compact power system made up of a collection of distributed generators and loads those function as a single and controllable entity in relation to the grid. In this work Design and analysis of upqc integrated Microgrid system is presented and performance of proposed microgrid in terms of Voltage sag, swell and Reactive power compensation is analyzed. On the other hand, because of its unstable output of DG's, several power quality (PQ) incidents have been created to allay PQ worries brought on by MG integration. Due to the significant penetration of DG units (distributed generation) with a variety of loads, microgrids could have issues with power quality and control and Reactive power adjustment is still challenging in grid linked mode because of nonlinear loads. Custom power devices (UPQC) are demonstrating to be a successful remedy for power quality problems. Harmonics in the load current is compensated by the UPQC's shunt compensator. By injecting the relevant or pertinent voltage in phase with the grid voltage, Issues with grid side power quality are corrected by the series compensator. The conventional grid system is initially modelled and simulated with a nonlinear load. The microgrid was added in a later stage. Microgrid consists of couple of renewable energy sources like a PV cell and a wind turbine.

Keywords—Microgrid,DVR,DSTATCOM,UPQC,Power Quality,VoltageSag/Swell,*TSR-Tip speed ratio*

DOI Number: 10.48047/nq.2022.20.19.NQ99220 NeuroQuantology2022;20(19): 2582-2588

I. INTRODUCTION

The burning of fossil fuels (coal, oil, and gas), nuclear power, and hydropower, where the power is supplied across great distances to customers, govern the production of electrical power worldwide. On the other hand, microgrid technology is a alternate methodto meet the demands of the upcoming electricity system.The intermittent nature of Renewable energy sources like solar PV and wind are being used in conjunction with power electronic converters. The main source of the current quality problems is the nonlinear loads were coupled by distribution networks.

Custom power devices are used to safeguard vulnerable loads against voltage quality issues on grid side as well as to reduce power quality issues brought on by the non-linear loads. DSTATCOM, a shunt-connected custom power device, corrects power quality issues raises due to nonlinear loads such as reactive current compensation, harmonics and load inequality. DVR, a series-connected custom power device that makes up the sags and swells in the grid voltage. UPQC incorporates the capability of both DSTATCOM and DVR and is composed of back-to-back coupled shunt and series compensators.

A microgrid system, as seen in Fig.1 Comprised of Non-linear load, a shunt active filters and series active filters, Distributed generation sources like photovoltaic and wind, UPQC (combination Series and Shunt connected custom power devices) and a Point of Common Coupling where the microgrid is interconnected with the Utility grid. The power quality issues in microgrids are comparable to those in traditional distribution systems. Power quality issues like Sags/swells, voltage flicker, harmonic distortion, and voltage disruptions are a few of them discussed in this work. Voltage sags can happen at any time during a disturbance.

Block diagram of proposed Work:

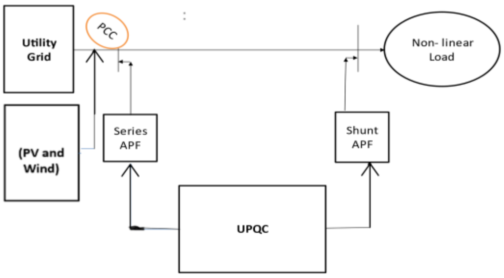

Fig.1: Block diagram

An increase in voltage over a short period of time (1/2 cycles to 1 minute w.r.to Power frequency), Voltage range between 110% to 180% raise (rms value) is known as voltage swell. Sag and Swell disturbances are caused in power system due to abrupt switching of a large inductive load or the energizing of enormous capacitor banks. Voltage sag and swell is responsible for damage of sensitive equipment and even may cause a blackout, generating an imbalance, substantial or immense current that may blow fuses or trip breakers.

The proposed microgrid system which is combination of Utility grid and Renewable energy systems (PV and Wind) and it can be controlled by UPQC with series and shunt active filters, has many advantages over traditional standalone grid-connected non-linear loads, including Low voltage ride through capabilities of the converter during transient period, improved grid power quality, and protection of essential loads from grid side disturbances.

II. MICROGRID MODELING:

A microgrid contains two Renewable energy sources, one is solar PV cell and the other one as wind turbine. The structure of upqc integrated Microgrid is displayed in fig.2.The microgrid is controlled by a upqc, which is a amalgamation of Distributed static compensator (shunt Connected converter with Active filter nearer to Load) and Dynamic voltage regulator (Series connected converter with Active filter nearer to source). Solar PV system is connected to three-phase inverter through filter and then output of inverter is fed to the grid. A two-diode model of PV cell is proposed for analysis because its performance is better than one diode model. Two diode model equivalent circuit consists of photo current (I_P), current through each diode (I_{S1} and I_{S2}), shunt branch current (I_{sh}),pv current or load current(I_L) Shunt and series resistance(R_{sh} and R_{se}). The following equations can be used to express the association between voltage and output current.

$$I_{PV} = I_p - I_{S1} - I_{S2} - I_{sh}$$

$$I_{S1} = I_{O1}\left(e\left(\frac{q*V}{N_1*K*T}\right)-1\right)$$

$$I_{S2} = I_{O2}\left(e\left(\frac{q*V}{N_2*K*T}\right)-1\right)$$

Where I_{01} and 1_{02} are the leakage currents of diodes and these currents are depending on temperature and V is the pv cell output voltage. The parameters Rs and Rp are considered while creating a mathematical model of a PV cell to represent a Practical PV module and I_{s1} and I_{s2} are represented as

$$I_{S1} = I_{O1}\left(e\left(\frac{V+R_{Se}*I}{N_1*V_T}\right)-1\right)$$

$$I_{S2} = I_{O2}\left(e\left(\frac{V+R_{Se}*I}{N_2*V_T}\right)-1\right)$$

Where V_T is Thermal voltage or volt equivalent of temp and it depends on Boltzmann constant, Temperature, Series connected pv cells and Charge of an electron.

$$V_t = N_S * K * \frac{T}{q}$$

The current through shunt branch is given by

$$I_{sh}=\frac{V+(R_{Se}*I_{pv})}{R_{sh}}$$

By solving above equations to get the interrelation among pv cell voltage and pv cell current and it is given as

$$\mathrm{I_{PV}} = \mathrm{I_P} - I_{O1}\left(\mathrm{e}\left(\frac{V + R_{Se} * I}{N_1 * V_T}\right) - 1\right)$$

$$-I_{O2}\left(\mathrm{e}\left(\frac{V + R_{Se} * I}{N_2 * V_T}\right) - 1\right) - \frac{V + \left(R_{Se} * I_{pv}\right)}{R_{sh}}$$

For Modelling of wind turbine,Permanent magnet synchronous generator (PMSG) is considered due to its wide range of power output between 100w to 100kw,offers smooth rotation over the entire speed range, zero field winding copper losses ,no brush drop and no brush damage, it provides better efficiency than other machines. The following parameters are considered for analysis of PMSM based wind turbine.

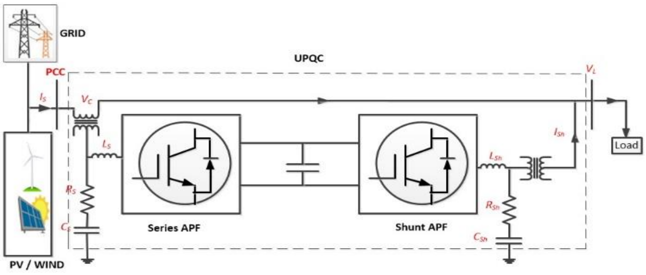

Fig.2: UPQC integrated Microgrid system

$$\mathrm{P_{mech}} = 1/2\ \rho\, \mathrm{A}\, \mathrm{V_{wind}^3}\ \mathrm{C}_P(\lambda, \theta)$$

where $\mathrm{P_{mech}}$ indicates the output power(mechanical) of the windturbine, Cp indicates the coefficient of power of wind turbine, λ indicates the TSR of the wind turbine blades, θ indicates the pitch angle, ρ indicates the air density, $\mathrm{V_{wind}}$ indicates the velocity of wind, A represents the swept area of wind turbine consider as 15.1 m/se and Cp(λ, θ) is expresses as

$$C_p(\lambda, \theta) = C_1\left\{C_2\frac{1}{\beta} - C_3\beta\theta - C_4\theta^x - C_5\right\}e^{-C_6\frac{1}{\beta}}$$

Where C_1,C_2,C_3,C_4,C_5 and C_6 are constants, selection of x value is based on the type of turbine is modelled in the analysis, θ is the angle and it varies between edge of the blade and the blade's rotation and β is defined by

$$\frac{1}{\beta} = \frac{1}{\lambda + 0.08\theta} - \frac{0.035}{1 + \theta^3}$$

The above equations are helpful while designing a PMSG based wind turbine in MATLAB. To implement Wind turbine model in Simulink following parameters need to be considered and those values are r=1.25m, wind turbine blade length L =2.5m, Area=6.25m^2, ρ = l.225 kg/m^2.

The output voltage of solar pv cell, the output voltage of PMSG based wind turbine and Utility grid voltage are interconnected at a Point called point of common coupling (PCC), now the voltage of microgrid is the voltage at PCC, which reference voltage, to design UPQC integrated Microgrid system delivers power to non-linear load, the parameters need to consider for MATLAB Simulink those are Line to line operating voltage is 415V, Depth of modulation index is considered as 1, DC bus voltage is considered as 677v,DC Bus capacitor rating is 7.3mf,Inductor which is an interface between shunt compensator and load is considered as 6.6Mh. Modulation index is approximated as unity for reduction of harmonics. The volt-Amp rating of series injecting transformer is considered as 5.35KVA. The switching frequency of series compensator and shunt compensator is considered as 10KHz.

III.CONTROL STRATEGY

The two primary subsystems of the proposed UPQC integrated Microgrod based system are the shunt compensator and the series compensator.Load pq issues that is harmonics at load current and reactive power compensation at load.To protect the lad from grid side pq issues such as sags and swells, series compensator adds voltage, which is in the same phase of grid voltage.

(a) Control scheme of Shunt Compensator:

To draw the peak power from the solar PV array shunt compensator is operated at its maximal power point.

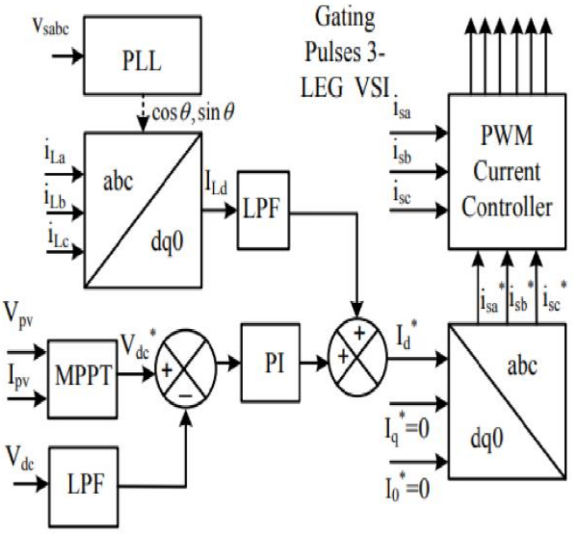

Fig. 3: Shunt compensator's Control scheme

The mppt technique is used to perform load current compensation. To maintain DC link voltage at ref PI controller is designed. In this work synchronous reference frame technique is employed to retrieve the active load current which is fundamental component that is helpful for controlling of shunt compensator. The control structure of shunt compensator is displayed below in fig.3. Once values of phase angle and frequency are obtained from Phase locked loop, based on the information of phase and frequency, load current is now changed into d-q-0 frame. The activating of PLL depends on grid voltage. Lowpass filter is used to filter the direct axis component of current from load current to get actual DC component. The obtained DC component indicates the a-b-c frame fundamental current. grid voltage acts as a input to the PLL. An LPF is used to get the DC component from the d-component of the load current, which indicates the fundamental current in the a-b-c frame of reference. Newly obtained fundamental a-b-c frame components gets added with DC bus PI controller, hcc is useful for comparison of grid ref currents and the determined grid current to generate gating pulses.

(b) Control scheme of Series Compensator:

In this case both grid voltage phase and the series compensator's voltage injection phase are same, due to which the series compensator's injection voltage is small. The control scheme of series controller is displayed below in fig.4.

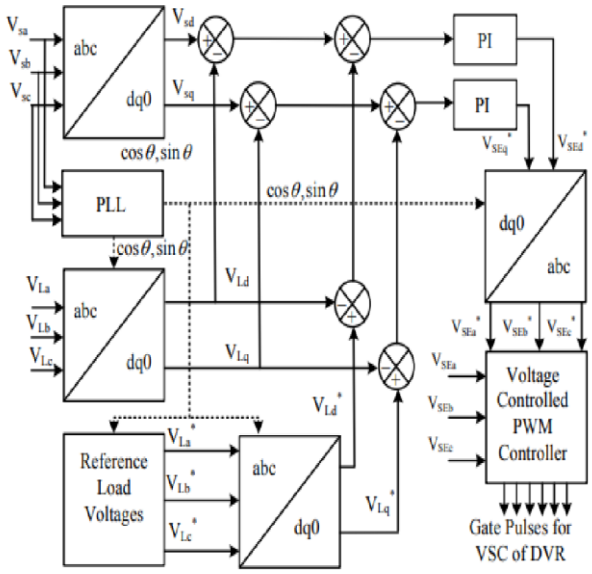

Fig.4: Series Compensator's Control scheme

In order to retrieve the fundamental or essential component of grid voltage a PLL is employed, apart from the above function, Phase Locked Loop is used to create the reference axis in the dq0 frame. To generate reference load voltage, PLL plays a crucial role to retrieve the grid voltage frequency and phase angle of grid voltage. voltages at grid, voltages at load and ref-voltage at load are transformed into dq0 frame.The contrast between ref-voltage for series compensator and original voltage for series compensator is sent through PI Controller for Direct-axis as well as for Quadrature axis signals. The ref-signal for series compensator is extracted from the output of PI controller is compared with original voltage of series compensator and then transmitted through hvc for generation of gating signals.

IV. MATLAB SIMULATION & RESULTS:

The Simulation of UPQC integrated Microgrid system is shown in fig.5. It includes Shunt active filter, series active filter, solar pv system and wind turbine which are coupled to Utility grid at PCC. The reference voltage at point of common coupling is 415V and per phase voltage is 339V(peak) is shown in fig.6 below and it is considered as 1PU.Series active filter is helpful to alleviate voltage disturbance and harmonics in the power system by injecting appropriated voltage in phase with grid voltage.

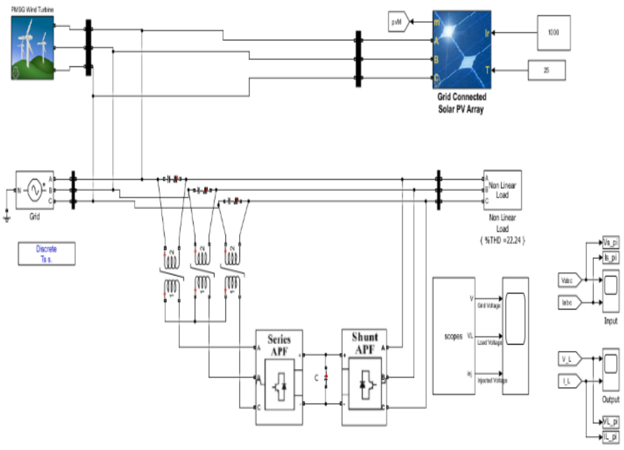

Fig.5: MATLAB simulation of UPQC integrated Microgrid system.

Shunt active filter is connected in shunt for compensation of reactive power in the power system network by injecting current and shunt active filter is used to regulate the dc link voltage. In the above simulation sag and swell disturbance are created based on the pu references.

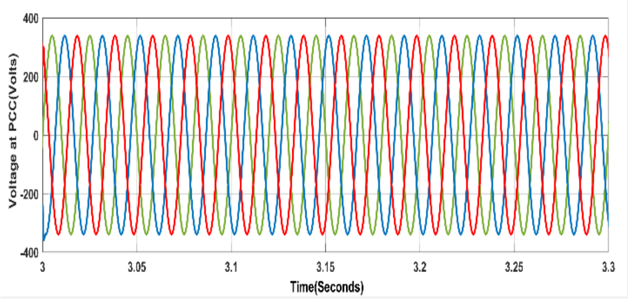

Fig.6: Voltage at PCC with UPQC

In the above fig.6, During sag condition the voltage at pcc is maintained sinusoidal and even at swell condition also voltage at pcc is same as above.

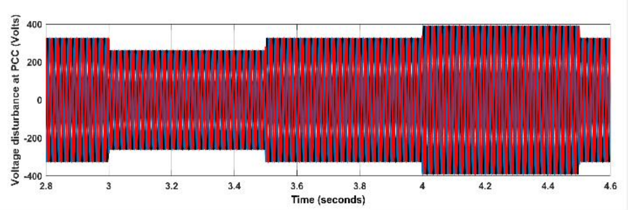

Fig.7: Voltage Disturbance in the power system network without UPQC.

In the above fig.7, disturbance scenario is created in the power system network. The voltage is maintained at 1pu between 0 to 3 seconds, Voltage sag is created in the duration between 3 to 3.5 sec leads to change(fall) in the magnitude of voltage as 0.8pu and Voltage Swell is created between the duration 4 to 4.5seconds leads to change(raise) in the magnitude of voltage as 1.2pu.

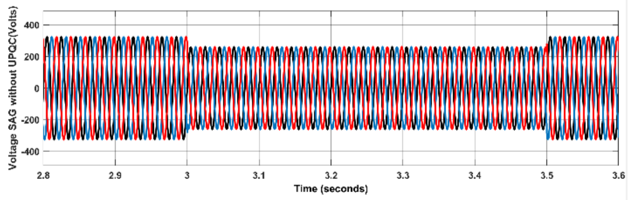

Fig.8: Voltage sag without upqc

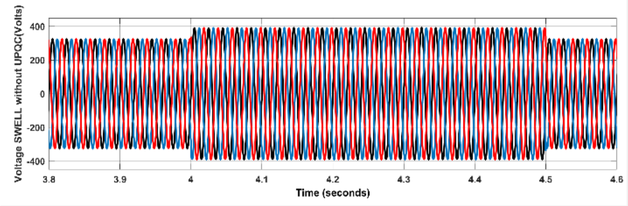

Fig.9: Voltage swell without upqc

Sag/Swell disturbances are created at power system network in the duration between 3 to 3.5s and 4 to 4.5sas shown in Fig.8 and Fig.9.

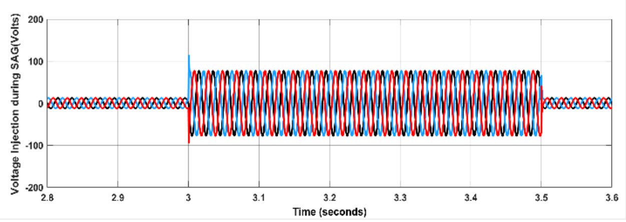

Fig.10: Voltage injection to alleviate sag disturbance

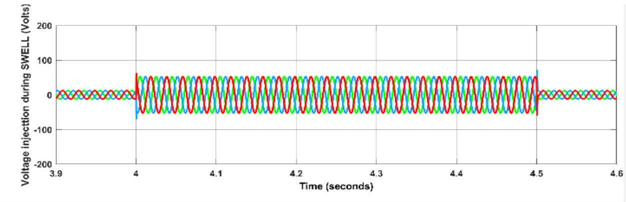

Fig.11: Voltage injection to alleviate swell disturbance

UPQC is amalgamation of series connected converter and shunt connected converter used to mitigate the disturbances like sag/swell, by introducing appropriate voltage which is in the same phase as the grid voltage, Voltage injections are displayed below in fig.10 and fig.11.

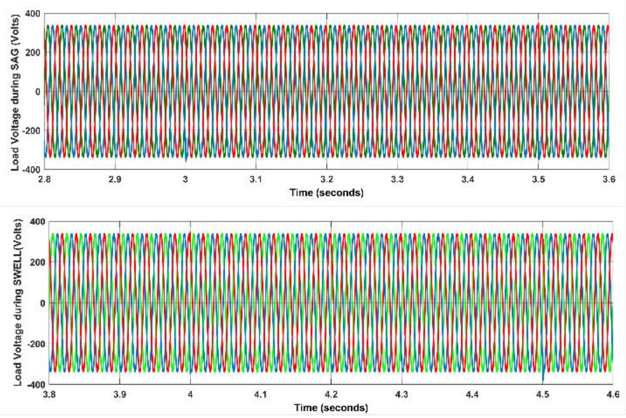

Fig.12: Load voltage during sag/swell with UPQC

Load voltage during sag/swell disturbance is a pure sinusoidal that is between 3 to 3.5s and 4 to 4.5s, the power system capable of delivering output voltage of 415Volts and it delivers per phase voltage of 339v(peak) to load. Due to connection of UPQC at source side and load side, it can mitigate disturbances there by load voltage raised to a level of reference voltage.

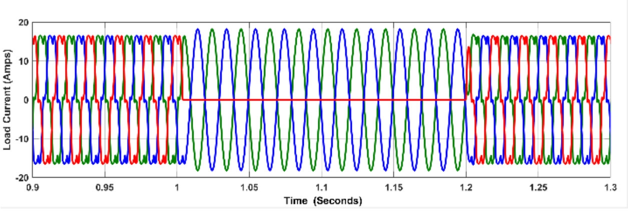

Fig.13: Unbalanced Load Current

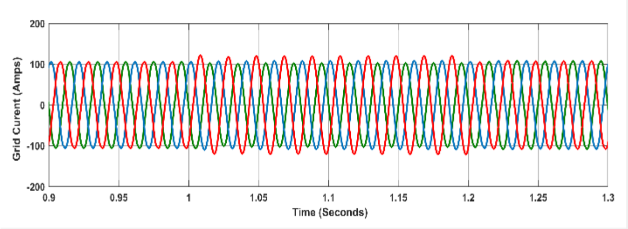

Fig.14: Grid Current during unbalance with upqc

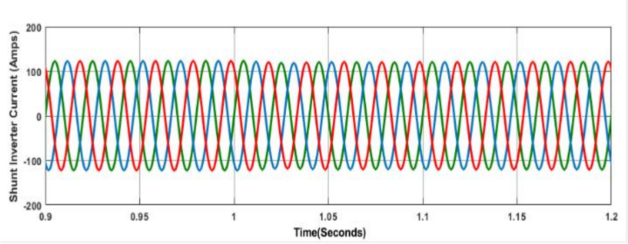

Fig.15: Shunt inverter Current during unbalance with upqc

The load current, grid current and shunt inverter current during disturbance or unbalance is shown in the fig.13, fig.14 and fig.15 create a unbalance in the load current, breaker is connected to the c-phase and breaker is operated between 1 to 1. 2sec. Breaker is closed between 0 to 1sec and it is opened between 1 to 1.2 sec leads to unbalance creation at load side. c-phase will be disconnected from the power system network, but due to upqc shunt and series converter it injects necessary voltage and necessary currents for reactive power compensation leads to maintain sinusoidal nature of grid currents and shunt inverter currents. The behavior of load current during sag/swell mitigation is shown in fig.16 and fig.17 and its nature is sinusoidal.

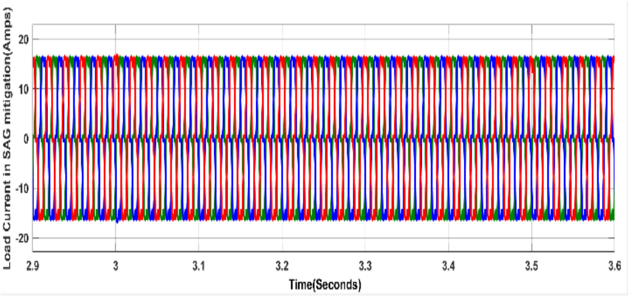

Fig.16: Load Current behavior during sag mitigation with upqc

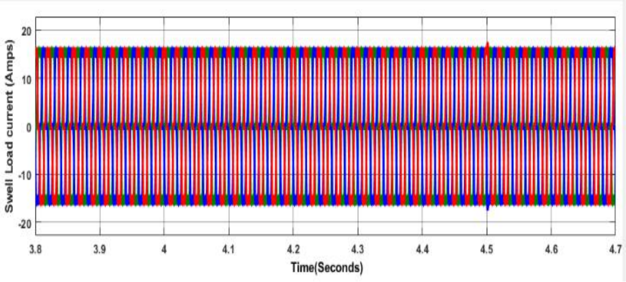

Fig.17: Load Current behavior during swell mitigation with upqc

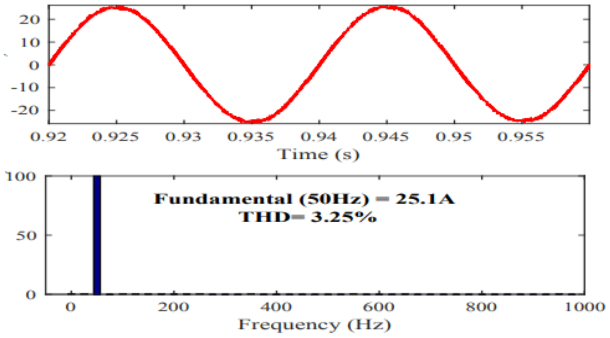

Fig.18: Grid current harmonic spectrum and THD

V. CONCLUSION:

The proposed microgrid system is a amalgamation of solar pv, wind turbine and Utility grid. The analysis is implemented in MATLAB Simulink environment, and it was examined for the various disturbance conditions i.e., voltage sag, swell and load unbalance. The behavior of the grid connected system has been verified in terms of voltage magnitude and power delivered for the nonlinear loads. It is noticed (from the matlab simulation results) that upqc mitigates all the disturbances caused by harmonics, voltage disturbances caused by nonlinear loads like sag/swells and even under load unbalance. The performance of upqc integrated microgrid system is satisfactory under all disturbance conditions and it gives superior performance for power quality improvement.

REFERENCES:

[1] D. Graovac, V. Katic, and A. Rufer, ‘‘Power quality problems compensation with universal power quality conditioning system,’’ IEEE Trans. Power Del., vol. 22, no. 2, pp. 968–976, Apr. 2007.

[2] R. Dharmalingam, S. S. Dash, K. Senthilnathan, A. B. Mayilvaganan, S. Chinnamuthu” Power Quality Improvement by Unified Power Quality Conditioner Based on CSC Topology Using Synchronous Reference Frame Theory” The Scientific World Journal Hindawi Publishing Corporation., pp. 1-7, 2014.

[3] S. Samal and P. K. Hota, ‘‘Power quality improvement by solar photovoltaic/wind energy integrated system using unified power quality conditioner,’’ Int. J. Power Electron. Drive Syst., vol. 8, p. 1424, Jun. 2017.

[4] Khadkikar V, Chandra A. “UPQC-S: a novel concept of simultaneous voltage sag/swell and load reactive power compensations utilizing series inverter of UPQC” IEEE Transaction on Power Electronics. 2011;p. 2414–2425.

[5] P. Deshpande, A. Shrivastava, and A. Khare, “Different Modeling Aspects and Energy Systems of Unified Power Quality Conditioner (UPQC): An Overview,” Int. J. Renewable Energy Research, vol. 3, no. 2, pp. 395-402, 2013.

[6] V. Sithidet, N. Isarachai, K. Somyot “Coordinated SVC and AVR for robust voltage control in a hybrid wind-diesel system” Energy Convers. Manage. 51 (2010) 2383–2393.