FUZZY CONTROLLER BASED POWER QUALITY IMPROVEMENT FOR A MICROGRID WITH ENERGY MANAGEMENT SYSTEM

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Abstract – There is a drastic decrease in availability of conventional energy sources such as coal, natural gas and oil. The need for using non-conventional energy sources has increased due to the fast rate depletion in conventional energy sources and the ill effects of using them. Research work in the area of renewable energy sources has hence been increased throughout the world. The rate at which power demands are increasing, requires the need for interconnections of various power generation methods. For the proper use of conventional and non-conventional distributed generation microgrid is essential. Microgrid combines one or more generation units and helps to use the power generated in efficient manner. Microgrid includes the generating units, battery storage system with power electronic converters. The use of power converter is important, but the presence of converter generates harmonics usually so that the power quality issues have become serious. Many controllers are used to solve power quality problems, where one of them is the Unified Power Quality Controller (UPQC). Problems linked to power quality become serious due to the use of power electronics appliances. Microgrid power quality is maintained by using UPQC compensating devices. To control UPQC, there must be some controller to intimate the voltage sag, swell and flickers. In this paper the fuzzy logic controller is used for UPQC. An energy management system (EMS) is a system used by electrical utility network operators to monitor, regulate and optimize transmission and generation system efficiency. The system model is created using MATLAB by merging all DC-microgrid, EMS and UPQC, to solve power quality issues.

Keywords- Microgrid, Unified Power Quality Controller, Energy Management System and Fuzzy Logic Controller.

I. INTRODUCTION

Microgrid is a set of interconnected loads and distributed energy resources that act as a single controllable grid entity within obviously defined electrical boundaries. A microgrid can be attached and disconnected from the grid to allow the grid or island mode to work.

A micro-grid consisting of low-voltage power distribution systems (micro-turbines, photo-voltaic), power storage devices (batteries, flywheels) and flexible loads. Such devices can function from the primary grid either linked or disconnected. Micro-sources operation in the network can bring benefits to the overall system performance.

An EMS is a computer-aided tool system used by electrical utility grid operators to monitor, regulate and optimize the generation or transmission system efficiency. It can also be used in small-scale structures such as microgrid's.

EMS is a system based on real-time energy generation and consumption tracking and forecasting. EMS makes it simple for utility operators to regulate load forecast generation and dispatch.

Energy management can be performed with the enterprise's optimal short- or long-term energy generation, consumption and purchase programs to determine energy costs, economic factors, and availability of energy.

The huge quality of EMS system makes it possible to manage the primary system parts comparatively easily. The system measures and analyzes the primary system devices ' real energy usage. When the maximum loads appear in the scheme, the EMS guarantees that the controlling systems are turned off while these users are activated by the EMS during time of low electricity consumption.

Different controllers are used to mitigate issues associated with different types of power quality in the microgrid. Mostly used as a compensating device called Unified Power Quality Conditioner (UPQC). VSI series mitigates supply side disruptions and VSI shunt mitigates load side disruptions. The importance of UPQC to mitigate several power quality issues is suggested from literature review especially towards distribution system.

The controller used for UPQC gating pulse is fuzzy logic controller instead of PI, PID controller, which helps in the performance of UPQC by mitigating power quality issues accurately.

Fuzzy rules assist to offer error signal in load for UPQC design, Fuzzy logic control scheme is expressed through a sequence of expert knowledge linguistic descriptions, often made up of conditional statements such as if ... then.' All membership functions are symmetrically distributed throughout the universe to simplify the calculation of triangular membership functions.

II. LITERATURE SURVEY

An intensive literature survey was done for about 10 papers and the proposed system was evolved which produces better outcomes.

The complete design and analysis of solar and fuel cells power generation for a microgrid with the proper energy management system. Results of simulation check's the feasibility of EMS from paper [1].

The functioning of UPQC for an AC microgrid under different conditions has been done. The mitigation of voltage disturbance in supply side and also across the load side is implemented and the simulation results shows that the performance of UPQC is better by compensating reactive power to resolve power quality issues from paper [2].

A dual three-phase topology of a unified IUPQC power conditioner is presented with a simple control technique. Here in this PWM is used to control IUPQC with the well-known frequency spectrum. The simulation and mathematical design was studied from paper [3].

The integration of solar and wind power system for a DC-microgrid with the operational controls is designed according to the specifications and sate of charge of battery according to the generation was clearly observed from simulation results from paper [4].

Hybrid Unified Power Quality Controller (UPQC) was used concurrently to mitigate voltage and present associated power quality issues. From the simulation outcomes, it was found evident that the suggested scheme can compensate for the active transfer of energy to load and source in grid attached and insulating mode, voltage barrier and enhance the quality of power. Simulation results shows the THD across supply side and load side to be less from paper [5].

Simple DC microgrid model described in matlab with easy EMS control approach. DC microgrid consists photovoltaic, generator PMDC as a wind turbine generating scheme, grid, storage battery system and controller for energy management from paper [6].

Neuro-Fuzzy based UPQC Controller used for active and reactive power compensation in the advanced microgrid. It can effectively fix power quality and energy control problems such as voltage stabilization, sag, swells and power factor correction requiring reactive power control. The simulation results shows THD to be 3.35% from paper [7].

The dynamic voltage restorer was used for the voltage swell, sag and flicker's mitigation and design of DVR in Simulink for the application of Microgrid is done from paper [8].

MG's economic and reliability issues was discussed by considering limitations along with alternatives to problems. Results for grid connected mode and microgrid insulation mode are verified from paper [9].

By incorporating dc-microgrid with both the Energy Management System and UPQC, microgrid effectiveness will be improved. Using EMS, overall microgrid operating costs can be reduced. The suggested scheme produces better outcomes than the individual use of each scheme. Results show that the suggested scheme delivers better energy management findings for dc-microgrid based on complete generation supply [10].

III. PROPOSED SYSTEM

From paper [10] the implementation of microgrid with EMS and UPQC with the PI controller was done. There was few drawbacks like voltage settling time and response to the load side distortion was slow. For the improvement of power quality issues compared to the paper [10], the proposed system was developed with fuzzy logic controller for betterment like fast response on the load side distortion, less voltage settling time and Total harmonic distortion (THD) in the load side is less (THD= 2.52%).

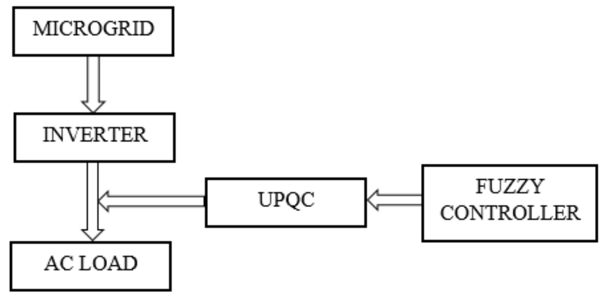

Figure 1.Proposed system

IV. MICROGRID WITH INTEGRATION OF EMS

The basic concept of EMS is shown in the below Figure 2

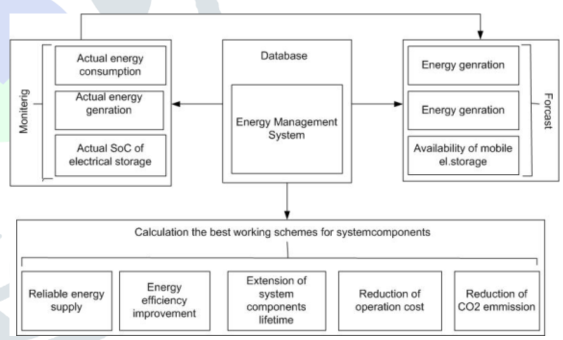

Figure 2. Energy management system's main concept

EMS ensures that the controllable devices are turned off during peak load while the EMS activates these consumers during periods of low electricity consumption. Such system component management is not always optimal as different consumers have different types of controllable devices.

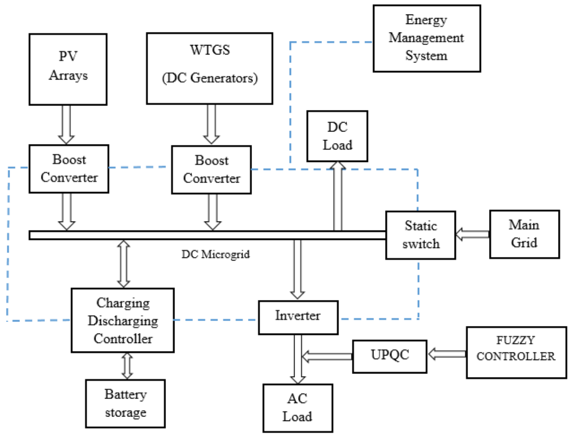

Figure 3. Block diagram of Microgrid with EMS

From Figure 3, It comprises of different renewable energy sources such as wind turbine generator (WTGS), photovoltaic (PV) generation, Lead acid battery storage (BS), grid controllable and uncontrollable load. PV and WTGS are linked via boost converter to 315V (dc). Lead acid battery system with a capacity of 96Ah is used to supply energy if the linked load is not supplied by the generation.

In this paper, where in WTGS, permanent magnet dc generator is used then generated power is given DC-microgrid via boost converter. Even power generated by solar panel is given to DC-microgrid through boost converter. Whenever there is a decrease in the generation because of climatic condition then with the help of charger controller (battery) a margin voltage of 285V is maintained in the DC-microgrid. The total power present is DC-microgrid is shared to DC load and AC load where in AC load there will be presence controllable load and non-controllable load. UPQC is implemented across both the loads, the non-controllable will get continuously connected to the generation where as in controllable load can operated according to our requirement. As per the block diagram the simulation is done using Simulink and the Figure 4 shows the Simulation model of microgrid. Where the solar and wind energy system is connected together with battery storage system to microgrid given to AC load and DC load connected.

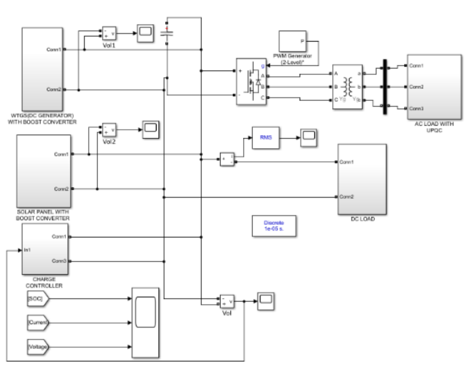

Figure 4. Simulation model of Microgrid

V. UNIFIED POWER QUALITY CONDITIONER

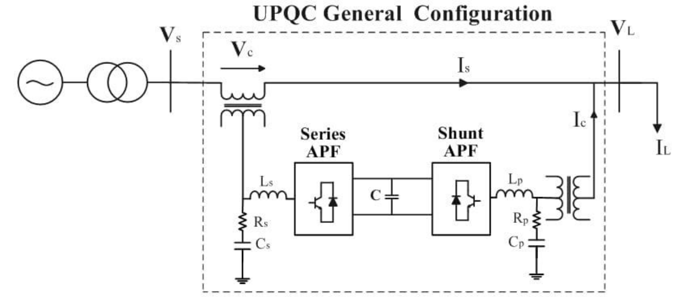

Figure 5. Basic circuit diagram of UPQC

The above circuit comprises of a series combination with a series active power filter and shunt active power filter to mitigate power quality issues. A dc-link capacitor connects two voltage source inverters (VSIs) back to back. The active filter and shunt filter series used primarily in UPQC to compensate for voltage, current imbalance and distortion. Figure 5 shows the UPQC circuit, which compensate the voltage and current on required correction to get the undistorted wave across the load. Shunt active filter helps to compensate current and series active filter helps to compensate voltage.

VI. MICROGRID WITH EMS and UPQC INTEGRATION

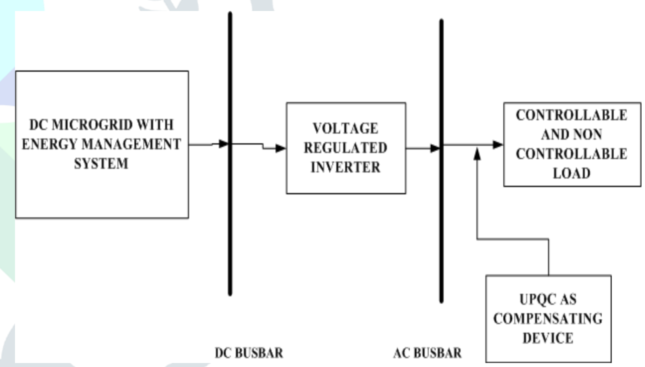

Figure 6. Integration of EMS and UPQC With Microgrid

It is clear from the above discussion what will be the significance of both EMS and UPQC, where EMS to better monitor, maintain, schedule dispatch of generation and UPQC to mitigate problems of power quality. Management of energy system is used for DC-micro-grid and UPQC connects dc-micro-grid to the utility. UPQC provides compensation for voltage-current sag, swell due fault, through its dc link. After both systems have been integrated with microgrid, the benefits of both technologies can only be achieved in a single scheme. In this case, DC-microgrid along EMS is incorporated with AC load and interconnected via UPQC. UPQC is used to mitigate problems of energy quality associated with voltage and electronic devices switching, swelling, flicking or distortion.

VII. MATHEMATICAL FORMULATION

The advanced Management of energy System is based on mathematical formulations that follows below. Which relies on the generation and linked load side data gathered. EMS formulation is as follows:

The sum of two power generated by solar and wind system is know as total power generated and represented by this equation

$$Ppv + Pw = P_{TG} \quad (1)$$

Where, P_{pv} is generated power by solar and Pw is generated power by WTGS and total load PT l is given by,

$$Pl1 + Pl2 = PT\ l \quad (2)$$

Where, Pl1 is DC load and Pl2 is AC load.

Total connected load is PT l.

$$PT\ g > PT\ l \quad (3)$$

The battery is then charged by triggering the charging controller via non-conventional energy sources.

$$PT\ g < PT\ l \quad (4)$$

Then battery is discharged and required margin voltage is supplied to microgrid. The flowchart as below is intended according to the above mathematical modeling of EMS. EMS work is based on the following flowchart for dc microgrid.

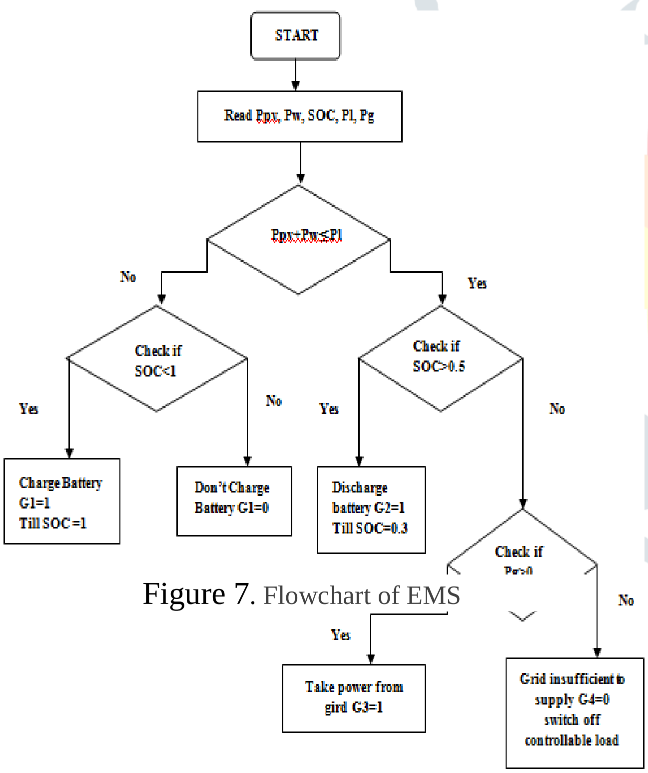

Figure 7. Flowchart of EMS

VIII. FUZZY LOGIC

Fuzzy logic has become one of the most effective techniques of today to develop advanced control systems. The reason is very easy. This fully addresses such applications as it resembles human decision-making with the ability to produce precise solutions from certain or approximate data. This is similar to that as regards Boolean Logic but unlike the fuzzy logic there will be the membership function which varies in between 0 and 1. In the fuzzy set theory there will be the transformation between the membership and non-membership functions.

While other methods require precise equations for modeling behaviors in the real world, fuzzy design can accommodate the ambiguities in the real world of human language and logic. It provides both an intuitive method for human system description and automates the conversion of these system requirements into effective models.

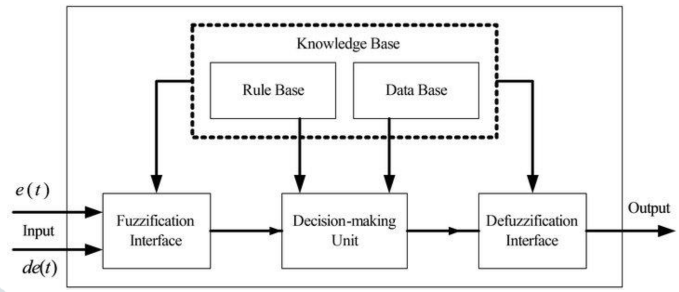

Figure 8. FUZZY CONTROLLED BLOCK

There are three steps in fuzzy controlled block namely fuzzification, rule evaluation and de-fuzzification. Fuzzy logic control system is expressed through a series of linguistic descriptions of expert knowledge, often made up of conditional statements such as' if... then.' In this paper Figure 9 shows the input membership used for UPQC control.

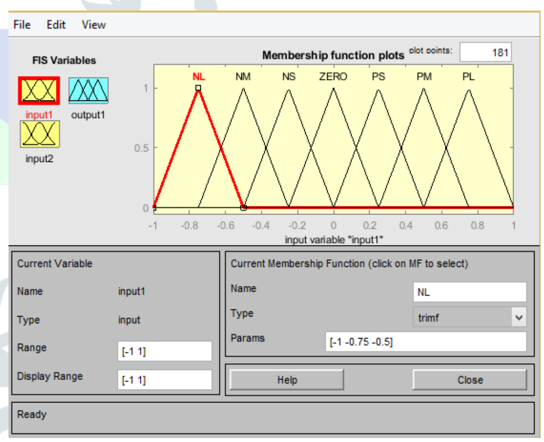

Figure 9. Membership function of input 1

The rule editor checks both input1 and input 2 according to the inputs the assigned output must be executed. Graphically input 1 and input 2 will same and compared with each other in every cases. The below figure clearly relates the rules given to the rule editor for this proposed system. 40 set of rules provided for fuzzy logic rule editor.

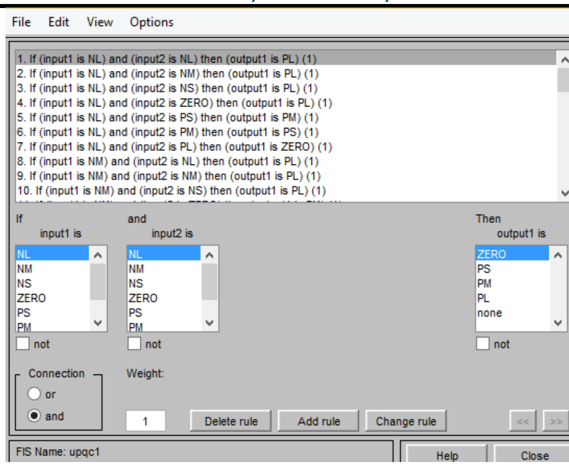

Figure 10. Rule editor

Basically NL is negatively large, NM is negatively medium, NS is negatively small similarly for positively large PL, positively medium PM and positively small PS. If the input 1 is NL and input 2 is NL then the output will be PL. There are 40 set of rules given to fuzzy rule editor such that it will be repeatedly checking the error signals. The Figure 11 shows the output membership function based on the inputs.

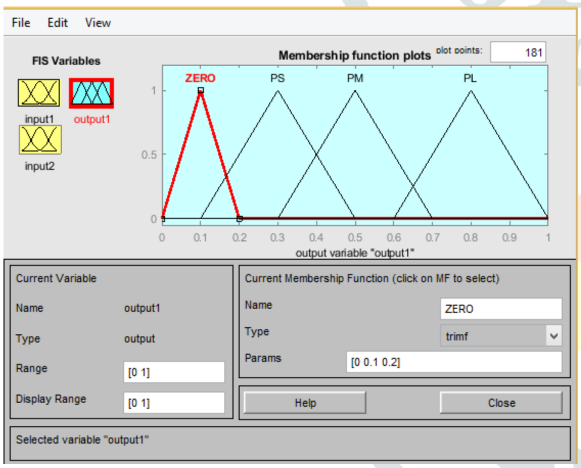

Figure 11. Membership function of output

IX. SIMULATION RESULTS

Whenever wind speed is given 20m/s which is around 120 in rad/sec. The generated power by wind turbine depending on speed is plotted below in Figure 12. According to change in speed there will be change in power generation by wind turbine. Initially it takes time to settle in wind power generation. Total power to be 3000W

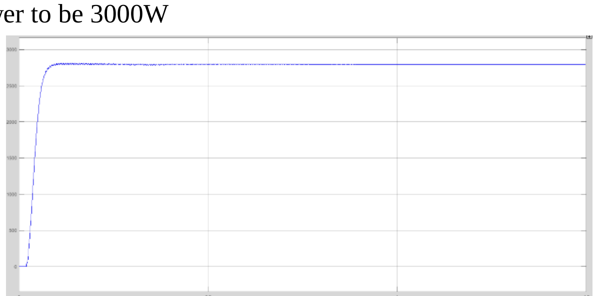

Figure 12. Total power generated by wind turbine

The irradiation won't be same as throughout the day hence irradiation for the solar panel is given using a signal builder according to that the solar generation is done. The below figure 13 shows the signal builder graph.

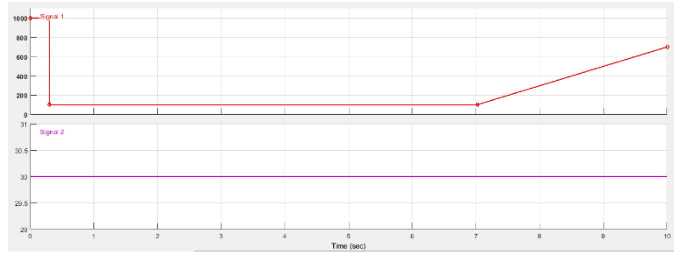

Figure 13. Signal builder given to solar panel

The above figure13 shows that 1000w/m2 is maintained till 0.3seconds, later it is reduced to 100w/m2 till 7seconds then it keep on increasing linearly. This is done because we won't get solar irradiation to be same throughout the day. Temperature is maintained 30 for simulation purpose.

According to above boundary condition the total power generated by the solar panel is shown in the Figure 14. The generated power is 6000W under irradiation 1000W/m2 and the generated power is reduced to 500W under irradiation of 100W/m2.

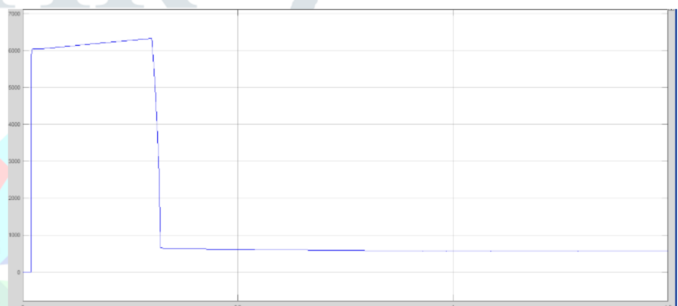

Figure 14. Total power generated by solar array

Initially the charge state of a battery is set to be 50%, if the generation is more than load power then the battery will get charged and during the less power generation the battery will get discharged. A marginal voltage of 285V is maintained when there is less generation. The below Figure 15 shows the state of charge in battery.

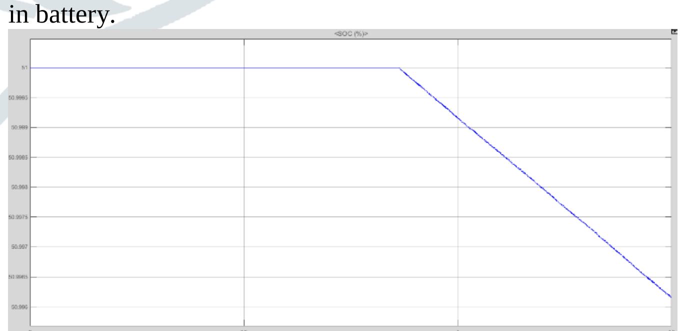

Figure 15. State of charge (SOC)

The above SOC graph clearly shows that the battery is charged till 0.8sec and it starts discharging after 0.8sec because the generation from the renewable energy source is reduced.

The Figure 16 shows the voltage across the DC-microgrid which is connected from the wind turbine generation system and solar generation system. Even this graph clearly shows that the generation is high during start later it is reduced then a marginal voltage of 285V is maintained by battery.

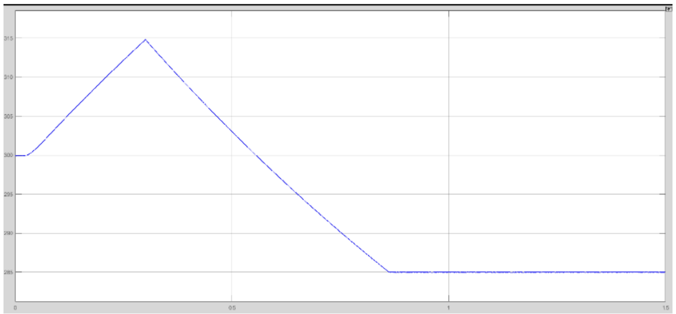

Figure 16. DC voltage across microgrid

The figure 17 shows the current in the DC load which is 6amps from the microgrid. The voltage across the DC load will be the same of microgrid and it will be around 285V.

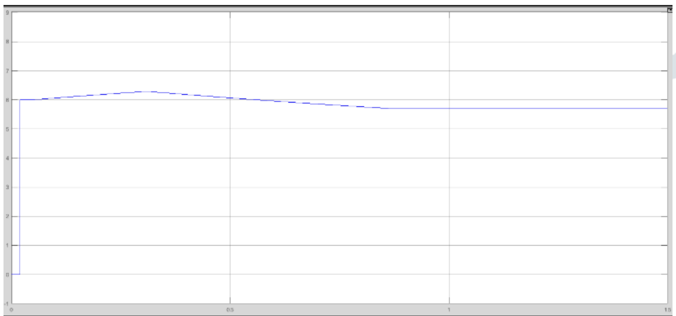

Figure 17. Current waveform in DC load

The figure 18 shows the supply voltage for the AC load after inverting DC-AC through inverter. There is a sag in the supply voltage which is from 0.2 to 0.3sec.

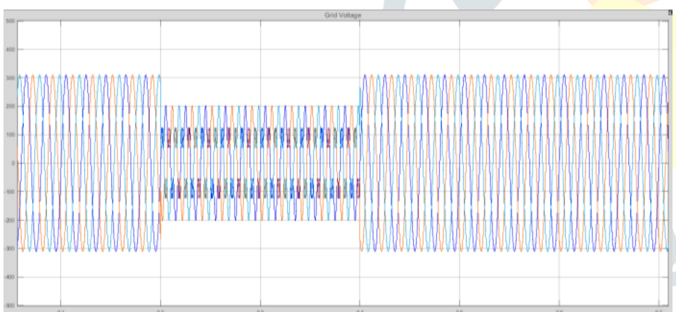

Figure 18. Sag in the supply voltage

The power quality issues are resolved by adding UPQC to the load side, the mitigation of sag is done and pure sine wave without distortion is found across the AC load. The figure 19 shows the load voltage after mitigating the voltage sag. The voltage sag from 0.2 to 0.4 is mitigated and shown clearly in the below graph.

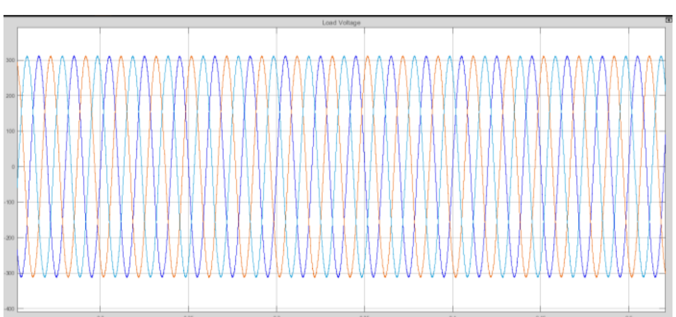

Figure 19. Mitigated sag in supply voltage

The THD (total harmonic distortion) in load is shown in the Figure 20, where the performance of the system can decided by knowing its output accuracy. Here in this scheme the harmonic factor is less compared to other controllers used scheme and hence it is justified that UPQC under fuzzy logic controller is best. THD in voltage across the load is THD=3.35% then Figure 21 shows the THD in current across the same load, where THD=2.52%.

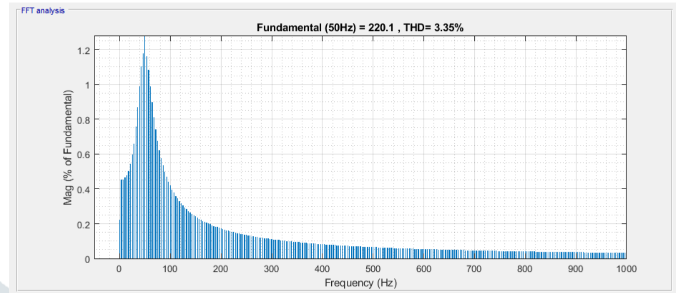

Figure 20. THD of voltage by FFT analysis

This FFT analysis graph's clearly shows that the problems associated with power quality is resolved in the better way since the power across the load is sure sine wave under disturbance also and the harmonics are found to be less.

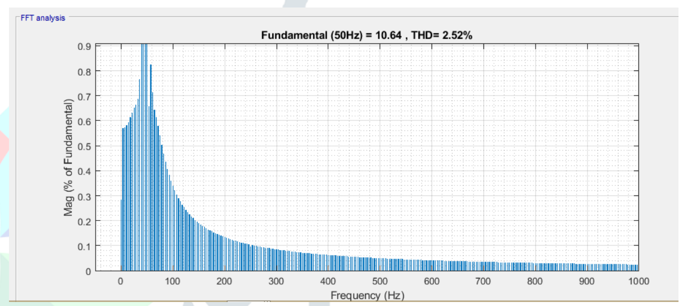

Figure 21. THD of current by FFT analysis

X. CONCLUSION

The results in the proposed system presents Microgrid efficiency will be improved by integrating DC-microgrid with both the Management of energy system and UPQC. The EMS contributes to general operating cost savings. In this paper there is an accurate and fast power quality improvement by using UPQC, the proposed system uses fuzzy logic controller for UPQC is designed in such a way that the power quality issues with the voltage settling time and distortion was reduced compare to other controllers like PI,PID controller. The total harmonic distortion is less across the load. The simulation results clearly tells that the combination of Micro-grid with EMS and power quality improvement makes the overall cost to be less.

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