iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 3 **Issue:** IV **Month of publication:** April 2015

DOI:

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Power Quality Enhancement in Grid connected Microgrid While Supplying Non-Linear Loads

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Abstract— The objective of the project shows how the power quality can be improved in a microgrid that is supplying a nonlinear load. The microgrid contains a hybrid combination of inertial and converter interfaced distributed generation units, where a decentralized power sharing algorithm called Hysteresis with fuzzy logic control is used to control its power management. The power quality parameters such as real power, reactive power, harmonics, power factor were enhanced. The efficacy of the proposed power quality improvement control and method in such a microgrid is validated through extensive simulation studies using MATLAB/SIMULINK software with detailed dynamic models of the micro-sources and power electronic converters connected with grid.

Keywords: Distributed generator, Hysteresis current controller, Fuzzy logic controller, Real power, Reactive power, power factor, Harmonics

I. INTRODUCTION

The world has been searching for an inexpensive, efficient and practical renewable energy source for the past few decades. With the ever growing concern about global warming, environmental pollution and the rising cost of fossil fuels, there is a greater interest in developing renewable energy sources to meet growing energy demand. Distributed Energy Resources (DERs), such as fuel cells, micro turbines, and photovoltaic systems offer many advantages for power systems. They can effectively mitigate peak demand, increase reliability against power system faults, and improve power quality (PQ) via sophisticated control schemes. Accordingly, distributed generators (DGs) have been installed in power systems and tested for better configurations and control schemes.[1]

The concept of a microgrid has been proposed in order to solve the common interconnection problems of individual DGs in various power systems. A microgrid is defined as an independent low or medium-voltage distribution network comprising various DGs, energy storages, and controllable loads that can be operated in three distinct modes: 1) grid-connected, 2) islanded (autonomous), and 3) transition mode. Microgrid can generally be viewed as a cluster of distributed generation connected to the main utility grid, usually through some voltages source inverter (VSI) based interfaces. Recently this scenario represents a complementary infrastructure to the utility grid due to rapid increase of the load demand. Distributed generation system based on renewable energy sources such as solar energy, wind turbines, hydro electric power, fuel cells etc. are used. They offer many advantages for power system. Concerning the interfacing of a microgrid to the utility system is an important area of study and to investigate the impact of power quality problems. If unbalance in voltage is serious, the solid state circuit breaker (CB), connected between the microgrid and utility grid will open to isolate the microgrid. When voltage unbalance is not so serious, CB remains closed, resulting in sustained unbalance voltage at the Point of Common Coupling (PCC). Generally Power quality problem are not new in power system, but rectification methodology are increased in recent years. The term Electric Power Quality broadly refers to maintaining a near sinusoidal power distribution bus voltage at rated magnitude and frequency.In addition, the energy supplied to a customer must be interrupted from the reliability point of view. The most significant among power quality problems are harmonic contamination, load unbalance, an increased reactive power demand and distribution system voltage fluctuations.[2]

II. MICROGRID CONCEPT

A microgrid is a cluster of loads and micro sources operating as a single controllable system that provides power to its local area. To the utility, the microgrid can be thought of as a single controllable load that can respond in seconds to meet the needs of the

transmission system. To the customer, the micro grid can meet their special needs; such as, enhancing local reliability, reducing feeder losses, supporting local voltages, providing increased efficiency through the use of waste heat, voltage sag correction.[3]
The microgrid has two critical components, the static switch (isolation switch) and the microsource. The static switch has the ability to autonomously island the microgrid from disturbances such as faults, IEEE 1547 events, or power quality events. After islanding, the reconnection of the microgrid is achieved autonomously after the tripping event is no longer present. This synchronization is achieved by using the frequency difference between the islanded microgrid and the utility grid insuring a transient free operation without having to match frequency and phase angles at the connection point. Each microsource can seamlessly balance the power on the islanded micro grid using a power vs. frequency droop controller. This frequency droop also insures that the microgrid frequency is different from the grid to facilitate reconnection to the utility.

A. Technical Challenges In Microgrid

Protection system is one of the major challenges for microgrid which must react to both main grid and microgrid faults. The protection system should cut off the microgrid from the main grid as rapidly as necessary to protect the microgrid loads for the first case and for the second case the protection system should isolate the smallest part of the microgrid when clears the fault. A segmentation of microgrid, i.e. a design of multiple islands or submicro grids must be supported by microsource and load controllers. In these conditions problems related to selectivity (false, unnecessary tripping) and sensitivity (undetected faults or delayed tripping) of protection system may arise.[4]
Mainly, there are two main issues concerning the protection of microgrids, first is related to a number of installed DER units in the microgrid and second is related to an availability of a sufficient level of short-circuit current in the islanded operating mode of microgrid since this level may substantially drop down after a disconnection from a stiff main grid. The short-circuit current calculations for radial feeders with DER and studied that short-circuit currents which are used in over-current (OC) protection relays depend on a connection point of and a feed-in power from DER. The directions and amplitudes of short circuit currents will vary because of these conditions. In reality the operating conditions of microgrid are persistently varying because of the intermittent microsources (wind and solar) and periodic load variation. Also n the network topology can be changed frequently which aims to minimize loss or to achieve other economic or operational targets.[5]
In addition controllable islands of different size and content can be formed as a result of faults in the main grid or inside microgrid. In such situations a loss of relay coordination may happen and generic OC protection with a single setting group may become insufficient, i.e. it will not guarantee a selective operation for all possible faults. Hence, it is vital to ensure that settings chosen for OC protection relays take into account a grid topology and changes in location, type and amount of generation. Otherwise, unwanted operation or failure may occur during necessary condition. To deal with bi-directional power flows and low short-circuit current levels in microgrids dominated by micro sources with power electronic interfaces a new protection philosophy is essential, where setting parameters of relays must be checked/updated periodically to make sure that they are still appropriate.

III. DISTRIBUTED GENERATION

A small power plants at or near loads and scattered throughout the service area. Installation & operation of electric power generation unit connected to the local network or off-grid generation characterized by:

Generation capacity ranging from kW to MW level.
Generation at Distribution Voltages (11kV or below).
Grid inter-connection at distribution line side
Inter-connected to a local grid, or
Totally off-grid, including captive

Distributed generation, also called on-site generation, dispersed generation, embedded generation, decentralized generation, decentralized energy or distributed energy, generates electricity from many small energy sources.
Distributed generation occurs when power is generated (converted) locally and sometimes might be shared with or sold to

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ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

neighbors through the electrical grid (or over the fence)
Large central generation is not directly used

The Public Service Commission may define only one supplier as a utility!
Distributed generation avoids the losses that occur in transmission over long distances; energy is used nearby
Varying wind and sunshine averages across several houses, blocks, cities, or states, stabilizing the system
Variability of one source is reduced by dividing by the square root of the number of sources
Supply is robust, but automatic precautions are required to protect electricity workers when main base-load power is out, and a local system might feed back into power lines.[6]
Distributed generation can be classified generally as renewable and nonrenewable DGs. Micro turbines and fuel cells are considered as dispatchable DGs due to their capability of producing active power on demand whereas the solar and wind are considered as non dispatchable DGs due to their operation according to their maximum power-tracking concept. This type of DG's output powers are dependent mainly on the weather rather than load. Hence nondispatchable loads are considered to be negative loads.

A. Photovoltaic array

A photovoltaic array (PV system) is an interconnection of modules which in turn is made up of many PV cells in series or parallel. The power produced by single module is not enough to meet the requirements of commercial applications, so modules are connected to form array to supply the load. In an array the connection of the modules is same as that of cells in a module. The modules in a PV array are usually first connected in series to obtain the desired voltages; the individual modules are then connected in parallel to allow the system to produce more current. In urban uses, generally the arrays are mounted on a rooftop. PV array output can directly feed to a DC motor in agricultural applications.

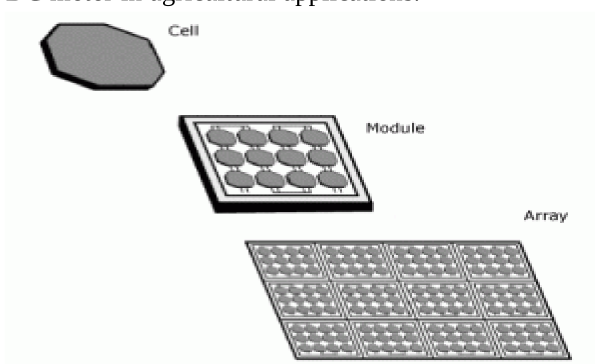

Fig. 1. Photovoltaic system

B. Wind turbines

With the use of power of the wind, wind turbines produce electricity to drive an electrical generator. Usually wind passes over the blades, generating lift and exerting a turning force. Inside the nacelle the rotating blades turn a shaft then goes into a gearbox. The gearbox helps in increasing the rotational speed for the operation of the generator and utilizes magnetic fields to convert the rotational energy into electrical energy. Then the output electrical power goes to a transformer, which converts the electricity to the appropriate voltage for the power collection system. A wind turbine extracts kinetic energy from the swept area of the blades. The power contained in the wind is given by the kinetic energy of the flowing air mass per unit time.[7]

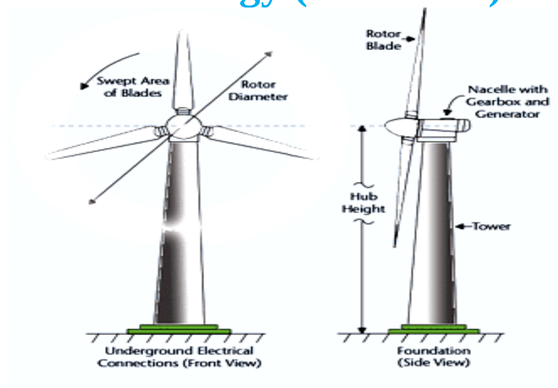

Fig.2. Wind turbine

C. Diesel generator

Foley features a wide range of gen sets and individual generator components from Caterpillar. Cat diesel generators are the perfect choice whether you are looking for a primary power source that can meet the heaviest electrical power generation demands or to serve as a dependable source of standby or emergency power. We carry a complete selection of new and used diesel generators, and we can also meet your short-term power needs with a diesel generator rental.[8]

1) The diesel engine is the source of the generator's power. Its size and output capacity are what determines how much power a unit can generate.
2) The genhead, like the alternator in a car, is what produces usable electricity from the mechanical energy produced by the engine.
3) A diesel fuel tank stores fuel to be used by the generator. Its size determines how long the generator can run without refueling.
4) The voltage regulator is an important component of your generator which ensures it produces the proper output for use with a given electrical system.
5) The radiator/cooling system components of a generator ensure it doesn't overheat.
6) The exhaust system directs harmful fumes away from the generator.
7) A generator's control panel includes start-up and shut down controls and well as fuel gauges, phase selector switches and more.
8) The generator frame holds it all together.

IV. PROPOSED SYSTEM

In existing system dynamic nature of the distribution network challenges the Power quality problems and control effectiveness of the microgrid in both grid-connected and autonomous modes. The Power quality of the microgrid operating in either mode is quite essential and it is affected by different parameters. The primary contribution of the base paper is to analyze the problem and discover the reason for not choosing proper parameter. Effective methods are then proposed to improve power quality & power-sharing performance taking the controller modes, configurations, and microgrid operations into account.

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ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

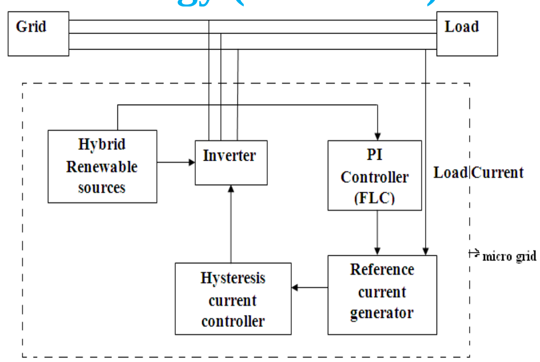

Fig. 3. Block diagram of Grid connected Micro Grid

The Microgrid structure assumes an aggregation of loads and micro sources operating as a single system providing both power and heat. The majority of the micro sources must be power electronic based to provide the required flexibility to insure controlled operation as a single aggregated system. This control flexibility allows the Microgrid to present itself to the bulk power system as a single controlled unit, have plug-and-play simplicity for each micro source, and meet the customer's local needs. These needs include increased local reliability and security. Key issues that are part of the microgrid structure include the interface, control and protection requirements for each micro source as well as microgrid voltage control, power flow control, load sharing during islanding, protection, Power quality, and over all operation. The ability of the Microgrid to operate connected to the grid as well as smooth transition to and from the island mode is another important function.

Fig.3. illustrates the basic microgrid architecture. Solar, Wind energy, diesel generator are used as a hybrid renewable sources. PI controller compares the voltage from hybrid renewable sources with fixed battery voltage by using fuzzy logic conoller converted into current. Reference current generator compares the current from PI controller and load current. Hysteresis current controller compares the current from reference current and inverter current gives appropriate gate pulses to the inverter. Inverter converts the DC into AC voltage . Non linear load used as the induction generator.

V. CONTROL METHOD

A. Simulink Model of Compensation Current Reference Estimator Using d-q-0 Theory

In this thesis synchronous reference frame theory is employed to obtain compensation current reference signal, since it deals mainly with DC quantities and computation is instantaneous. The component diagram of synchronous reference frame theory model is depicted in Fig.4.

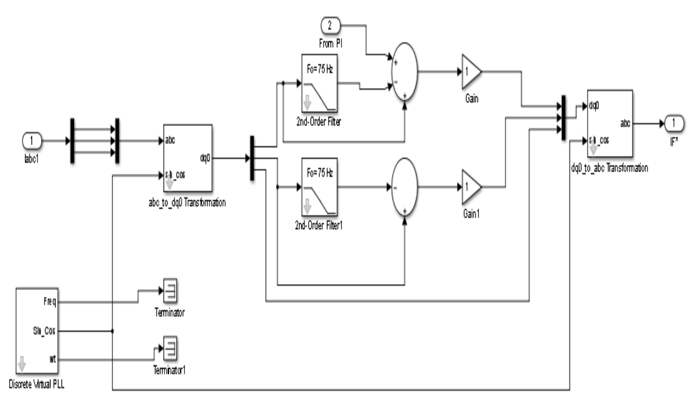

Fig. 4. Simulink model of d-q-0 theory based reference current estimator.

This control strategy uses „discrete PLL" block for generating sinusoidal reference currents, „a-b-c to d-q-0 transformation" block

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ISSN: 2321-9653

for Park‟s transformation, and d-q-0 to a-b-c transformation block for Inverse Park‟s transformation. Two „second order digital low pass filter‟ blocks are used for extracting fundamental component from load currents. From simulink block set "Discrete Phase-Lock Loop" block is selected from "SimPowerSystems\Discrete Control Blocks" library and its parameters are set as: Frequency = 50 Hz, Phase angle=0, Sampling frequency= 20 kHz. The "a-b-c to d-q transformation block" converts three phase a-b-c-reference

frame currents in to stationary d-q reference frame currents and applied to a "Discrete 2nd-Order LPF" block from "SimPowerSystems/Discrete Control Blocks" library for noise filtering. For the simulation model of Butterworth LPF, the design parameters are selected as ζ = 0.707, fLPF= 75 Hz, fs= 40 kHz, where ζ is the damping ratio, fLPF is the

cut-off frequency and fs is the sampling frequency of the digital Butterworth LPF. The low frequency fundamental components obtained from LPF are subtracted from nonfiltered signal and added to current signal obtained from DC bus voltage controller to obtain compensation reference currents in d-q reference frame. By applying these currents to "d-q-0 to a-b-c transformation block" the compensation reference currents in a-b-c reference frame are obtained.

B. Simulink Model of Hysteresis Current Controlled Switching Signal Generator

In this thesis Hysteresis band Current Controller model is used for generating switching signals for the transistors of VSI, and is illustrated in Fig. 4.8.This current control technique imposes a bang-bang type instantaneous control that forces the compensation current to follow its estimated reference. The actual compensation current is subtracted from its estimated reference. The resulting error is sent through a hysteresis controller to determine the appropriate gating signals. In the simulation model, the hysteresis band (*H*) is chosen as 0.1 A with 0.05 as upper limit and -0.05

as lower limit. The hysteresis controller is constructed using "Relay" block set from "Simulink\Discontinuities" library as shown in Fig.

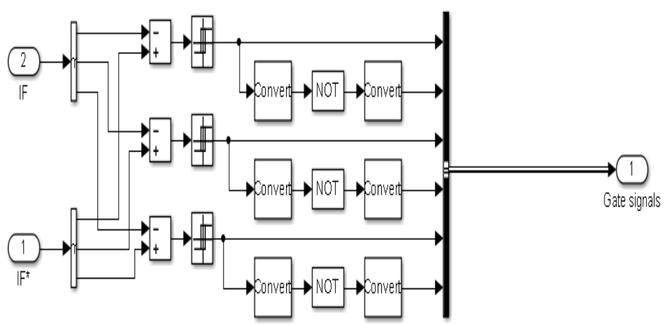

Fig. 5. Simulink model of Hysteresis current controller for phase-a.

C. Simulink Model of Fuzzy Logic based DC-Bus Voltage Controller

For maintaining DC bus voltage constant at a reference value, Fuzzy Logic Controller (FLC) is employed in this simulation work. The details of the "Fuzzy logic controller" block is shown in Fig.6.

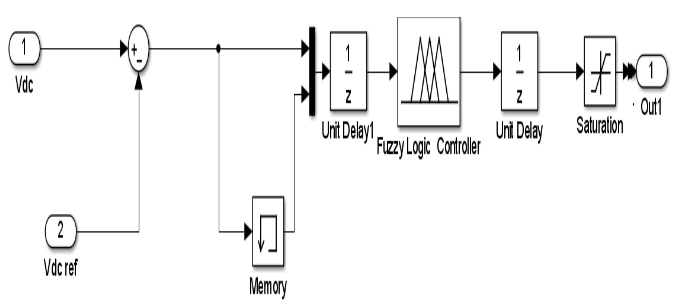

Fig.6. Simulink model of Fuzzy logic controller

The DC-bus voltage is first sensed and compared with DC reference voltage and error signal is generated. The error signal and its derivative are applied to fuzzy
logic controller. Error signal is applied to “Memory” block and its output is subtracted from the error signal to obtain derivative of error signal as shown in the Fig.6.

The two inputs and the output use seven triangular membership functions namely Negative Big (NB), Negative Medium(NM), Negative Small(NS), Zero(ZE), Positive Small (PS), Positive Medium(PM), Positive Big(PB). The type and number of membership functions (MFs) decides the computational efficiency of a FLC. The shape of fuzzy set affects how well a fuzzy system of If–then rules approximate a function. Triangles have been the most popular for approximating non-linear function because the parametric functional description of triangular membership function is most economic one.

Also these are preferred because of their striking simplicity, solid theoretical basis and ease of computation, since they are symmetrical and have zero value at some point away from their center. Hence the triangular MFs are chosen in this work.In this controller seven membership functions are considered which will give precisely accurate results. Reducing the number of MFs will produce improper results at some band, while increasing the number of MFs will produce a delay due to more computational steps required. The linguistic variables are defined by M˜ = (a, b, c), where a, b, c are starting, middle point with unity membership grade, and end points, respectively.

The membership values of input and output variables are shown in the Fig.7.& Fig.8. Each input has seven linguistic variables, therefore there are 49 input label pairs. A rule table relating each one of 49 input label pairs to respective output label is given in Table.1. The type of fuzzy inference engine used is mamdani and the centroid method is used for defuzzification.

E / de	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NM	NM	NM	NS	ZE	PS
NS	NB	NM	NS	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PS	PM	PB
PM	NS	ZE	PS	PM	PM	PM	PB
PB	ZE	PS	PM	PB	PB	PB	PB

Table.1.Fuzzy rule representation

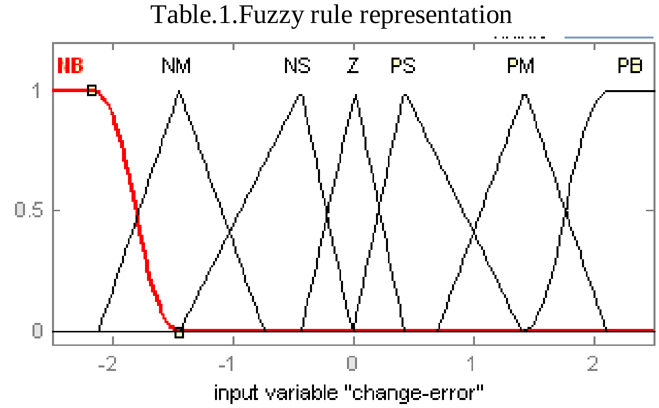

Fig.7.The degree of membership functions for the derivative of error

Volume 3 Issue IV, April 2015
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

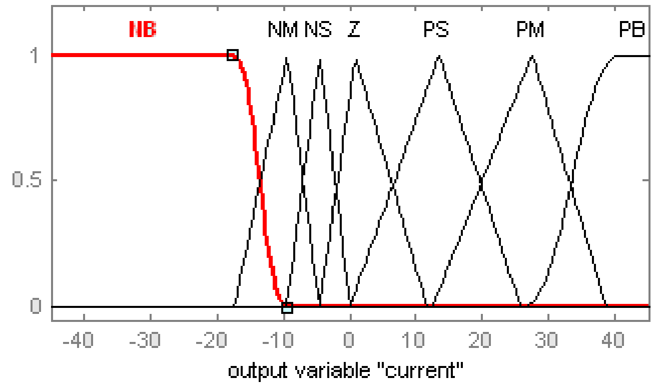

Fig.8.The degree of membership functions for the output

VI. DEVELOPMENT OF THE PROJECT

The simulation diagram shows that Modeling of micro grid. Works under both modes Grid connected and islanded mode. Here Hysteresis current controller is used for droop control by using renewable energy resources. Real power, Reactive power, power factor and Harmonics were analyzed while supplying non linear loads. The real power achieved at load side is 1.57e7, The reactive power achieved 186, The power factor achieved 0.9 and the harmonics ila=29.68, ilb=110.45, ilc=38.40 were achieved in each phase, similarly in source side the real power is 1.57e6, the reactive power is 181.6 ,the power factor 0.9 and the harmonics isa=2.74, isb=4.23, isc=2.85 were achieved in each phase.

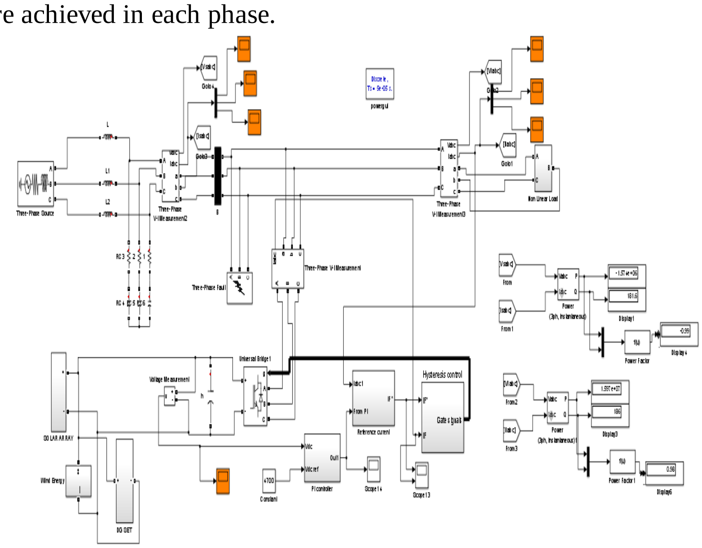

Fig. 9. Modeling of Grid connected Micro grid

9) Simulation Results

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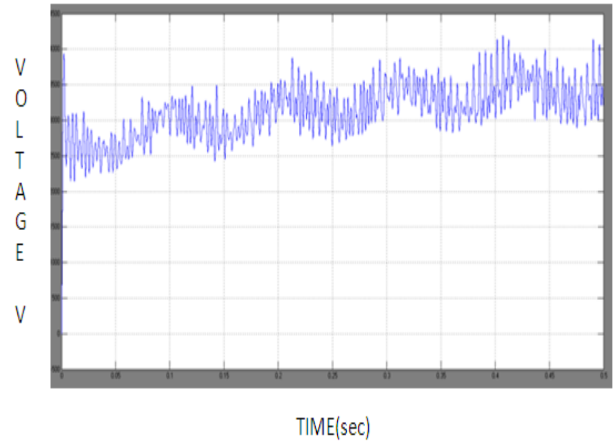

Fig.10. Output of Renewable Energy

The above figure shows the voltage versus time waveform. This is output voltage from the three micro sources i.e.solar, wind energy, diesel acts as DGs.

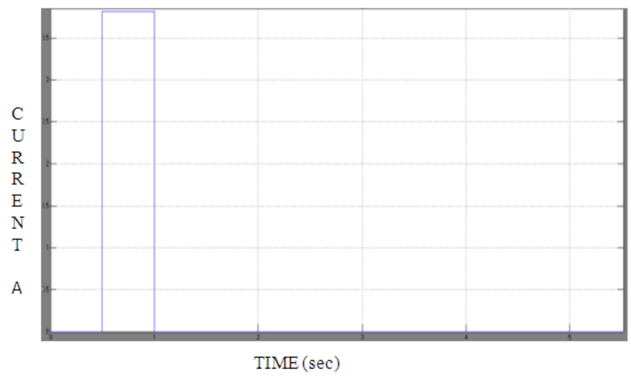

Fig.11. Output from PI controller

The above figure shows the current versus time waveform. This is output voltage from the PI controller in which the renewable energy voltage compared with battery voltage and the output voltage converted into current by using fuzzy logic controller.

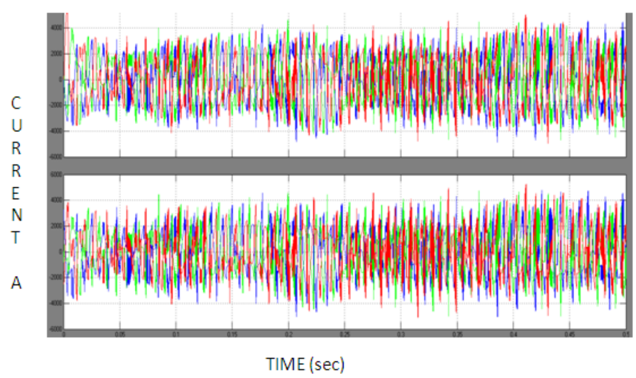

Fig.12. Reference current and Actual current

The above figure shows the current versus time waveform. This is the comparison of reference and actual current waveform.

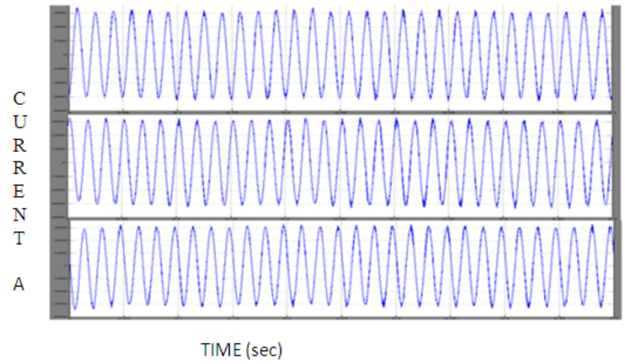

Fig.13. output current from source side while supplying non linear load

The above figure shows the current versus time waveform. This is the output current from source side while supplying non linear load.

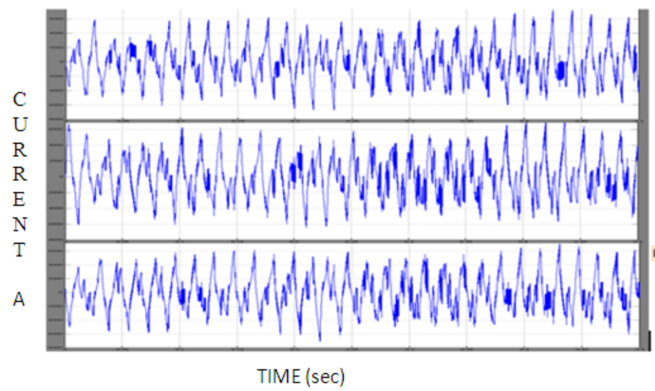

Fig.14. output current from load side while supplying non linear load

The above figure shows the current versus time waveform. This is the output current from load side while supplying non linear load.

VII. CONCLUSION

The power quality enhancement in micro grid while supplying non linear load was done and the power quality parameters such as real power, reactive power, power factor, harmonics were enhanced, when the micro grid connected with the grid.The power sharing among the various DGs were done by using conventional droop control method called Hysteresis with fuzzy logic control method. The efficiency of the power quality improvement will be validated through simulation usingMATLAB/simulink.

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