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Fuzzy logic controller for maximum power point tracking and voltage stability control in distributed generation

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***Abstract*---**Distributed Generation Resources are gaining popularity in power systems because of their closeness to the consumer loads, their capability of producing clean power and their ability to provide reactive power compensation. In this paper renewable energy resource which is Photovoltaic Power Generator has been used as a Distributed Energy Resource. For achieving Maximum Power Point Tracking (MPPT) from the Solar Panels under certain insolation a fuzzy logic controller has been utilized. Similarly for reactive power compensation of the loads in the three phase grid through DC-AC converter, Fuzzy Logic controller has been used for controlling the gate pulses to the three phase inverter. Matlab Simulation has been implemented to study the waveforms of the three phase voltages and currents at the point of common coupling ie interface between the three phase inverter and grid.

***Keywords*---**MPPT, fuzzy logic, inverter, converter, photovoltaic.

Introduction

Renewable energy sources are gaining importance in the traditional Power Systems because of their ability to produce clean Power, their proximity to consumer loads, their availability abundance. For interfacing of these distributed generation resources to the three phase grid power electronic equipment’s are required. The switching of the custom power devices used in Power Electronic Equipment’s causes power quality issues such as harmonic generation, power loss etc. The power electronic equipment’s themselves provide solutions to these power quality problems. Now a days PV generation has gained significant importance because of their availability in abundance and ease of interfacing of PV with the grid by using power electronic equipment. A two stage configuration has been used for interfacing of PV with the grid in this paper. The DC voltage

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produced by PV cells is boosted by DC-DC converter and the boosted DC voltage is applied to the DC link capacitor. The DC-AC converter converter converts this dc voltage into three phase voltage and injects three phase currents into the three phase transmission lines through the three phase transformer and active filter. The active filter is a combination of L and C devices which are responsible for elimination of harmonics in the three phase voltages and currents generated in the output ofthree phase inverter. For maximum utilization of PV resource maximum power should be extracted from it. Hence maximum power point tracking is required for maximum power extraction which is obtained by utilizing a Fuzzy Logic Controller. The PV resource is very unreliable because of unpredictable weather conditions. As the solar insolation changes according to the cloud cover the output of PV resource also changes. This causes voltage instability at the output of three phase inverter ie at the point of common coupling of the inverter with the grid. By controlling the reactive power injection or absorption to/from the grid through the the three phase inverter voltage stability can be obtained at the PCC.

Literature Review

Jing Li, Fang Zhuo, Xianwei Wang, Lin Wang, Song Ni in [1] “A Grid-Connected PV System with Power Quality Improvement Based on Boost + Dual-Level Four-Leg Inverter have proposed a research, which not only allows a wide range of input voltage, but also compensates unbalance current of the local load in three-phase three-wire PV system with the help Dual-Level Four Leg Inverter. Work by V. Hima Leela, S. Thai Subha in [2] “Control of Power Converter for Power Quality Improvement in a Grid Connected PV System focuses on the design, modeling and control of power converters for power quality improvement in a grid connected Distributed Generator system. In this paper Photovoltaic is considered as DG.

Digvijay B Kanase A. R Thorat H. T Jadhav in [3] “Distribution Static compensator for Power Quality Improvement using PV Array” have proposed distribution static compensator for improvement of power quality using PV cell. Dstatcom is used for reducing the reactive power that resulted from various types of load on the distribution systems. Seyyed Abbas Saremi Hasari, Ali Rasoolzadeh Akhijahani, Alunad Salemnia in [4] “Power Loss Reduction and Power Quality Improvement in Distribution Systems Using a Modified Converter of Distributed Generation Resources” have enhanced the performance of a distributed generation converter with the aim of reducing the power loss and improving the power quality

Xioquing Han, Ruifen Cheng, Peng Wang, Yanbing Jia in [5] “Advanced Dynamic Voltage Restorer to Improve Power Quality in Grid have proposed Dynamic Voltage Restorer based on Photovoltaic Generation /battery units to improve voltage quality in microgrid. The Dynamic voltage restorer can handle voltage sag or surge and thus improve the power quality in grid. Hamad, M.S.Fahmy and Abdel-Geliel in [6] “Power Quality Improvement of a single-phase Grid-Connected System with Fuzzy Logic MPPT Controller” have come up with single-phase shunt active filter to improve the power quality in terms of current harmonics, mitigation and reactive power compensation.

Hui Li, Hao Zhang, Fei MA, Weihua BAO in [7] " Modeling, Control and Simulation of Grid-connected PV System with D-STATCOM" have introduced a device D-STATCOM as the grid connected converter to realize power co-ordination, voltage stabilizing and power quality improvement. The PV system with STATCOM can output active power stably, keep grid connected voltage steady and improve power quality of voltage and current.

Solomon Oyegoke, Yehdego Habtay and Spyros Skarvelis-Kazakos in [8] "Contribution of Inverter based photovoltaic generators to power quality at low voltage" have examined performance of solar PVs on load voltage. They have used D-STATCOM to achieve voltage stability by reactive power compensation. Meenakshi Jayaraman1, Sreedevi V.T. and Rajkiran Balakrishnan in [9] "Analysis and Design of Passive Filters for Power Quality Improvement in Standalone PV Systems" have used passive filters which include LC, LCL and LLCC filter topologies. A comparison study of the total harmonic distortion reduction with the above filters is done.

Process and Methodology

Fig. 1 shows the three phase system with the load connected. The PV array is used for DC voltage generation with initial values of irradiance of 1000W/m2 and temperature of 25 degree celsius. The output of PV array is provided to boost converter which consists of semiconductor switch, inductor, diode and capacitor. The load is a resistor across which maximum power is obtained.

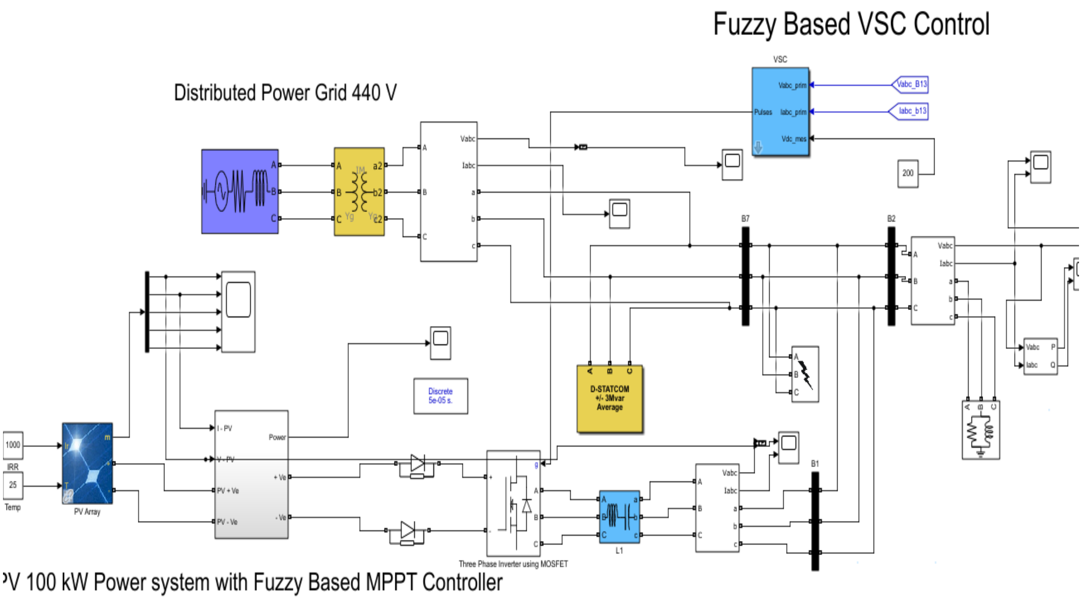

Fig.1:Three phase Grid with PV System and three Phase Inverter

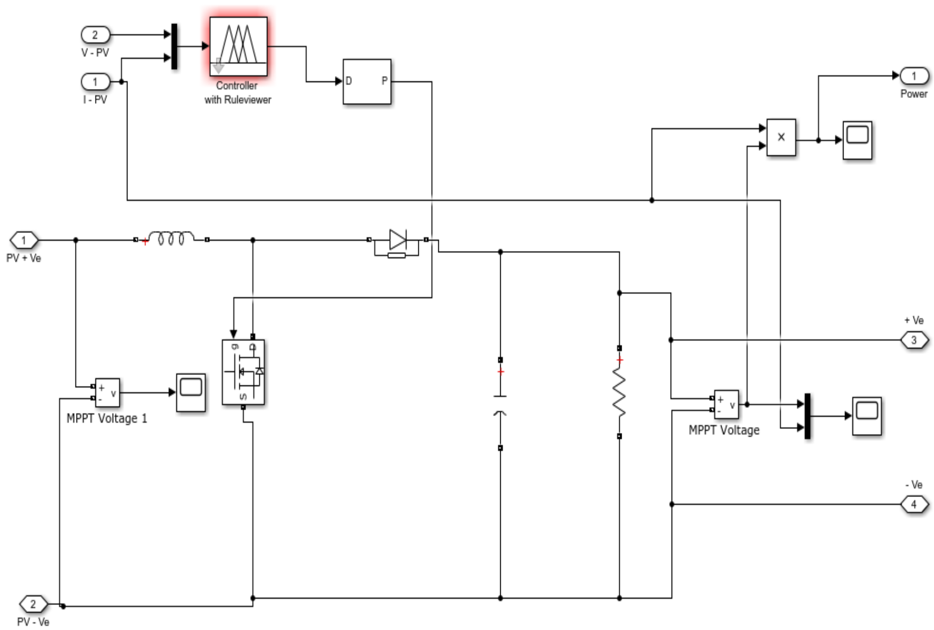

Fig. 2:Fuzzy Logic Controller for the Boost Converter for MPPT

The semiconductor is controlled by a Fuzzy logic controller [10] which produces gate pulses to the semiconductor switch having certain duty cycle for maximum power point tracking. The inputs to the Fuzzy Logic Controller are values of V and I from the IV curve of the Photovoltaic Array. The Mamdani Fuzzy Inference System is used for Fuzzification of the inputs and Defuzzification of the output in the Fuzzy Logic Controller. The Fuzzy Inference System consists of two inputs and one output. The output of the Fuzzy Logic Controller is the Dutycycle which varies between 0 and 1 and accordingly the pulse generator produces pulses which are applied to the gate terminal of semiconductor switch of boost converter. Fig. 2 shows the boost converter and it's Fuzzy Logic Controller.

The Membership functions for the input 1 which is Voltage are trapezoidal. The input1 has three trapezoidal membership functions. The first membership function is represented by low which ranges from 0 to 75. The second membership function for the input 1 i.e. V is medium which ranges from 75 to 200. The third membership function for V is Max which ranges from 200 to 250. The figure 3 shows the membership functions along with their parameters and Range. The membership functions for input 2 which is current also have been designed. There are three membership functions for the input 2 which is current and the current values are obtained from IV curves of the PV Array. The first membership function for input2 (Voltage) is low which ranges from 0 to 200. Similarly the second membership function of the input 2 is denoted by medium and ranges from 200 to 450 and the third membership function ranges from 450 to 540. The output of the fuzzy inference system is duty cycle which ranges from 0.3 to 1. The output has three membership functions which are low, medium and high. The low membership function varies from 0.3 to 0.5. The medium membership function varies from 0.49 to 0.75. Similarly the third membership function ranges from 0.74 to 1. The rules for the inputs 1 and 2 and the output have been designed using Rule Editor and are follows:

1. If (Voltage is Low) and (Current is Low) then (output1 is max) (1)
2. If (Voltage is Low) and (Current is med) then (output1 is max) (1)
3. If (Voltage is Low) and (Current is Max) then (output1 is max) (1)
4. If (Voltage is Med) and (Current is Low) then (output1 is max) (1)
5. If (Voltage is Med) and (Current is med) then (output1 is med) (1)
6. If (Voltage is Med) and (Current is Max) then (output1 is med) (1)
7. If (Voltage is Max) and (Current is Low) then (output1 is max) (1)
8. If (Voltage is Max) and (Current is med) then (output1 is med) (1)
9. If (Voltage is Max) and (Current is Max) then (output1 is low) (1)

The rule viewer and membership functions for the above fuzzy inference system are shown below:

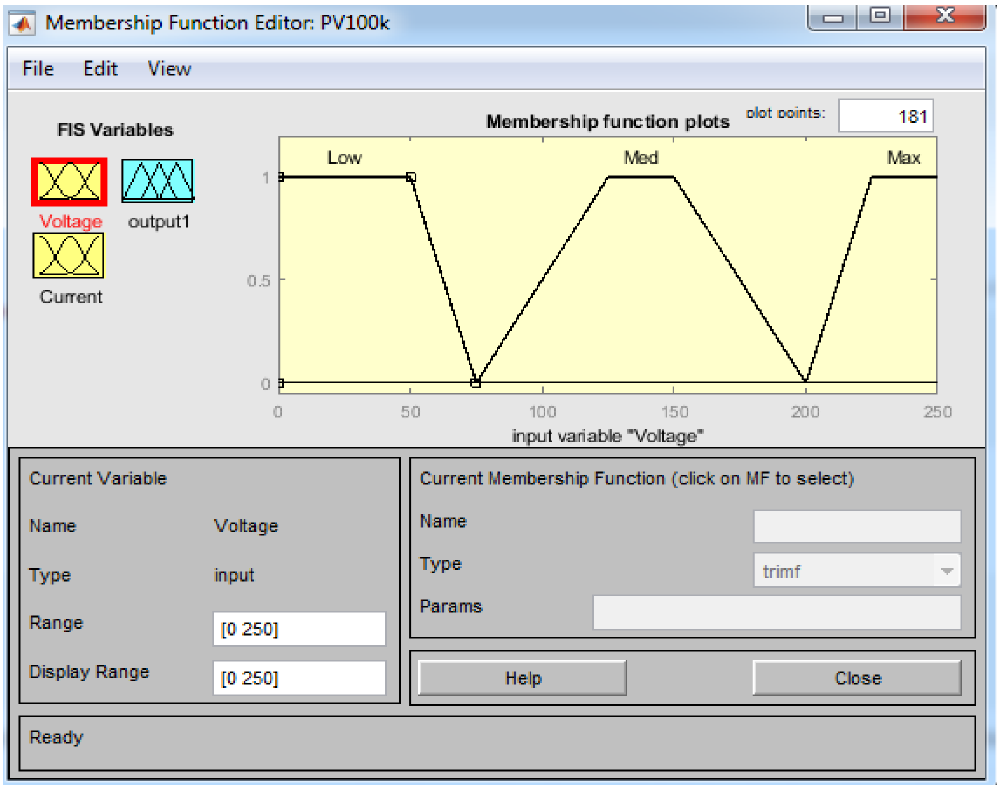

Fig. 3: Membership Functions for the input Voltage from PV Array

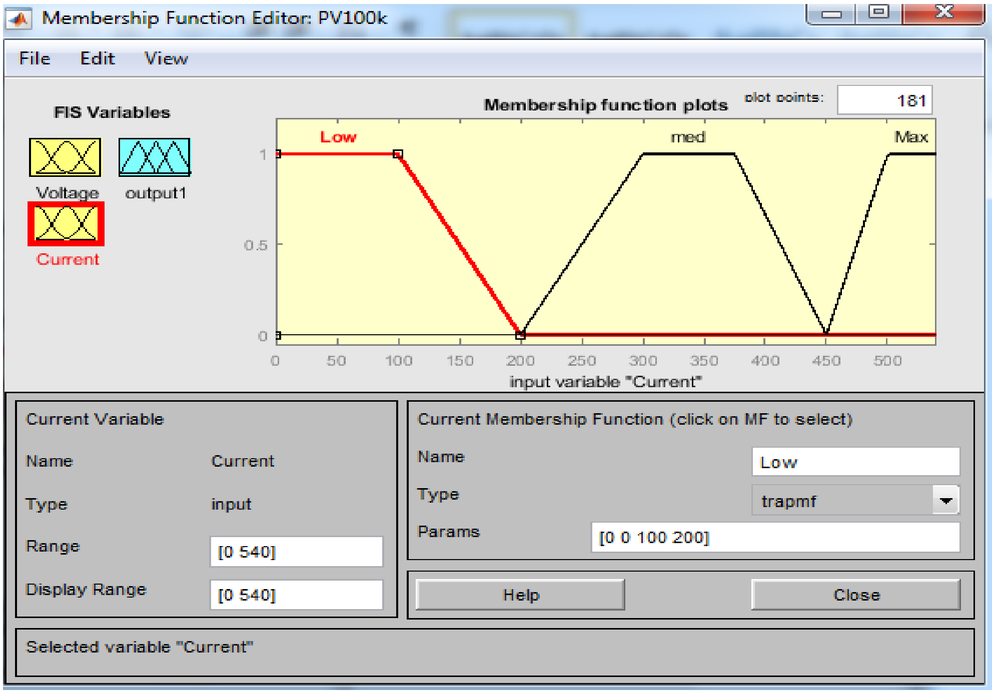

Fig. 4:Membership Functions for input Current from PV Array

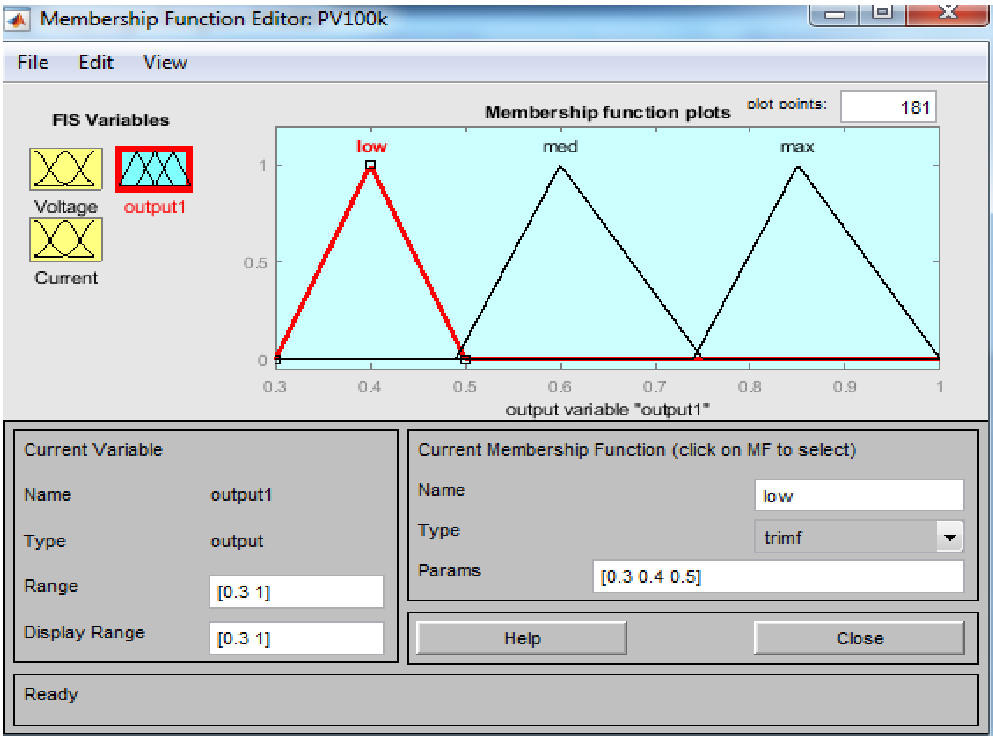

Fig. 5: Membership Functions for Duty Cycle

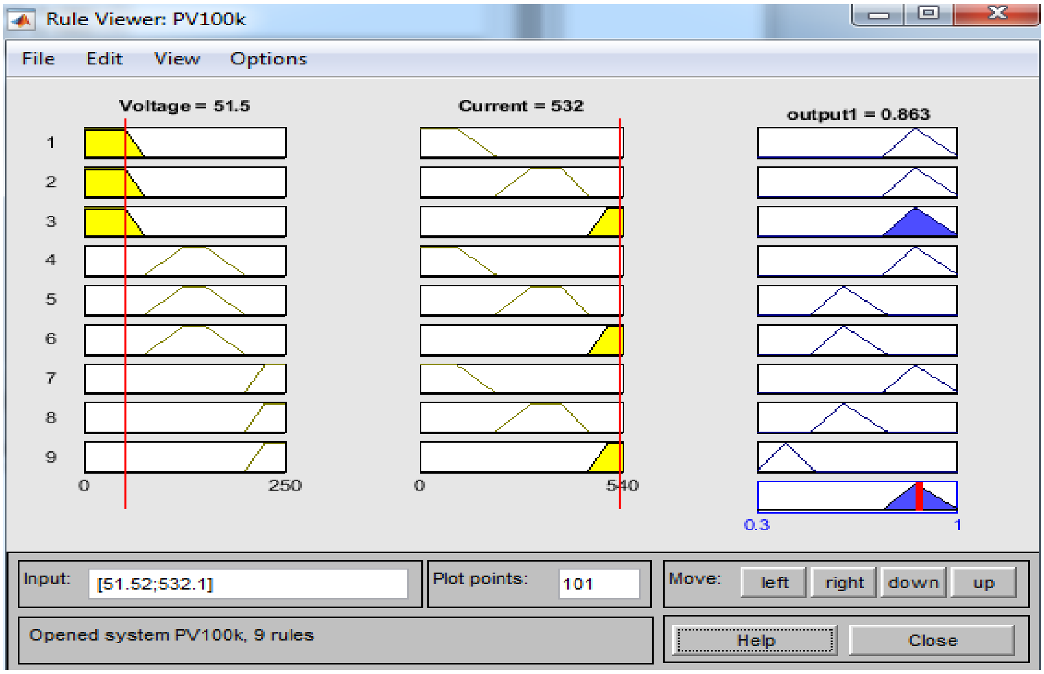

Fig. 6: Rule Viewer showing various Rules designed for MPPT

Results and Discussion

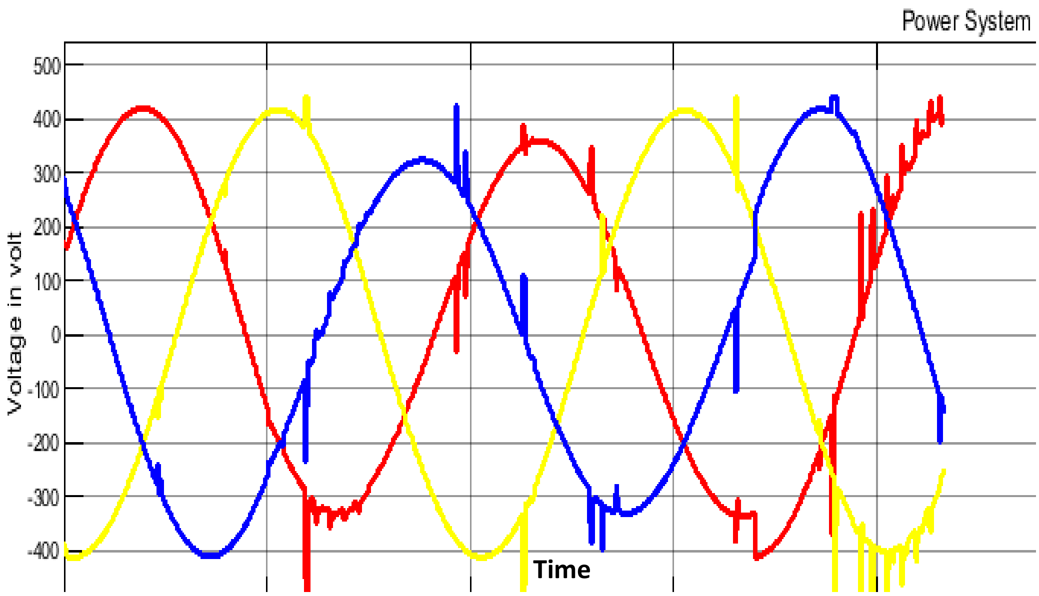

Fig. 7: Load Voltage when Irr=800

For different values of irradiances the inverter output has been shown in Fig. 7 and Fig. 8. When the irradiances decreases, the inverter output of the solar module decreases. Hence the inverter injects reactive power into the transmission lines at the point of common coupling. Therefore reactive power required from the grid for the load reduces and the load voltage comes back to rated voltage.

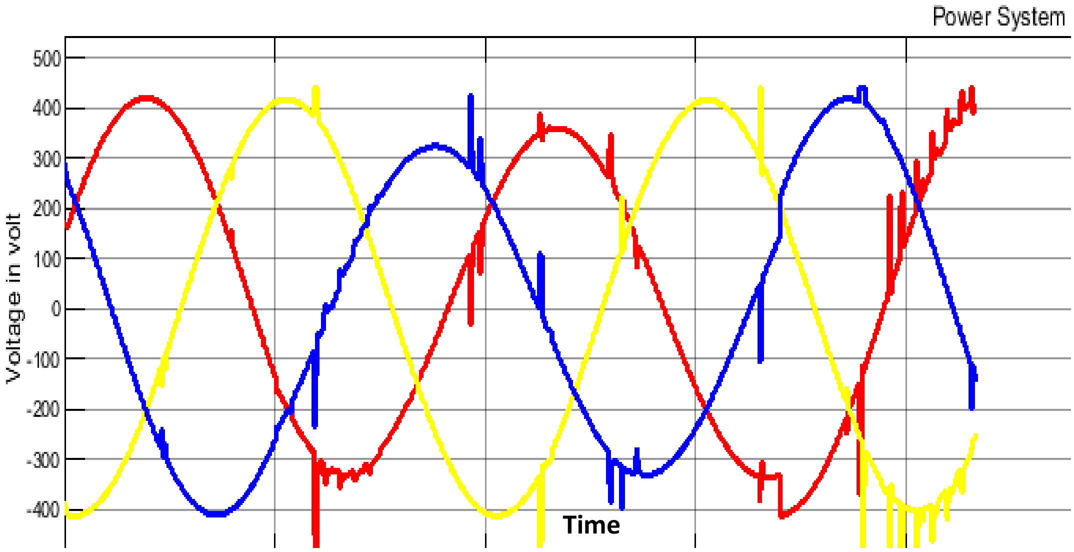

Fig. 8: Load Voltage when Irr=1200

When the irradiances increases, the output of solar module increases and therefore the inverter voltage also increases. When the voltage increases, the inverter absorbs the reactive power so that the reactive demand of the load is fulfilled by the grid. Hence there is a voltage drop in the transmission lines and the load voltage reduces back to the rated voltage.

Conclusions

It is observed that the Fuzzy Logic Controller is an efficient technique for providing the Maximum Power Point Tracking in the PV System. The Mamdani Inference system has been utilised in this paper for fuzzification and defuzzification of the output. The rules have been designed using Rules Editor and the output is defuzzified using the centroid method. The waveforms for Irradiance of 1000W/m2, temperature of 25 Degree Celsius and the variation in the PV Array voltage and current have been shown. The above system has been used for Voltage Stability by absorbing or injecting the reactive power from/to the three phase grid at the point of common coupling.

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