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P-Q AND V-FCONTROL OF HYBRID MICROGRID

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Abstract—***This paper proposes a method of Maximum Power Point Tracking (MPPT) of solar array and a new control method of transferring this MPPT power to the inverter side ensuring the DC voltage stability by using the concept of Space Vector Modeling (SVM) with the assistance of Particle Swarm Optimization (PSO). This technique obtains stable voltage by giving triggering pulse to output power in the inverter. The dissertation also proposes a new coordinated control method for voltage and frequency regulation as well as active and reactive power control of Hybrid Microgrid with solar PV system and wind mill. The speed control of PMSG is made through Pitch and Yaw control of wind turbine. The control of active and reactive power is made through injecting power from grid by storing excess power when available. The voltage frequency regulation is proposed through regulating power from battery by applying triggering pulse. By the combined action of SVM and frequency regulation, amplitude and phase angle are also controlled in the Microgrid. Through the coordinated control of active and reactive power and Voltage-frequency regulation power reliability can be improved and the synchronization of power is also made possible when connected to distribution utility system.***

Keywords—***Photo Voltaic, MPPT, PSO, SVM, Voltage-Frequency Regulation, DERs.***

I. INTRODUCTION

Microgrids are small-scale networks designed to supply electrical loads for a small community, such as a housing estate or a suburban locality, or an academic or public community such as a university or school, a commercial area, an industrial site, a trading estate or a municipal region [1]. In a microgrid, the microsources and storage devices are connected to the feeders through the microsource controllers (MCs) and the coordination among the microsources is carried out by the central controller (CC) [2]. The generators or microsources employed in a Microgrid are usually renewable DERs integrated together to generate power at distribution voltage. From operational point of view, the microsources must be equipped with power electronic interfaces (PEIs) and controls to provide the required flexibility to ensure operation as a single aggregated system and to maintain the specified power quality and energy output [3]. This control flexibility would allow the Microgrid to present itself to the main utility power system as a single controlled unit that meets local energy needs for reliability and security.

The key differences between a Microgrid and a conventional power plant are as follows:

- Microsources are of much smaller capacity with respect to the large generators in conventional power plants.
- Power generated at distribution voltage can be directly fed to the utility distribution network.
- Microsources are normally installed close to the customers premises so that the electrical/heat loads can be efficiently supplied with satisfactory voltage and frequency profile and negligible line losses.

The technical features of a Microgrid make it suitable for supplying power to remote areas of a country where supply from the national grid system is eitherdifficult to avail due to the topology or frequently disrupted due to severe climaticconditions or man-made disturbances [4]-[8].

From grid point of view, the main advantage of a Microgrid is that it is treated as a controlled entity within the power system [8]. It can be operated as a single aggregated load. This ascertains its easy controllability and compliance with grid rules and regulations without hampering the reliability and security of the power utility [9]-[14].

From customers point of view, Microgrids are beneficial for locally meeting their electrical requirements. They can supply uninterruptible power, improve local reliability, reduce feeder losses and provide local voltage support [15]. From environmental point of view, Microgrids reduce environmental pollution and global warming through utilization of low-carbon technology.

II. SOLAR PV AND WIND MODELING

2.1 Solar PV

The commonly accepted solar cellmodel is a one diodemodel [15].

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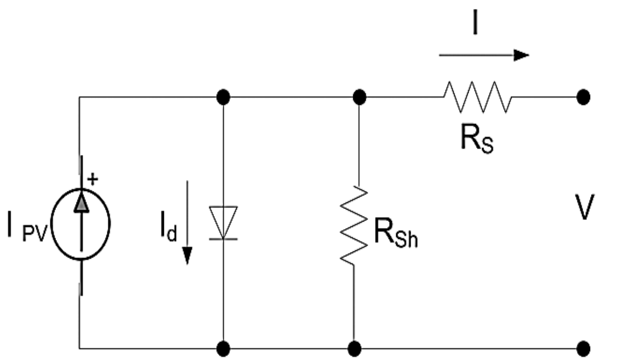

Fig 1 : One diode equivalent circuit of Solar PV.

This work uses the single diode model of the solar cell to model the SunPower SPR -305-WHT solar array, which is shown in Fig. 1. The I-V characteristics of a solar array, as shown in Fig. 2, are represented by (1).

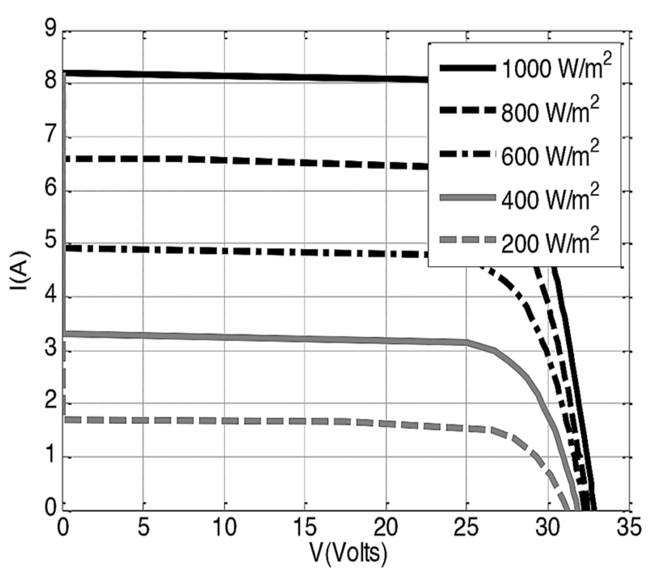

Fig 2 : The I-V characteristics of SunPower SPR -305-WHT from simulation with varying irradiance of 1000W/m .at a cell temperature of 25 C.

$$I = I_{PV} - I_0\left[\exp\left(\frac{V + R_s I}{V_{therm}\,a}\right) - 1\right] - \frac{V + R_s}{R_{sh}}$$

Where $I_{PV}$and I are the photo current and the diode saturationcurrents, respectively; $V_{therm} = (N_s\,kT/q)$ is the thermal voltage of the array,N_s being the cells connected in series for greater output voltage, k is the Boltzmann constant ($1.3806503 \times 10^{-23}$J/K), (Kelvin) is the temperature of the p-n junction of the diode, and (1.60217646× 10^{-19} C) is the electron charge; R_s and R_{sh} are the equivalent series and shunt resistances of the array, respectively.

Model	SunPower SPR -305-WHT
P_{MPP}	200W
V_{MPP}	26.30V
I_{MPP}	7.61A
V_{OC}	32.90V
I_{SC}	8.21A

2.2 Wind Mill

The first contribution is focused on the wind farm energy management using balance control, delta control and absolute control strategy. -The second contribution is based on the performances comparative study between DC and AC configurations. In DC configuration, the generators are linked to grid through the fully controlled frequency converters, which consist of two three phase rectifiers, an intermediate DC-bus, and a PWM inverter as illustrated in Fig.1.about its solar PV.

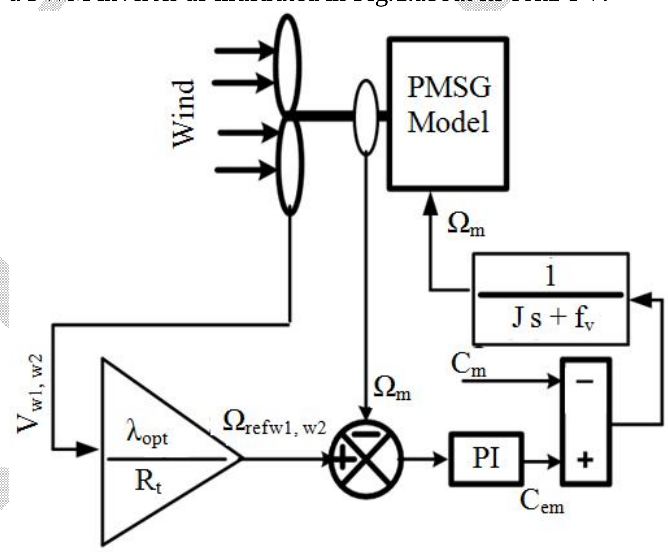

Fig 3 : PMSG speed control loop for each wind turbine.

The theoretical power generated by wind turbine is expressed in (2), where ρ is the density of the air; S is the circular area swept by the turbine; β is the angle of wedging of the blades, Vw1, w2 is the wind speed in [m/s].

$$P_{avilW1,W2} = \frac{1}{2}.C_P(\lambda,\beta).\rho.S.V_{W1,W2}{}^3, S = 2..R_t{}^2$$

The DC configurations are connected to grid of 20kV phase to phase RMS voltage. The proposed control strategies include the Maximum Power Point Tracking (MPPT) for PMSG speed control, the active/reactive power control, and DC-bus voltage control. To show the performances of the control strategies, simulation results are presented and analyzed using Matlab/Simulink software.

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2.3 DC configuration control strategy

The proposed control strategies include: - PMSG speed control based on Maximum Power Point Tracking (MPPT) technique. - Active and reactive powers control using the inverter connected to grid. - DC-bus voltage control through the rectifiers connected to stator. The similar control strategies are presented in [8] for wind turbine application based on the doubly feed induction generator.

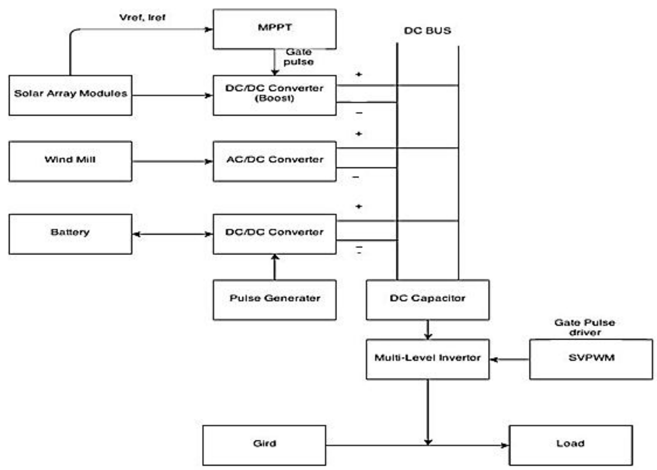

Fig 4 : Block Diagram

2.4 Maximum power point tracking (MPPT) and pitch angle control method

The PMSG speed control is based on MPPT and it is same to that presented in Fig.5 shows that, in the each wind speed there is an optimal speed of the turbine which corresponds to the maximum power.

A pitch angle control is used to reduce the aerodynamic power captured by the wind, and to keep the output power of PMSG at the power reference when the wind speed is greater than the nominal speed [11]. The control method of the pitch angle is shown in Fig.6.

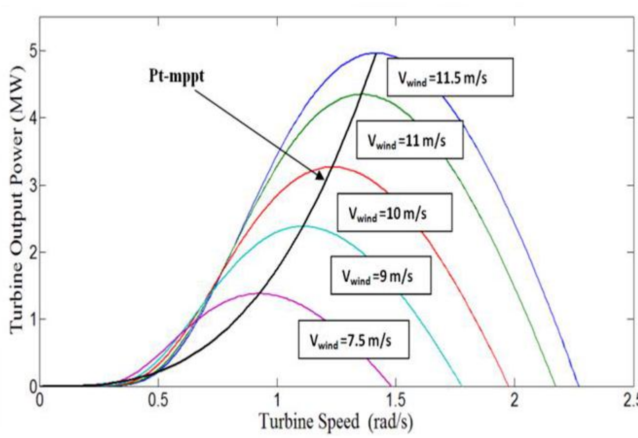

Fig 5 : Principle of the MPPT.

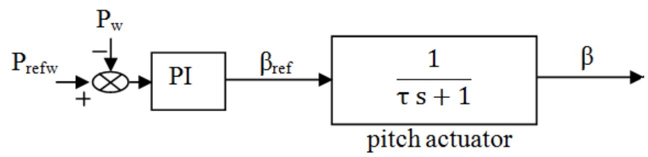

Fig 6 : Pitch angle control method.

The below flow chart explains the flow of Particle Swarm Optimization in MPPT technique.

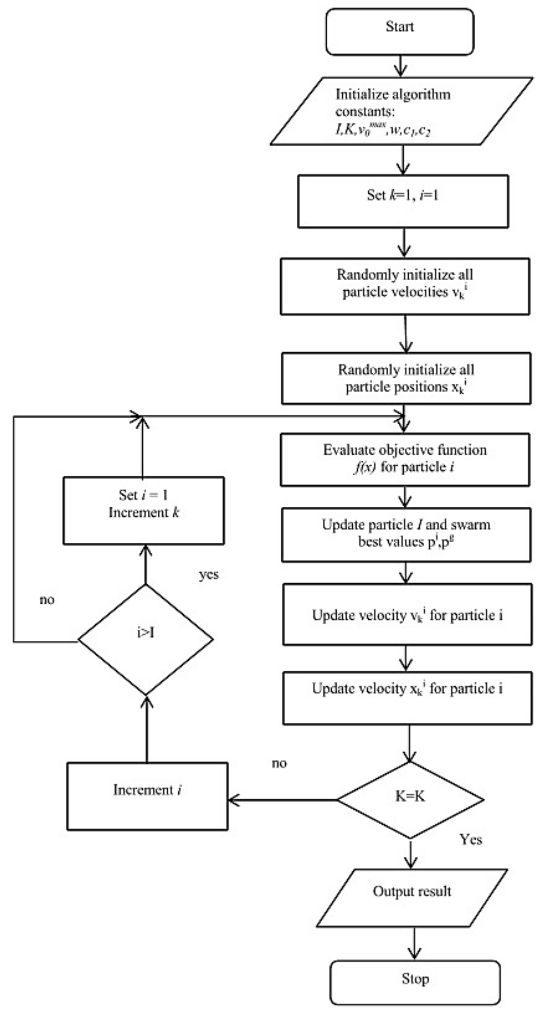

Fig 7 : Flowchart of PSO algorithm.

2.5 Battery Modeling

In this paper, the battery model is taken from the MATLAB Sim Power Systems library with appropriate parameters which will be used for the proposed V-f and P-Q controls. The detailed description about the battery model is given in [21]. Due to theintermittent and uncertain nature of solar power output and also the highly fluctuating load demands, deep cycle lead acid batteries are the most common type of battery storage in microgrid applications because the maximum capacity of the

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battery can be utilized. Hence, in this paper, a battery is modeled as a lead acid battery with appropriate choice of parameters for deep cycle application. It is assumed that the lead acid battery can be discharged up to SOC of 20% and can be charged up to SOC of 80%.

The battery model in [21] is an analytical model with two equations representing the battery discharge and charge models. The battery discharge and charge model for a lead acid battery is given by (3) and (4), respectively

$$V_{Batt} = V_0 - R.i - K.\frac{Q}{Q - it}(it + t^*) + Exp(t) \quad (3)$$

$$V_{Batt} = V_0 - R.i - \left[K\frac{Q}{it-0.1Q}\right]i^* - \left[K\frac{Q}{Q-it}\right].it + Exp(t) \quad (4)$$

III. DYNAMIC MODELING OF COMPONENTS

A set of models capable of simulating the response of theMG under several conditions was developed in order to analyze MG dynamic behavior.

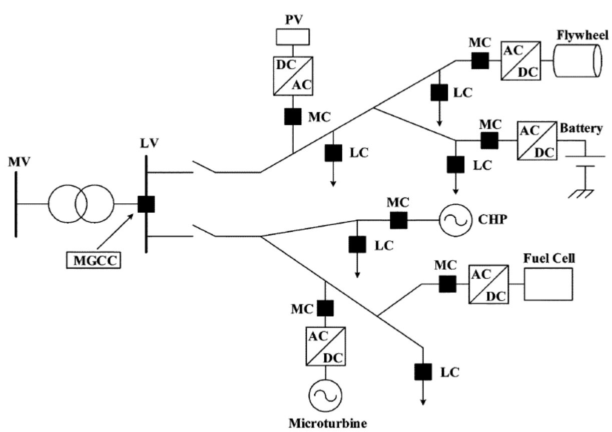

Fig 8 : MG Architecture

3.1 Microsource Modeling

The dynamic model [11] was adopted for the primary unit of microturbines, since these units are small simple-cyclegas turbines. Both high-speed single-shaft units (with a synchronous machine) and split-shaft units (using a power turbine rotating at 3000 rpm and a conventional induction generator connected via a gearbox) were modeled. The single-shaft microturbine (SSMT) requires an ac/dc/ac converter for grid connection.

A wind generator was also included in the library of MSusing for that purpose an induction generator directly connected to the network and represented by a fifth-order model, available in MatLab Simulink toolboxes.

Concerning the PV generator, it was assumed that the array is always working at its maximum power level for a given temperature and irradiance. Basically, it is an empirical model based on experimental results as described in [13], where a detailed description on MS modeling adopted in the MG project can also be found.

IV. STORAGE DEVICES MODELING

Due to the large time constants of the responses of some MS, such as fuel-cells and microturbines, storage devices must be able to provide the amount of power required to balance the system following disturbances and/or significant load changes.

Considering the time period of interest for analyzing MG dynamic behavior, storage devices, such as flywheels and batteries, are modeled as constant dc voltage sources using power electronic interfaces to be coupled with the electrical network. These devices act as controllable ac voltage sources to face sudden system changes such as in load-following situations. In spite of acting as voltage sources, these devices have physical limitations and thus a finite capacity for storing energy. The active power needed to balance generation and consumption inside the MG is injected into the grid using a proportional to frequency deviation control approach.

V. INVERTER MODELING

Two kinds of control strategies may be used to operate an inverter. The inverter model is derived according to the following control strategies.

- PQ *inverter control*: the inverter is used to supply a given active and reactive power set-point.
- *Voltage source inverter (VSI) control:* the inverter is controlled to "feed" the load with pre-defined values for voltage and frequency. Depending on the load, the VSI real and reactive power output is defined

The PQ inverter control is implemented as a current-controlled voltage source, Current components in phase and quadrature with the inverter terminal voltage are computed based on a method presented in [9] for power calculation in single-phase inverters. Power variations in the MS induce a dc-link voltage error, which

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is corrected via the PI-1 regulator by adjusting the magnitude of the active current output delivered to the grid.

The VSI acts as a voltage source, with the magnitude and frequency of the output voltage controlled through s described in the following equations:

$$\omega = \omega_0 - k_p \times P \quad (5)$$

$$V = V_0 - k_Q \times Q \quad (6)$$

where P and Q are the inverter active and reactive power outputs, k_p and $k_Q$are the droop slopes (positive quantities), and ω_0 and $V_0$are the idle values of the angular frequency and voltage

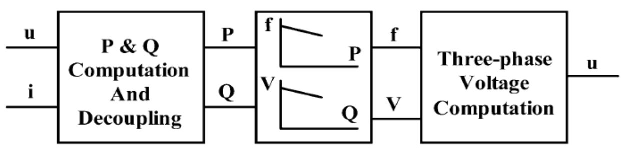

Fig 9 : VSI model.

VI. RESULTS AND DISCUSSION

The proposed simulation were developed using MATLAB 7.10 software package and the system configuration is Intel Core i3-4000M Processor with 2.40 GHz speed and 4 GB RAM. In proposed work two energy sources are considered. Computational results of Active, Reactive power problem attained by the proposed PSO method with Space Vector Pulse Width Modulation (SVPWM) for the two energy sources analyzed.

6.1 Simulation Model for Proposed PSO With PV

PV panel works under the principle of photoelectric effect. In Incremental Conductance (IC) method is used for get the maximum power from the PV panel. The array terminal voltage is always adjusted with respect to the MPP voltage it is based on the incremental and instantaneous conductance of the PV module with assistance of PSO. The ratio of change in output conductance is equal to the negative output conductance. Simulink model for PV system is shown in Fig. 8.

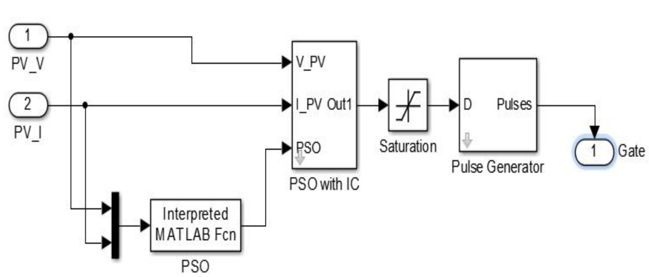

Fig 10 : PSO with IC

6.2 Simulation Model for SVPWM with Inverter

Results obtained from the coordinated V-f control are presented which is followed by the results from the coordinated P-Qcontrol. In grid connected mode, the distribution feeder is considered to be suppliedby 115 kV and a PV generator of irradiance 1000W/m2. Hence, in an islanded case,the grid is supplied with battery of 100V and 1.5Ah.

In the islanded mode, the microgrid frequency which initially dips to a value of 47.8 Hz due to the load-generation imbalance and increase to 52.9Hz due to the same. The frequency control from the PV generator starts at 2.2 sec which quickly regulates the frequency back to 50 Hz in 300 msec. It can be observed that voltage is also quickly regulated at 1 p.u. after the control is started. The active power injection from the inverter, which is required to maintain the frequency at 50 Hz in both cases, is around 40 kW. Below given waveforms shows the simulation result of HMG‘s active and reactive power as well as voltage-frequency regulation.

The below waveforms show the control of Active and Reactive power usingSpace Vector Pulse Width Modulation technique.

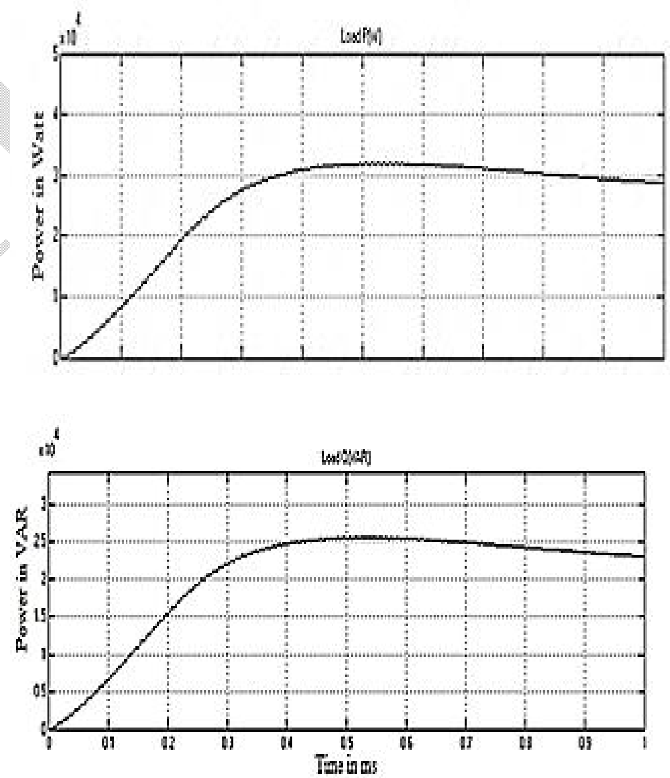

Fig 11: Active and Reactive Power Waveform

The below waveform explains that initially there is some fluctuation in frequency that has become stable (i.e. 50Hz) after 300ms.

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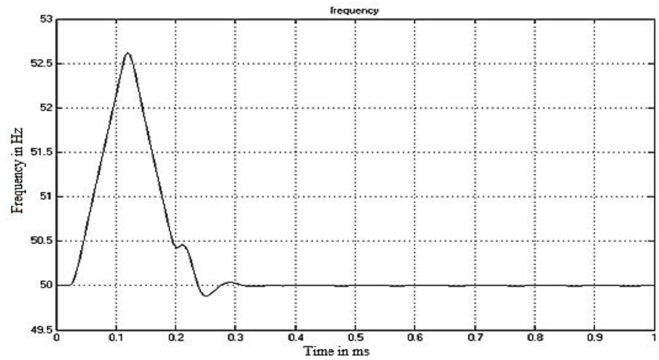

Fig 12 : Output Frequency waveform of Inverter

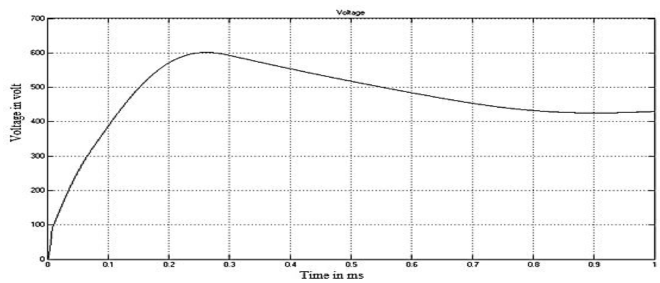

Fig 13 : Output Voltage Waveform of Inverter

The above waveform shows the existence of some fluctuation in the Voltage initially, after 700ms it becomes stable (i.e.440 Volts).

VII CONCLUSION

The proposed PSO along with Incremental Conductance gives quick response, which reduces the number of iterations and error has been find quickly as the MPPT drive is actuated. By implementing PSO algorithm driven MPPT gate can obtain uninterrupted power supply. It obtains reliability of power supply and high quality services. The PV output is utilized first in the residential electric power supply system and the microgrid realizes the desired power flow control in the grid-tied operation mode. Integrating DG and energy storage units makes the home energy supply more reliable, more efficient, and greener. The power electronic interfaces make the residential powersupply system controllable and at the same time provide the approach to realizing intelligent home energy management. It will allow the customer to play an active role in the supply of electricity, which can help the utility grid respond to equipment failures, extreme weather conditions, etc.High reliability coming from utilizing both the utility grid and the on-site PV, wind and battery, high efficiency owing to directly feeding dc loads, and green because of integrated renewable energy DGs. More importantly, because multiple power sources and energy storage are integrated and power electronic converters are used popularly in this system. Thus in HybridMicrogrid better control of power can be engaged with reliable and flexible power.

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