ISLANDED AND GRID CONNECTED MODE OPERATION FOR POWER MANAGEMENT IN PV FED MICROGRID SYSTEM WITH BATTERY SUPPORT

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Abstract:
To maximize energy consumption, solar photovoltaics and energy storage must be integrated using a sophisticated control system. The study includes the design and evaluation of an advanced system that uses a DC-AC converter to serve AC loads, a bidirectional DC-DC converter for effective battery charging, and PV maximum power point tracking (MPPT) via a boost converter. The main goal is to clarify the complexities of power management such that it functions flawlessly in both grid-forming (islanded) and grid-connected (fed) modes. The capacity of the system to adjust to changing load conditions allows power to be transferred between the DC and AC microgrids efficiently. Using a MATLAB-based platform, extensive simulations are performed to evaluate and validate the proposed system. This paper contributes to advancing the understanding and implementation of power management strategies within solar PV fed microgrid systems with battery support.

Key words: Converter, bi-directional converter, inverter, energy storage unit, grid feeding, grid forming, microgrid, power management.

I. INTRODUCTION

Due to the depletion of fossil fuel supplies and growing worries about creating an emission-free environment, humanity is now obliged to rely on innovative technologies to meet its energy needs. Distributed power resources based on solar photovoltaics are emerging as one of India's fastest-growing sectors. When it comes to operating in both islanded and grid-connected modes, all renewable energy resources are finding consequences [1]. The development of power electronics has led to an increase in the use of DC appliances, paving the way for DC microgrid systems that require careful examination and analysis by power engineers. Concerns linked to DC microgrid systems are becoming more prevalent, as evidenced by a review of the literature [2].
Power management has been explained through the use of energy storage components and a bidirectional DC-DC converter coupled to the DC bus [1][3]. DC microgrids allow for flexible operation in implementing control schemes, such that the DC microgrid voltages are within acceptable limits and capable of maintaining system power balance in both islanded and grid connected mode [4]. Power management and coordination control ensure a reliable operation of microgrid system under varying operating conditions. There is a discussion of the many bidirectional DC-AC converter control techniques. The battery storage unit's state of charge, or SOC, serves as an indication for determining the safe charge and discharge limits. Additionally, the SOC slope shows the battery's rate of charge and discharge [5].

This paper focuses on power balancing in both islanded and grid connected mode of operation as illustrated in section II. The solar PV is injecting power to loads as well as charging/ discharging the battery during the day time. The voltage control of DC-AC converter is done using SPWM method. In night time, bi-directional DC-AC works in controlled rectification mode and bidirectional DC-DC converter operates in buck mode. DC microgrid voltage is controlled by balancing the power generated via solar PV, consumed by loads and power exchanged with grid (in grid connected mode only).

II. SYSTEM MODEL DESCRIPTION

The generalized block diagram of the system in grid connected and islanded modes is shown in fig. 1. System toggles between various modes using the operating switches which connect solar PV, battery, AC/DC loads and utility grid as per requirements [6]. The islanded operation takes place during day time where it can be divided in different modes according to the load power demand. The battery storage unit is integrated with DC microgrid to perform power exchange according to the input solar radiation, temperature and load demand [7]. In the morning time, solar power is more

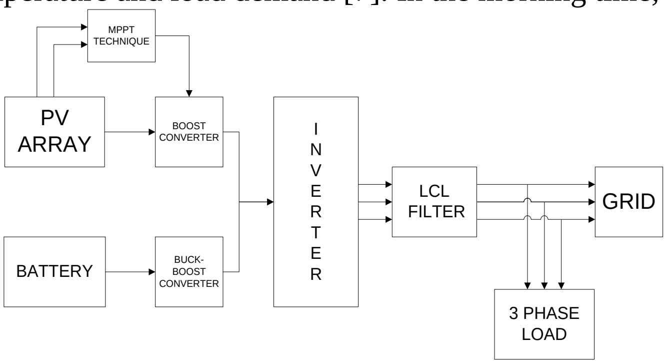

Fig.1. block diagram of system

than load demand. Hence, solar PV transfers the power to load as well as charges the ESU. In afternoon, peak load demand requires more power at load side (considering generalized load profiles) which could be fulfilled by discharging the battery. Moreover, if SOC is greater than 80% (let) and solar PV power is greater than loud demand, solar PV MPPT is turned off. Thus, net power generated via solar PV is equal to net power demand by load. In last mode, at evening no solar power is available, then grid is connected (grid connected mode) which charge the storage unit for emergency purposes. Operation of system in various modes is as discussed below [8].

III.PROPOSED CONVERTER AND POWER MANAGEMENT

1)Solar PV maximum power point tracking:

The solar irradiance as well as temperature levels keeps on changing. Perturb and observe algorithm is used to extract the maximum available power from solar PV. Solar PV voltage (Vpv) is compared with the reference MPP voltage (VMPP), which passes through PI controller so as to generate PWM signal for DC-DC converter. The product of the MPP voltage (Vmpp) and MPP current (Impp) yields the power at the MPP (Pmpp). The perturb and observe (P&O) method involves the controller making modest modifications to the voltage from the array and measuring the power. If the power grows, the controller tries making further adjustments in that direction until the power no longer increases. The DC-DC boost converter uses this method to stabilize the DC voltage.

2) Bi-directional DC-DC converter for battery:

A converter that steps up or steps down DC voltage from one side of the converter to the other when powered by an attached controller and gate-signal generator is represented by the Bidirectional DC-DC Converter block. Bidirectional DC-DC converters are helpful when alternating between energy storage and utilization, as in the case of electric cars. Non isolated converter is a Bidirectional DC-DC converter without an electrical barrier. This converter contains an inductor, two capacitors, and two switches that are of the same device type.

3) Bi-directional DC-AC converter control:

In a bidirectional DC-AC converter, the closed-loop sinusoidal pulse width modulation (SPWM) technique regulates the voltage. The error signal is produced by comparing the DC-AC converter's (VAC) output voltage to the sinusoidal signal reference (Vm sin wt), which is passed through a PI controller. In order to create switching for a bidirectional DC-AC converter, this error signal is compared with a carrier signal at 10.0 KHz. The other switches receive a 180˚ phase shift. When solar PV is abundant, the battery begins to charge using a bidirectional DC-DC converter in buck

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mode. Converters enter boost mode when load power demand side rises above solar PV capacity. The real battery current (battact) that flows through the PI controller is compared to the reference signal (Ibatt) representing the actual battery current. To create pulses for battery converter control, the output of the PI controller is compared to a carrier signal at a frequency of 10.0 KHz. When solar PV generates excess power, it powers DC and AC loads and the bidirectional DC-DC converter operates as a buck converter in ON mode. Batteries with a bidirectional DC-DC converter operating in boost mode come into play when solar PV is unable to meet load demand and discharge power to the load side in accordance with requirements.

4)LCL filter:

Filters are critical components of grid-connected PV inverters. Such systems should have a filter with high harmonic attenuation. The voltage drop across the straightforward inductor L filter is extremely high, and it only offers modest harmonic attenuation. Since they have all the benefits that the L and LC filters do not, LCL filters make a good substitute. The grid receives the filtered, harmonic-free current that the LCL filter successfully smooths out of the inverter's output. High attenuation, enhanced performance, cost-effectiveness, and reduced weight and size are the benefits of LCL filters. With small values of inductors and capacitors, the LCL filter provides effective harmonic rejection.

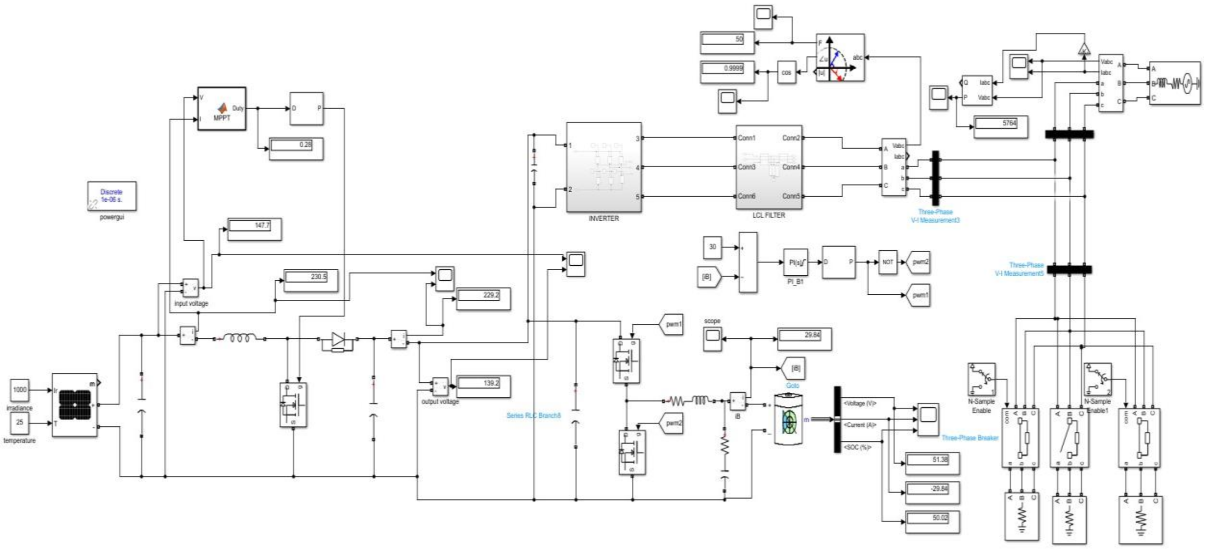

Fig.2.Simulink diagram Proposed system

IV. RESULTS AND DISCUSSION

The system parameters used in simulation results are elaborated in Table 1.

TABLE 1. DESIGNED SYSTEM SPECIFICATIONS

PARAMETERS	**VALUES**
Solar PV modules	50KW
PV array MPP current	32A
PV array MPP voltage	289.5V
Inductance, L (dc-dc boost converter)	3.63mH
Capacitance, C (dc-dc boost converter)	0.545µF
Inductance, L (bidirectional converter)	0.02mH
Capacitance, C (bidirectional converter)	10µH
Inductance, L (AC filter)	50mH
Capacitance, C (AC filter)	100mF
DC link capacitor	10µF
Battery	10A/hr
Battery voltage	50v

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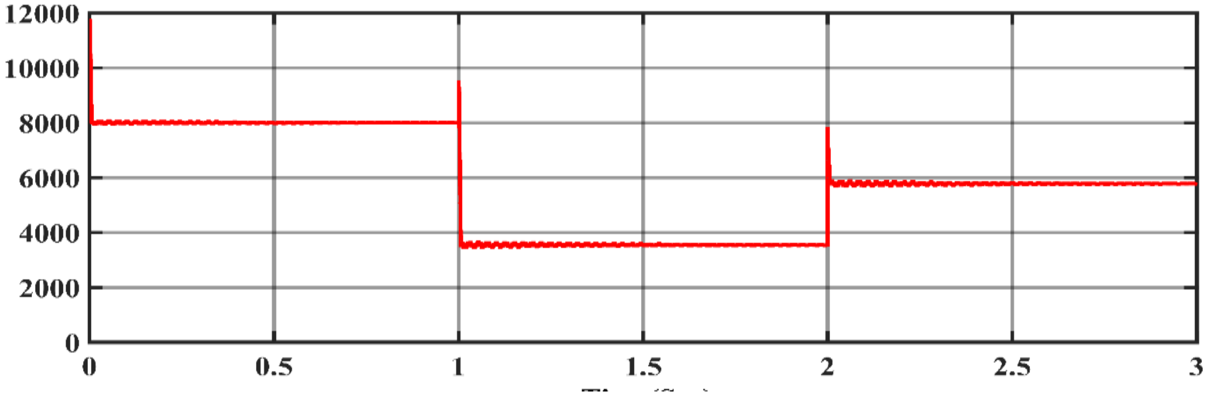
AC grid voltage	380.0V, 50.0Hz



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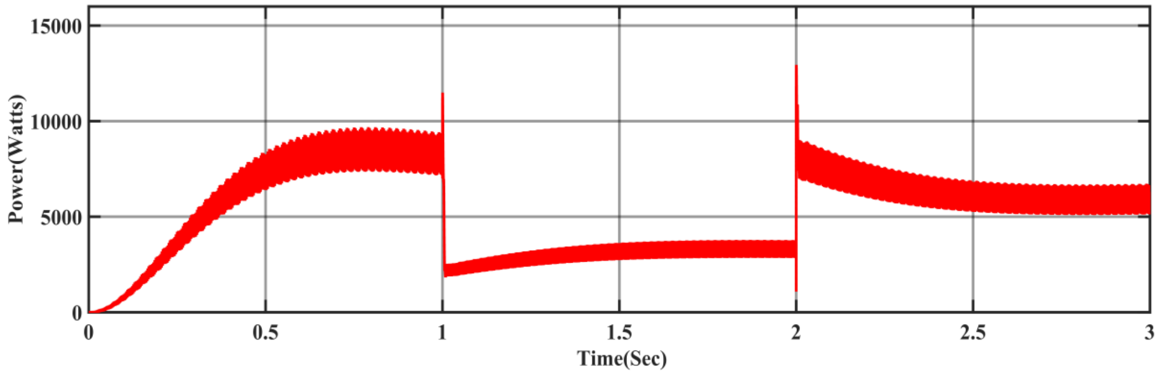

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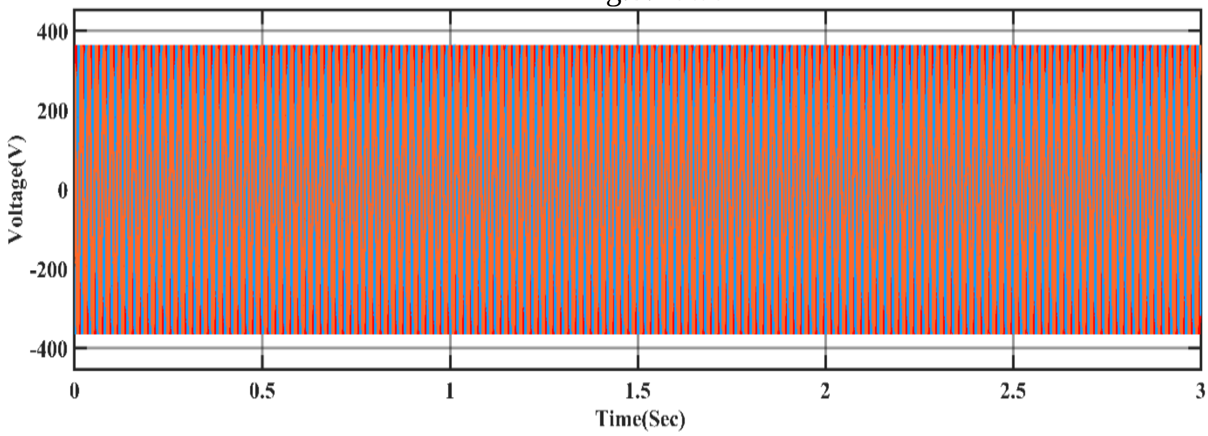
Fig.3.Power



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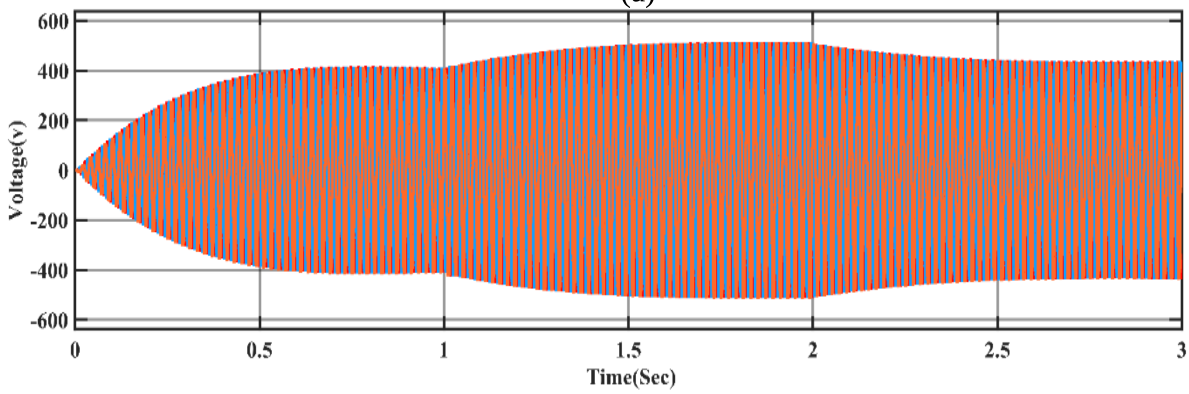

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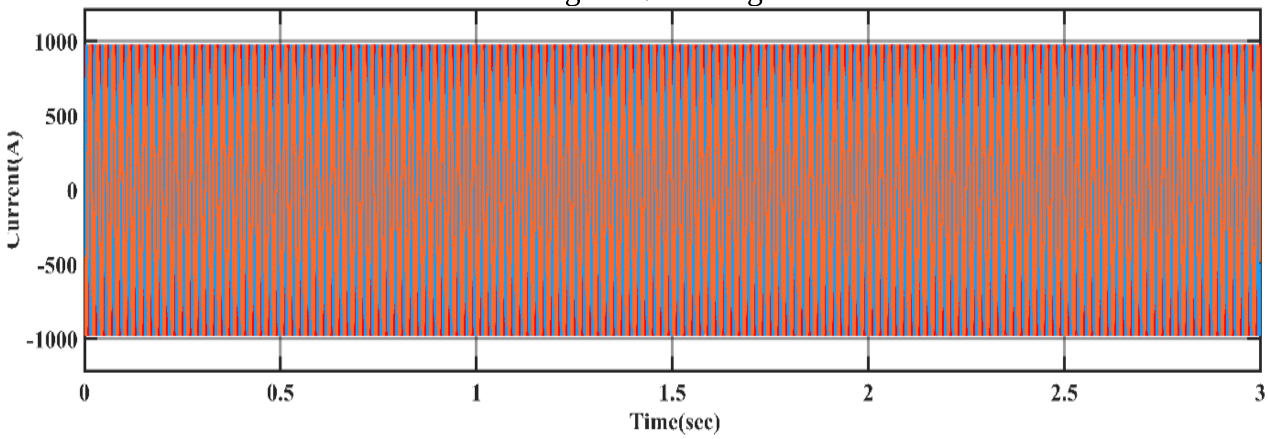
Fig.4. 3 Ø Voltage



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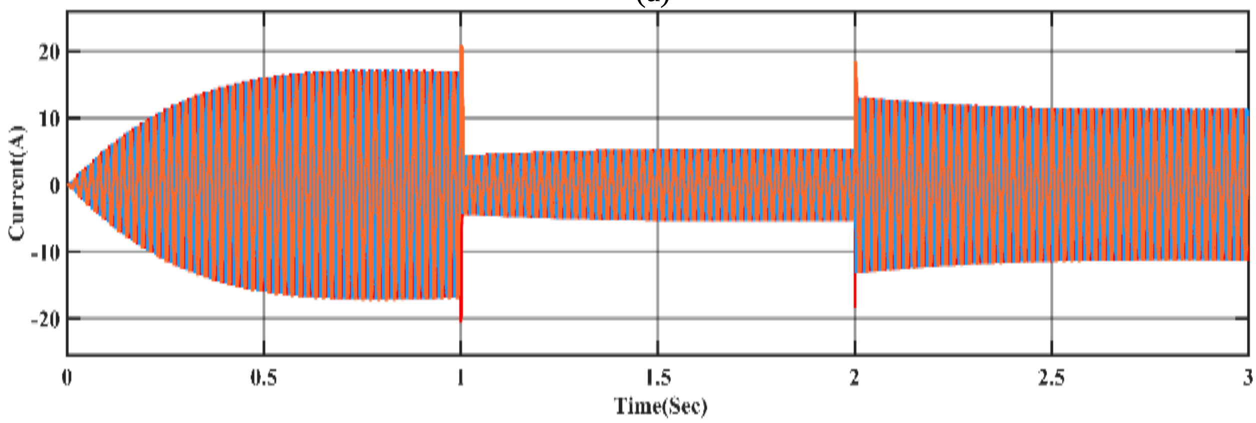
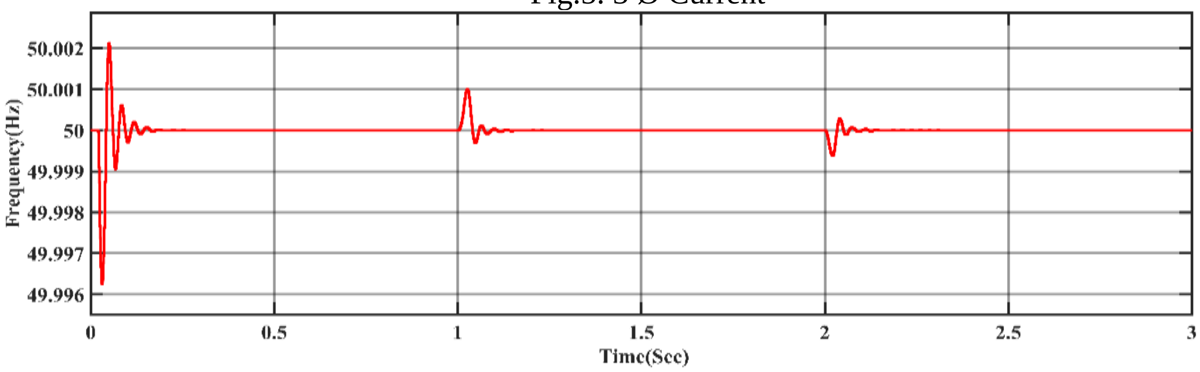


(b)

Fig.5. 3 Ø Current



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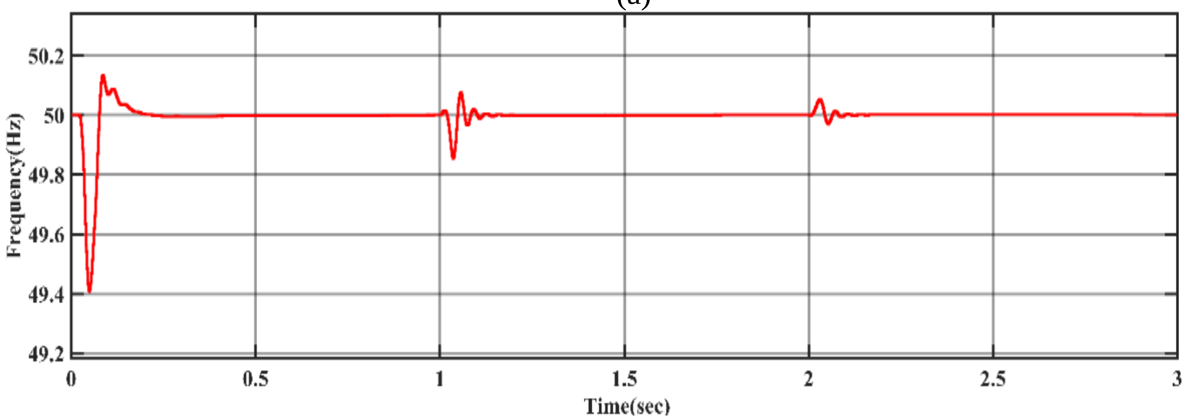
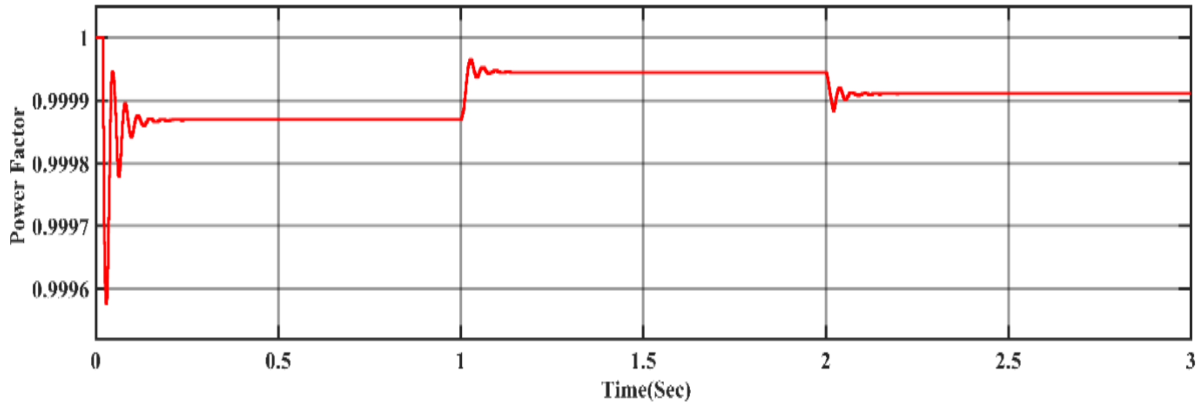


(b)

Fig.6. Frequency



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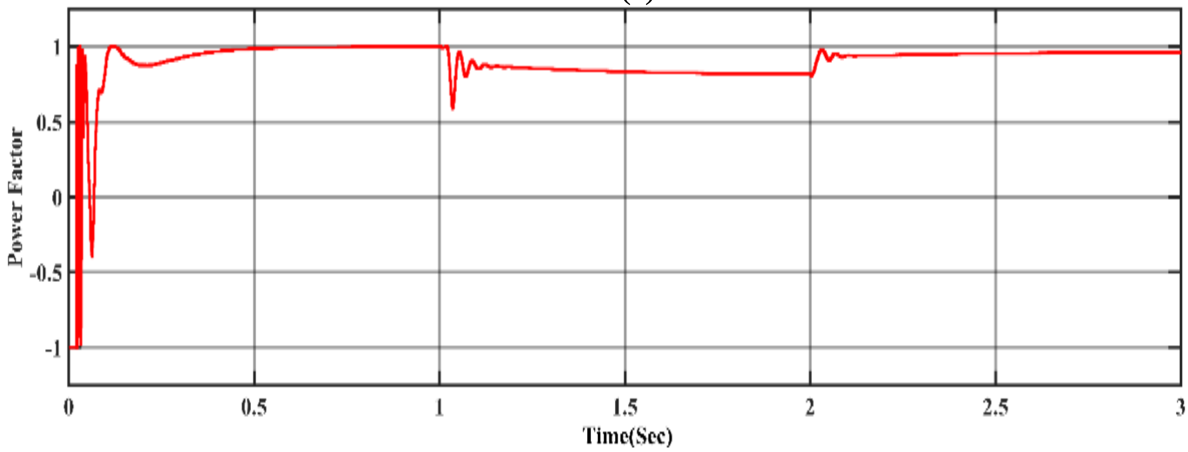

(b)

Fig .7. Power factor

Graphs: (a) grid connected mode; (b) islanded mode

The graphs of system show the variation when different loads change particular time period in islanded mode and grid connected mode. The time period for each load is 1 second in both islanded mode and grid connected mode. There are some fluctuations which have been occurred when there is sudden load at a particular time period.

In fig .3. power of the system is observed where (a) denotes the graph of power at grid connected mode, we can observe that a smooth waveform of load power with respect to time that change according to time. Some disturbance occurs when the load changes and settles to original position, whereas in (b) the graph denotes the load power when in islanded mode, where the waveform slowly settles to its position when there is a fluctuation when load changes and also its not a smooth waveform. In fig .4. three phase voltage of the system is shown where (a) denotes the system in grid connected where the voltage is a 380V,50Hz sinusoidal wave whereas in (b) voltage keeps changing with respect to load but is also a sinusoidal wave. In fig .5. three phase current is shown which is constant sinusoidal wave when is in grid connected (a) with a frequency of 50Hz, whereas in (b) islanded mode the current changes its amplitude with respect to load such as when calculated for 380V of voltage and 8Kw power, the current should be 21A and so on the value changes for respective loads. In fig .6. frequency of the system is denoted where in (a) the waveform takes less fluctuation in grid connected mode but in (b) the waveform oscillates to maximum and takes time to reach its original state. In fig .7. power factor of system is shown where the oscillations are less in (a) grid connected mode when compared to (b) islanded mode.

V. CONCLUSION

This paper proposes a novel converter control strategy so as to integrate distribution energy resource (solar PV in specific) to the single-phase residential consumer premises. Power in both islanded and grid connected mode of operation. Bi-directional DC-AC converter is used to supply power to AC load via solar PV, along with the power exchange with battery storage unit. Battery works in charging / discharging mode to control the DC microgrid voltage. In islanded mode of operation, the available solar PV power along with the battery (operating in buck / boost mode) power is used to fulfil the load power necessity. The bi-directional DC-AC converter is operated in voltage control mode using unipolar SPWM technique. In grid connected mode. the AC-DC conversion takes place and bidirectional DC-DC converter is operated in buck mode so as to charge the battery for emergency purposes.

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