# Continuous Operation of Micro-Inverter for Constant Supply in Grid Connected and Off Grid Operation

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***Abstract-*** **In this paper, a photovoltaic (PV) micro-inverter capable of operating in both off-grid mode and grid-connected mode is proposed. The main advantage of this system is that in grid-connected mode, the micro-inverter works as grid tied micro inverter which will receive power from the grid if the load is more and supply power to the grid if the connected load is less this is the operation mode of most commercial grid-connected PV micro-inverters. The idea is to provide those micro-inverters with the additional functionality of working in off-grid mode without changing their control algorithms for grid-connected mode, which were developed and refined over time. In this system if the power supply from the grid is interrupted the micro inverter will start working as off-grid mode. This system will isolate the grid from the micro inverter without supplying any power to the grid and its full concentration will be to the connected local load. If the connected load is low the micro inverter will charge the small battery connected as the dummy source, if no load is connected across the micro inverter it will stop working by switching off the solar panel from the micro inverter.**

***Keyword-*** **Single ended primary inductance converter (SEPIC), Photovoltaic Cell, Micro-inverter**

## I. INTRODUCTION

In recent years, one of the priorities worldwide is developing alternative sources to produce electric energy, particularly from renewable sources, which produce low environmental contamination levels. Those renewable energy sources play an important role in the long term, and they will give rise to substantial changes in the technologic, environmental, and organizational profile of the global energy system. The most available renewable energy source is the solar power. Solar panels are used for converting solar energy into electrical energy. The solar panels must be used such that to get the maximum efficiency. The most efficient way is using a micro-inverter

A solar micro-inverter is an inverter that is generally allocated to each solar panel module that converts direct current to alternating current. The output of each module can be paralleled to combine the capacity and interconnected to the grid. The inverter connected to each panel provides maximum power point tracking (MPPT) functions independently which provides redundancy as each pair is independent from other name micro-inverter came from Module Incorporated Inverters (MIC) – Each solar panel module incorporates its own inverter.

Each integrated module provides AC output and are connected together in parallel. This arrangement provides easier installation, redundancy and more effective capture of energy when they're partially shaded. As of 2010, they're mainly used for single phase applications and most units in production relied exclusively on electrolytic capacitors for buffering and there is a concern of long term reliability of these capacitors in each module. For getting maximum efficiency from the solar panels, micro inverters are used in a grid-tied system. The main drawback of grid-tied micro inverter is that whenever the electrical supply from the grid stops (for maintenance work or for any other reason) the micro converter also stops working And the supply to the local load from the solar panel will also stops. The objective of this project is to make the on-grid micro inverter to work in both grid-tied mode and in off-grid mode. At low cost, simple control with using small back up battery.

## II. PROPOSED METHODOLOGY

The proposed methodology can be best explained with the below block diagram in fig.1.Here we have the input supply from the PV panel which is connected to the micro-inverter and also a battery is connected to the micro-inverter which is in connected to the single phase grid. Now the output of the micro-inverter supplies the corresponding ac signal for driving the connected load. The output of each module can be paralleled to combine the capacity and interconnected to the grid. The output of each module can be paralleled to combine the capacity and interconnected to the grid.The output of each module can be paralleled to combine the capacity and interconnected to the grid The control part is implemented with microcontroller or DSP connected to the micro-inverter and the DC-DC converter enables proper switching as per the MPPT algorithm implemented. Battery is present to supply initial voltage till solar panel voltage builds up and also when there is off-grid mode of operation. Now excess energy after supplying the connected load is utilized for charging the battery as per the check on charge level by ammeter connected. Now even after fully charging the battery excess voltage is utilized in driving a dummy load connected. Thus operation of grid connected micro-inverter in both modes can be made working for continuous supply to load.

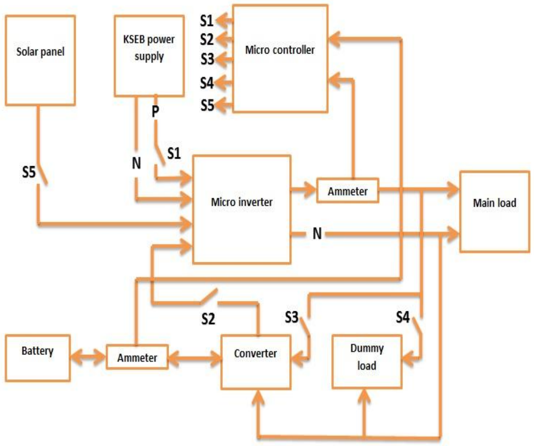


Fig.1.Block diagram of proposed method

## III. MODES OF OPERATION

### *A) ON GRID MODE*

In this mode micro-inverter is directly connected to the solar panel and the grid. The switches s1 and s5 are on during this mode. The micro-inverter is turned on by the supply from the grid. The power required to meet the main load is supplied through the micro inverter and the excess power generated from the solar panel is fed back to the grid through micro-inverter. If required power is more than the solar panel power then the extra power is taken from the grid. At this mode switch, s2, s4 are open because there is no need for this circuit. The switch s3 will be closed if the charge of the battery is low. An ammeter is used for this purpose. The ammeter will check the power available in the battery and if the charge is very low the battery will be charged. After charging the battery the switch s3 will be opened using the micro controller circuit. This is the working of the solar micro-inverter during on grid mode.

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### *B) OFF GRID MODE*

If due to some technical reasons the supply from the grid is not be available then the micro-inverter will stop working .the main reason for this is safety problem. If the grid is turned off for maintenance work and the micro inverter is still on then there is a chance for accident because the excess power from the solar panel will be given to the grid and this power is enough for causing an accident. So the micro-inverter will only work if the grid power is on. In order to turn on the micro-inverter at power cut time a battery backup is provided. This battery will work as a dummy power supply to the micro-inverter and acts as a grid power. This will be enough for the micro-inverter to turn on. Thus the power generated from the solar energy can be transferred to meet the required main load through micro-inverter. At that time we have to make sure that the grid is isolated from the micro inverter, using the switch s1 the grid is isolated from the home network. The switch s2 is turned on . If there is excess power generated, the solar panel cannot be fed back the power to the grid. So the additional power generated is used to charge the battery by switching the on the switch s2. A rectifier is provided to convert the ac power from the micro-inverter into dc power so that the battery can be charged. If more than the required amount of power is generated after the battery charged, then the additional unwanted power is connected to the dummy load through switch s4. This is the working of the solar micro-inverter in off grid mode. If no load is connected then there is no need for the solar panel. so the switch s5 can be turned off and the solar panel will be turned off with the micro inverter

## IV. PROPOSED SYSTEM CONFIGURATION

### *A. MPPT TECHNIQUE*

Many methods are present for tracking MPP. Among them the most common methods are mainly 4 types which are Perturb & Observe, Incremental Conductance method, Fuzzy logic & Neural network. Out of the four Perturb & Observe is simple but has the steady state oscillation which leads to wastage of energy. Now neural & fuzzy logic method involves complexity in design and implementation. Now so we take IncCond Method with variable step size method which has advantage of higher efficiency and faster tracking time compared to fixed step size IncCond method. The step size for the INC MPPT method is generally fixed. The power drawn from the PV array with a lager step size contributes to faster dynamics but excessive steady state oscillations, resulting in a comparatively low efficiency. This situation is reversed while the MPPT is running with a smaller step size. Thus, the MPPT with fixed step size should make a satisfactory tradeoff between the dynamics and oscillations. Such design dilemma can be solved with variable step size iteration. The flowchart of the modified variable step size INC MPPT algorithm is shown in Fig. 2, where the converter duty cycle iteration step size is automatically tuned. The PV output power is employed to directly control the converter duty cycle, contributing to a simplified control system.

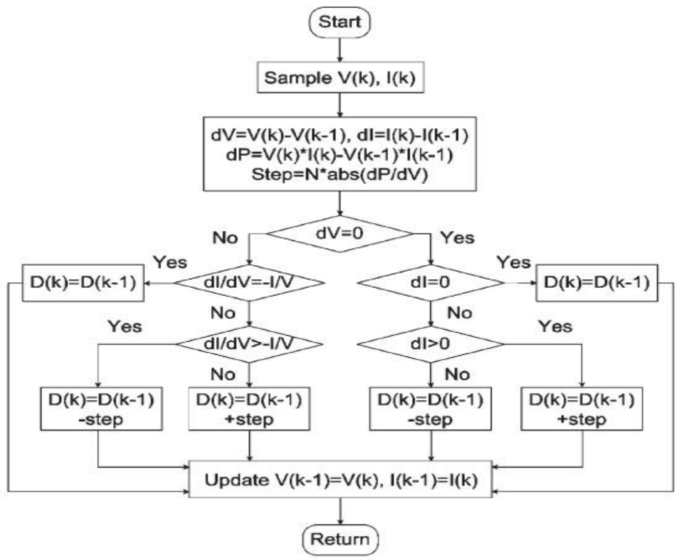


Fig.2.Flowchart of variable step size INC algorithm

*B. MICRO-INVERTER*

Micro-inverter works with an operating dc voltage range of 22-45V with MPPT range of 28-36V,to produce single phase ac voltage of range 190-260V. Inverters take DC power and invert it to AC power so it can be fed into the electric utility company grid. The grid tie inverter must synchronize its frequency with that of the grid using a local oscillator and limit the voltage to no higher than the grid voltage. A high-quality modern GTI has a fixed unity power factor, which means its output voltage and current are perfectly lined up, and its phase angle is within 1 degree of the AC power grid.

*C. MICRO CONTROLLER*

The main control is achieved by programming a PIC micro controller which will sense the current AC grid waveform, and output a voltage to correspond with the grid. It also checks for the availability of generated voltage to the required load voltage and correspondingly the other components are enabled for maintaining constant single phase ac voltage.

*D. SEPIC CONVERTER*

When proposing an MPP tracker, the major job is to choose and design an efficient converter, which is supposed to act as main part of MPPT. The efficiency of switch-mode dc-dc converter is highly exploited. Most switching-mode power supplies are well designed to function with high efficiency.

Among all the topologies available single-ended primary inductance converter (SEPIC) is a DC-DC converter topology that provides a positive regulated output voltage from an input voltage that varies from above to below of output voltage. It operates in continuous, discontinuous and boundary conduction modes. SEPIC has the merits of non-inverting polarity, easy-to drive switch, and low input-current pulsating for high-precise MPPT.SEPIC is controlled by the duty cycle of control transistor. SEPIC Converter can raise the output voltage to a suitable range, and can supply an isolation route to isolate the input and output terminal after terminate charging. SEPICs are useful in applications in which a battery voltage can be above or below that of regulator’s intended output. On comparison with other switched-mode power supplies specifically DC-DC converters. SEPIC converter exchanges energy between inductors and capacitors in order to convert voltage from one voltage to another. Design equation for the calculation of duty cycle as per the design consideration of SEPIC is as below;

$$Dmin = \frac{Vout + Vd}{Vin(\mathrm{max}) + \mathrm{Vout} + \mathrm{Vd}} \qquad (1)$$

$$Dmax = \frac{Vout + Vd}{Vin(\mathrm{min}) + \mathrm{Vout} + \mathrm{Vd}} \qquad (2)$$

Now as per the design we have the value of Input voltage=10-50V DC; Maximum duty cycle=0.855; Minimum duty cycle=0.5; Switching frequency=10Khz.For above specification the inductor and capacitor values are calculated by using standard design equations and the values used are $L_1$=2.5e-6H, $L_2$=2.5e-6H,$C_1$=4e-6F,$C_2$=100e-6F. Due to change in the temperature and irradiance the respective maximum power changes. The maximum power is tracked at 70% duty cycle.

*E. BATTERY*

Battery backup is provided for the continuous operation of the micro-inverter to constant load voltage even when the grid is in off condition. Here when in on grid the inverter is operated from supply from grid and in that case after the load requirement is met the excess energy charges the battery. Now in off grid mode the battery supplies energy for the operation of micro-inverter for constant load output.

## V. SIMULATION RESULT

In simulation results we have the simulation result for the solar cell shown in fig.3 which shows the variation of current and voltage and the power and voltage graph for change in the illumination level and corresponding MPP. Here in the figure we have the graphs for 700W/$m^2$ and 1200 W/$m^2$ in which for both cases we have open circuit voltage which is specific for panel as 45V.But the short circuit current value for 700W/$m^2$ is 23A and for 1200W/$m^2$ is 40A.Now also in the P-V curve we have the product of open circuit voltage and shot circuit current values and the panel voltage plot which gives the corresponding values for the two different illumination.

In fig.4 we have the simulation result for the state of charge (SOC) of the battery, its current and output voltage according to the illumination level. Here initially battery is in full charge but at the time of startup it will take time to build up the MPPT voltage till that time the battery is utilized for supplying voltage to inverter for constant output voltage. The output current simulation is shown for charging and discharging of battery. Also the simulation for output voltage of battery shows the variation of charging and discharging as per the illumination level and the build of MPPT voltage.

In fig.5.simulation model of the proposed system is shown. Here we have the PV panel, Sepic dc-dc converter, Rechargeable battery, followed by the inverter section to convert the dc into corresponding ac for supplying constant load voltage.

In fig 6, we have the constant output voltage shown as 300V AC voltage which is used to power the load connected. Now though there is change in the output from solar panel, the output to the load can be maintained at constant rated voltage by battery to ensure smooth operation of the connected load.

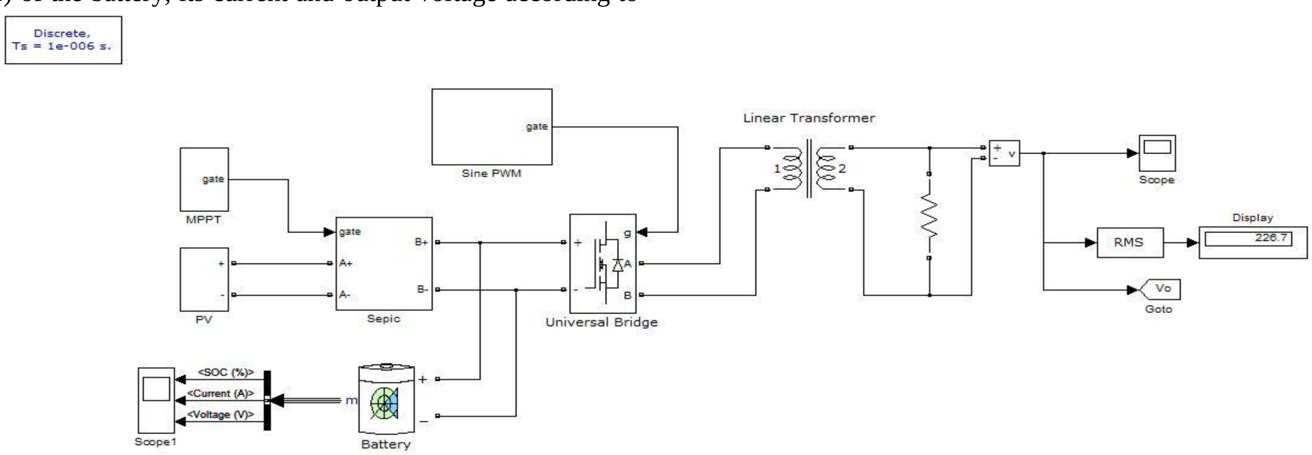


Fig.4.MATLAB Simulink model of proposed system


Fig.4. MATLAB Simulation of SOC, Current and Voltage of battery

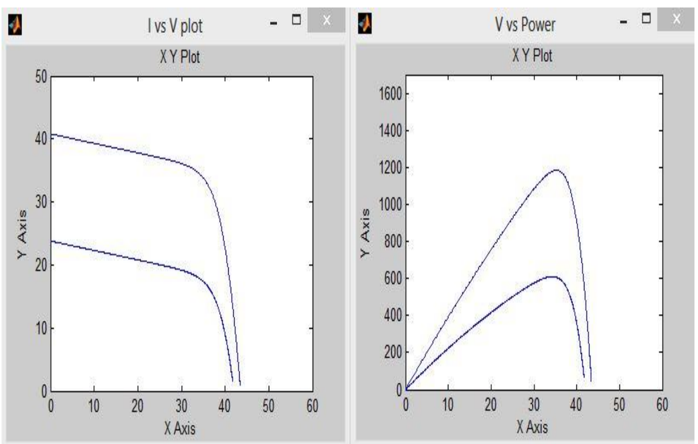


Fig.5.Current versus Voltage and Voltage versus Power characteristics of PV array Simulink model

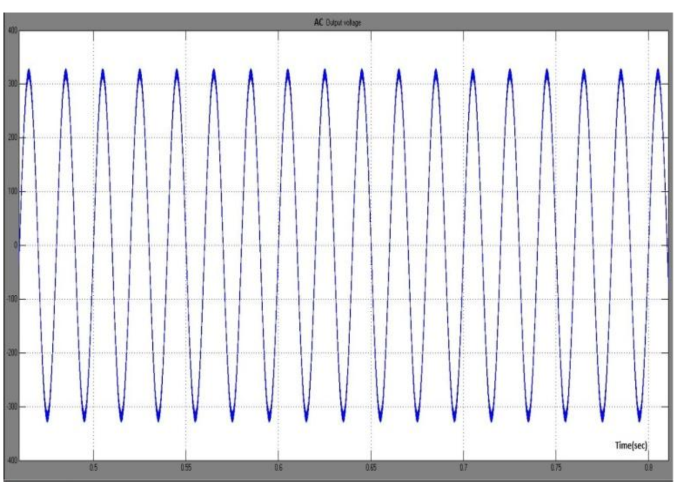


Fig.6. MATLAB Simulation of output voltage of proposed system

## VI. CONCLUSION

Solar energy is utilized for powering the single phase connected load continuously in off grid and on grid modes of operation by powering it with an additional back up with an rechargeable battery. Here we have Sepic dc-dc converter and variable step size incremental conductance MPPT method was adopted. The Proposed system provides constant output voltage for the On grid and Off grid mode. So we have an regulated ac output from a solar panel for grid connected system The proposed system is simple and easily constructed to achieve expected efficiency level of the PV module. The proposed system can thus reduce the steady state oscillations, power loss and system cost to a great extent. The topology has got wide future scope since the demand of solar systems are increasing.

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