International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-2 Issue-1, March 2013

Design of Intelligent Solar Grid Oriented PWM Inverter for Livelihood Generation in Rural Areas

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Abstract: Excessive demand of power is always difficult to meet and as a result national economy is being hampered severely due to this deregulation of electricity. Unfortunately most IPS i.e., Instant Power Supply system has poor charge controlling mechanism which makes it a massive power consumer. The cost of solar panel and the consumers' awareness to preserve AC power has stimulated the demands of high effective Grid connected power sources. Here the designed interfacing PWM inverter is operated by both solar energy and storage batteries that highly satisfies the necessity in rural areas where National Grids are hardly available and power cut problem reduces the effectiveness of IPS. Solar energy gets priority rather than AC source to charge storage battery that may save hundreds of mega watts power every day. To extend the battery lifetime and keep system components hazard-free, it includes exact battery-level sensing, charging-current controlling by microcontroller unit (MCU) and a cumulative DC/AC MPPT (Maximum Power Point Tracking) charges to obtain maximum PV energy from AC Solar Modules.

Keywords: Charge controller, Grid, inverter, MPPT charger, PWM, Solar energy.

I. INTRODUCTION

When AC main fails, inverter section will provide uninterrupted AC power supply which should be maintained by the storage batteries. These storage batteries will be charged efficiently by the solar source when sunlight is available regardless of the AC line status. While, in dark night or cloudy weather AC grid source will charge the batteries. We are using PV array of medium capability in this prototype but it is restricted to charge the battery and being miniature amount, harvested AC will not be reflected to Grid which is left open for future.

IPS system consists of PWM (Pulse Width Modulation) type inverter, storage battery & inverter-cum-charger transformer regardless of the concern for overload, overcharging or low battery cut problems and in the same time huge wastage of power and extends electricity bill. So, intelligent modification is needed in the existing IPS system. Exact voltage level sensing and battery-charge controlling are also unavailable. It results in degradation of battery lifetime The proposed system utilizes microcontroller unit to successfully overcome these tribulations.

Revised Manuscript Received on 30 March 2013.
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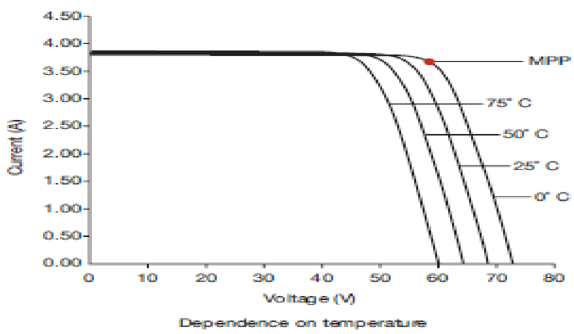
Moreover, due to limited sunshine hours and non-ideal conditions, it is not only desired to accumulate maximum PV energy from panels but also to ensure maximum utilization. Therefore, a superior technique like MPPT is employed here to match the output of the solar panels with the battery voltage to ensure maximum charge.

II. MPPT SECTION

The operation of MPPT is to adjust photovoltaic interfaces so that the operating characteristics of the load and the photovoltaic array match at the maximum power point considering some criteria like cell temperature, shadowing etc. Here Photovoltaic voltage is a preferable control variable in case of MPPT since current is heavily dependent of weather conditions. The photovoltaic current value at MPP is close to 86% of the short-circuit current. Because the photovoltaic current dramatically varies with insulation, the transient response of MPPT can occasionally cause the photovoltaic current to reach its saturation point, which is the short-circuit current. This should be prevented because its nonlinearity causes a sudden voltage drop and results in power losses. However, for the regulation of PV voltage, the voltage saturations can easily be avoided because a controller knows the operating range is bounded about 70%–82% of the open-circuit voltage.

Here, MPPT is utilized to ensure maximum gain when battery voltage is low. During the lower voltage period, this MPPT charge controller provides the extra power to recharge the battery. In normal operating environment, it forces to operate at battery voltage and not Vmp, modules maximum power.

AC supply	Solar Availability	Inverter input	Inverter o/p socket	Battery Charged by
present	No	X	AC direct	AC
present	Yes	X	AC direct	Solar
absent	Yes	Battery	Harvested AC	Solar
absent	No	Battery	Harvested AC	X



I-V characteristics of MPPT charge controller system

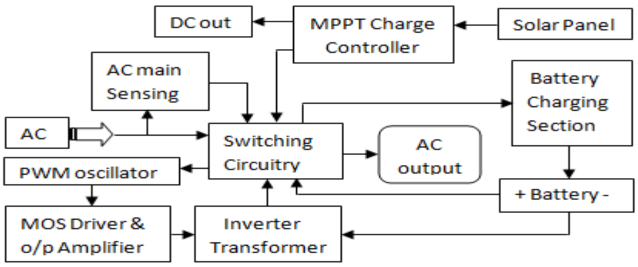
A) Working of MPPT circuit:

This circuit consists of BJT i.e., Bipolar Junction Transistor that works like a step-down converter. The circuit operation can be divided into two modes. Mode 1 begins when transistor is switched on. The input current which rises flowing through filter inductor, filter capacitor and load battery. And Mode 2 begins when transistor is switched off. The freewheeling diode conducts due to energy being stored; inductor current continues to flow through inductor, capacitor and load. Diode current falls until transistor is switched on again in the next cycle.

In this circuit the main intelligence is to measure the voltage of PV supply and battery immediately when the transistor is being switched off. For this, switching duty cycle would be measured from following equation and well-configured transistors should be used according to exact duty cycle.

III. DESCRIPTION

It consists of three sections. They are Input power section, intelligent processing section and Output power section.



The core part of this system is the intelligent switching circuit which is composed of PIC 16f876A based MCU unit which ensure uninterrupted output power based on the available input. This pre-programmed section intelligently not only maintains maximum AC output power with greater efficiency but also DC supply to small DC load that may reduce pressure of AC output. The following sub-sections give the details of entire system.

A) Input Power and Switching Section:

Input power section has three different sources of energy like grid line, storages battery and Photovoltaic energy (controlled by MPPT charge controller). To minimize the burden on the grid line, the system is designed as follows: when Grid supply is present, switching circuitry gets informed about its availability from AC main sensing section and passes AC main's signal to inverter output socket. In absence of AC grid supply, switching circuitry takes DC input from storage battery and turns on inverter circuit i.e. composition of oscillator, MOS driver, output amplifier and transformer section and AC low-pass filter. Oscillator section generates 50 Hz MOS driver signal that gets amplified, sent to inverter transformer using MOSFET switching and transforms into AC and injects AC energy to the AC-side output connection. Such periodical switching ON/OFF of MOSFET starts an alternating current with 50Hz frequency at primary winding of step-up transformer that results in 220V AC supply at the secondary winding. All these functionalities are done here by implementing PIC 16f876A MCU unit that resembles the change-over section of commercial IPS section implementing by analog circuitry.

B) Intelligent Processing and Battery Charging Section:

In absence of solar energy, it is mandatory to use AC mains to charge storage battery. But, in daytime, it prefers solar energy to AC grid in battery charging for power saving purposes. To ensure maximum possible PV energy, some intelligence is applied in this proposed system. With a regular charge controller, if the batteries are low at say 12.4 volts, then a 100 watt solar panel rated at 6 amps at 16.5 volts (6 amps times 16.5 volts = 100 watts) will only charge at 6 amps times 12.4 volts or just 75 watts, losing 25% of panel's capacity. Proposed MPPT in this case compensates for the lower battery voltage by delivering closer to 8 amps into the 12.4 volt battery maintaining the full power of the 100 watt solar panel. The intelligent charging section involves three level of charging like absorption level charging, bulk level charging and float charging. A bulk level charging is maintained for initializing charging process for a discharged battery. When Battery voltage exceeds a critical level, charge controller maintains adsorption level charging. A full charged battery gets only float level charging that maintains trickling current (i.e. one tenth of full charge current) causes available solar energy being unused.

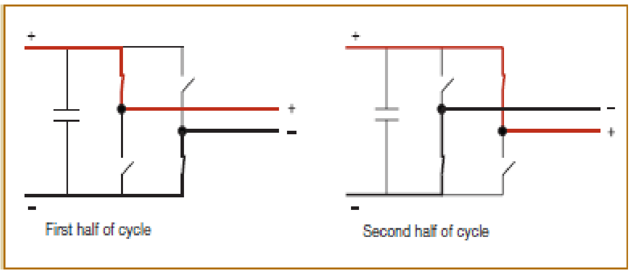
C) Output Power section:

Maximum utilization of photovoltaic energy is not yet confirmed practically. In semi-urban areas, where load-shedding are not much frequent, almost 80% of available solar energy are being left unused. To utilize such power, this system contains an output pin that supplies additional DC power to small loads likes in mobile charging application, DC fan, DC light, DC iron, electric filters etc. This output DC power is obviously regulated in MPPT charge controller section to ensure safe and maximum usages. Here we also implemented a fine adjuster of output DC voltage level to power large possible and even tiny loads. A voltmeter is also integrated for this purpose at the output section to make this as user-friendly as possible.

IV. WORKING

The method by which dc power from the PV array is converted to ac power is known as *inversion.*

Conversion is done via a set of solid switches- *MOSFET - IRFZ44N.*



A combination of two transistor pair like BC547, a NPN Transistor and BC557, another PNP Transistor is used for safety that can ensure security for avoid miss pulse which cause the damage of MOSFET. Additional diode, resistance and non-polar capacitor are also used for proper biasing of MOSFET. Since maximum focus should be given to avoid the damage of MOSFET.

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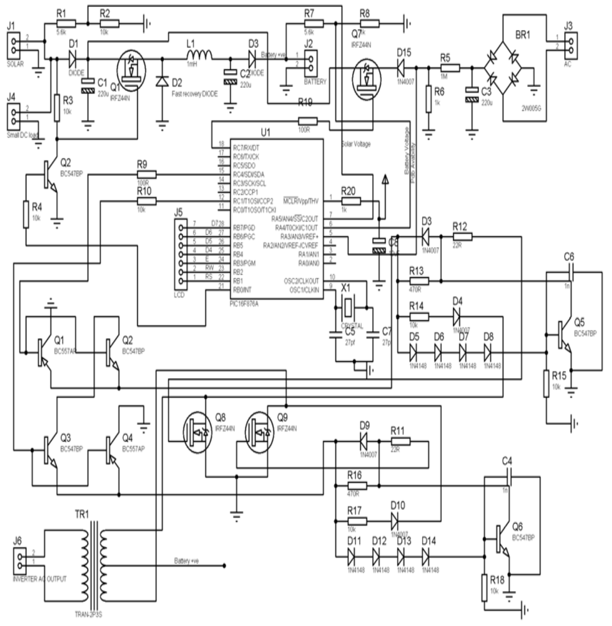
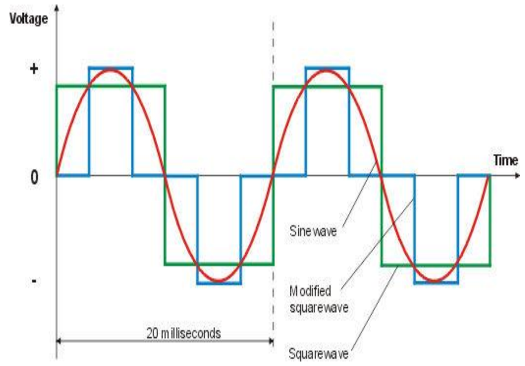


Circuit diagram

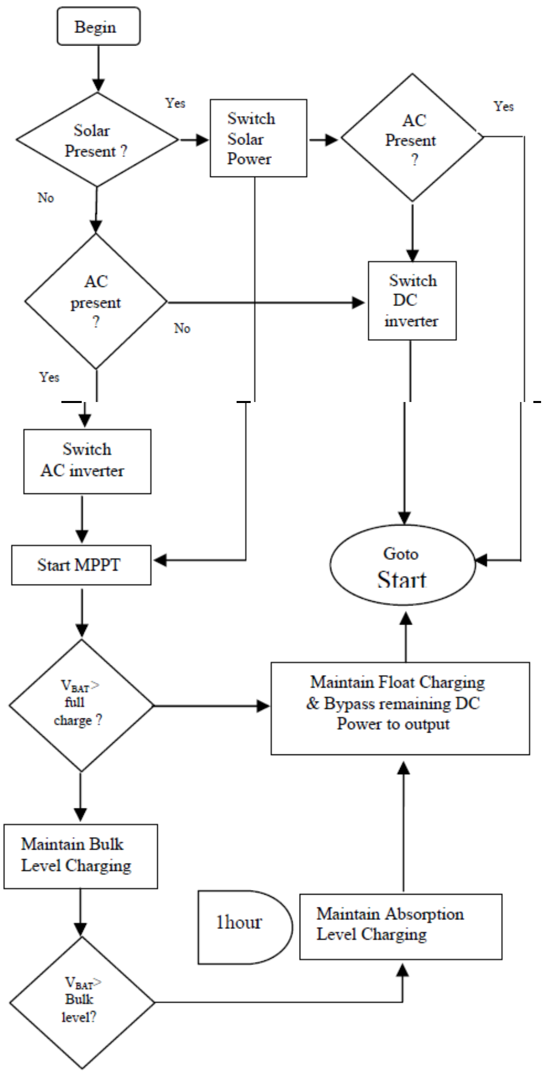
Oscillator gives signal generated due to oscillations as input to MCU. PWM signals are generated from the two pins of micro controller which are driven to MOSFETS. So switching of MOSFETs at 50Hz i.e. at 20 ms is needed. So the first half cycle would be 10 ms and then another half cycle would be 10ms. This system always keeps checking output voltage. When output voltage is noticed greater than 220V, by controlling switching of MOSFET and at the same time, minimizing the percentage of duty cycle output current can be controlled. Again when output voltage less than 220V, it can be controlled by rising the percentage of duty cycle. In this way, the output is always restricted to be fixed at 220V. This is called modified sine wave. And that's how the inverter efficiency is proved greater than the normal square wave inverter. Its efficiency goes to almost 83-85%.



It has overload-protection system and when the load is crossed over its limited value, this system cuts its load and show overload in its LCD (Liquid Crystal Display). For this purposes, a 4 line LCD is engaged here to display highest 80 characters at a time. Here, an arrangement for showing the Bat voltage, Percentage of Voltage available, percentage of load, solar voltage, available solar energy etc is implemented using MCU to make this system user friendly.

V. SOFTWARE FLOW CHART

The whole work is being monitored by MCU that controls the switching action and exact voltage level charging. Based on available charges in storage battery, MCU unit switches three-layer charging i.e. Bulk level charging when battery voltage is less than 80%, Absorption level charging when charge is between 80-99% and Float level charging when battery is in full charged state. It is suggested to employ absorption level charging for 1 hour to achieve best performance of it. This system indicates that MPPT charging section employs for both Photovoltaic energy and AC supply. Grid's AC is always recommended to use after filtration not directly. Inverter section is being decided intelligently to switch according to the availability of Grid supply. In presence of AC main, MCU will switch on AC inverter portion and in absence, it will turn on DC inverter being run by solar PV energy.



VI. FEATURES

This ensures maximum continuous power at full load and simultaneously pollution free and noiseless maintenance. It has feature of easy installation, maintenance free use, no requirement of fuel or lubricant, stainless steel hardware, built-in over-load, over-charge, low voltage protection, temperature compensated charging and low battery disconnect facility. It has the ability to charge the battery in low voltage so it will get sufficient backup in case of power failure.

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VII. IMPROVEMENTS

Low solar radiation, photovoltaic ageing, dust collection, slightest shading of any tiny portion of any module causes reduction in peak power. To avoid such degradation in performance, this system follows the parallel module combination with DC/AC MPPT module with anti-islanding function to continually sense grid status and power quality of solar generation and to disconnect the system from the grid in case of any islanding problem.

VIII. APPLICATIONS

Household or office appliances like Light, Fan, TV, Video Player, Audio-Player, Fax and PABX. Only it is required to mount solar panels and enclosure and connect them to the electrical accessories.

Besides rural habitation, the proposed system might be used to meet power requirement of Business centers, Medical facility departments & testing labs, in security systems, railroad signaling, wireless data transmission, irrigation control, navigational aids, flow monitoring, lighting, UHF/ VHF radio and tower beacons etc..

IX. CONCLUSION

Usages of this system ensures, no matter what location or application, safe and reliable generation of electricity to power our equipments anywhere the sun shines, even under the most hazardous conditions. Also, it can provide AC supply with high quality backup in emergency needs during power cuts. These isolated inverters are more likely to get attentions for gigantic applications that demands huge power.

FUTURE SCOPE

We are getting efficiency around 83%-84%. To improve efficiency, necessary changes must be done in the components. To provide the circuit from over current and under current, we can use Current Transformer coil to measure the current passing through circuit. If it is more or less when compared to required current, then relay acts as open switch and buzzer rings. By adding these components, we can improve the efficiency.

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