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DESIGN OF SOLAR INVERTER USING MPPT TECHNIQUE

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ABSTRACT

This paper demonstrates the implementation of a prototype of IPS (instant power supply) system to ensure continuous output current to load in residential application utilizing both Photovoltaic (PV) energy and AC Grid. Utility interfacing PWM inverter designed here to operate 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 here to charge storage battery rather than AC source that may save hundreds of megawatts 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 congregate maximum PV energy from AC Solar Modules. Investigation on improvement of power-interfacing control and optimization of overall system operation assent to intend usage recommendation in this exposition. Computer simulations and experiment results show the validity of this proposed system to have high power conversion efficiency and low harmonic distortions.

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KEYWORDS: Charge controller; Grid; inverter; PWM; Solar energy.

INTRODUCTION

Gigantic population and comprehensive electrical energy consumption have made power crisis one of the gravest national problems in the developing countries like Bangladesh. 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. Alternative power sources that can deliver output currents in absence of grid supply are now automatic choices in home grid-connected system. In urban areas, IPS (Instant Power Supply) system is being used massively to cope up with load shedding. But in the large context, it is worsening the situation roughly since it consumes huge power from grid to charge its storage battery. Unfortunately most IPS system has poor charge controlling mechanism which makes it a massive power consumer. Now-a-days, the practical cost of solar panel and the consumers' awareness to preserve AC power have stimulated the demands of high effective Grid connected power sources.Starting from the utilization of solar energy and digital power conversion application, this paper demonstrates such a solution of implementing PV energy in existing isolated IPS system. 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(s) when sunlight is available regardless of the AC line status. While, in dark night or cloudy weather AC grid source will charge the batteries. These are schematically represented in Table 1. Since PV array of medium capability has been used in this prototype, usage of PV energy here are only restricted to charge the battery and being miniature amount, harvested AC will not be reflected to Grid which is left open for future.

SYSTEM DEVELOPMENT

1. Input Power and Switching Section

Input power section allows 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 ATmega32 MCU unit that resembles the change-over section of commercial IPS section implementing by analog circuitry.

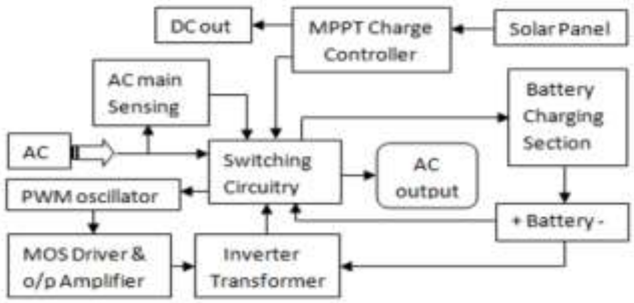

Fig.1 Block Diagram of Proposed IPS System

2. *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.

3. *Output Power section*

Implementing such configuration described in previous 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..

ATMEGA32 Microcontroller

In 1996 ATMEL developed 8bit RISC single chip microcontroller of modified Harvard architecture. It is the first microcontroller families which has on-chip flash memory. Also AVR 32 bit RISC microprocessor architecture designed by ATMEL. Its architecture designed by Norwegian University of science and technology including lead designer. It has feature of 32 KB of programmable flash memory,1KB EEPROM,2KB SRAM,8 channel 10 bit A/D converter and JTAG interface to provide on-chip debugging. Device operates at 4.5 to 5.5 volts with throughput of 16 MIPS at 16 MHz Also it can achieve the lower power consumption, high processing speed and throughput of 1 MIPS per MHz by executing instruction in single clock pulse.

Table I. Key Parameters

Parameter	**Value**
Flash (Bytes)	32 Bytes
Pin Count:	40

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Max. Operating Freq. (MHz):	16 MHz
CPU:	8-bit AVR
Hardware Q Touch Acquisition:	No
Max I/O Pins:	32
Ext Interrupts	3

2. LCD

The Liquid crystal display (LCD) is being used for proposed system. 16×2 character LCD module is a very basic module. Each character is displayed using 5×7 or 5×10 pixel matrix. 16×2 LCD can be interfaced with a microcontroller in 8 Bit or 4 Bit mode.

3. Implementation of MPPT Section

Unlike the applications of space programs, significant solar radiation power is filtered and blocked by the atmosphere and cloud before it is received at the earth surface, which dramatically affects the available insulation for photovoltaic generators. 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 (MPP) 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 study [2] shows that 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 [2, 3]. Furthermore, a good-quality measurement of voltage signal is cheaper and easier than that of current measurement. 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.

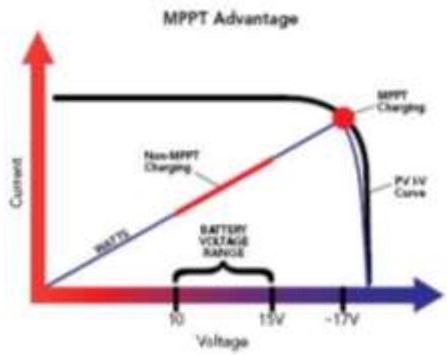

Fig. 2.

4. *MPPT circuit description*

This circuit utilizes a power BJT (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. Here switching frequency is 25 KHz. Inductor should be 160uH that was measured using following calculations:

L = { Va×(Vs-Va)} / f ×Vs× (peak to peak ripple current) (1)

Here, Vs=Input voltage, Va= required input voltage, f=frequency. And capacitor is 200 µF. The Equation is

C = peak to peak ripple current / 8×f× peak to peak ripple voltage (2)

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. If k is the duty factor, then:
$V_a=kV_s$ or, $k=V_a/V_s$ (3)

4. Working

Circuit Proposed system is such an online system that the inverter should always run if a load is connected. A lot of configuration is deployed here for switching MOSFET (metal–oxide–semiconductor field-effect transistorIRFZ44N) [4,5,6]. 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 (Fig.3). Since maximum focus should be given to avoid the damage of MOSFET

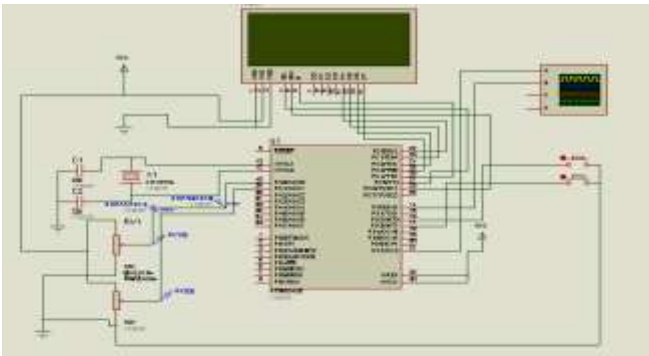

Fig. 3. Circuit Diagram of System

in 50Hz system. Also, an iron-core type center-tapped transformer is implemented here. 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 [7]. Its efficiency goes to almost 83-85%. It has also 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. (Details circuit description is omitted.).

FLOWCHART

The entire procedure done by the proposed system may be described in a software flowchart shown in Fig.4 that schematically reflects the facilities provided by it. 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. So, MPPT charging is also needed in such case of usage of AC from National Grid in Bangladesh. 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.

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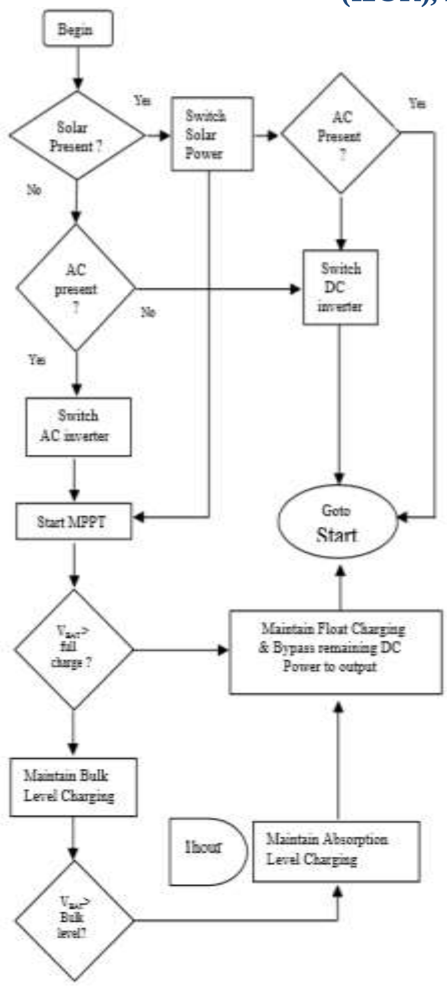

Fig. 4. Flowchart

RESULT

System used for	Used time	Using normal system consumption	Proposed system (Consumed Energy) Direct From solar
Charger Fan (15 Watt)	10 Hr	150 Watt	0 Watt
Electric filter (25Watt)	10Hr	250 Watt	0 Watt
Mobile charger (4.5 Watt)	10Hr	45 Watt	0 Watt
Energy saving bulb (10 Watt)	10 hr	100 Watt	0 Watt

Table:II Proposition of a power-saving

Due to gradual decrease in the installation price and as a safe and easy-to-install unit, this complete standalone solar IPS system will provide more comfort to 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.

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CONCLUSION

Proposed hybrid IPS system could be the ideal solution during main grid failure. It has many distinct features over the conventional generators. This precession IPS is designed according to our power line characteristics. Usages of this system ensures, no matter what location or application, safe and reliable generation of electricity to power our equipment's 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. High capacity solar panels and large sized batteries are only needed to provide that support without any moderation of our proposed system.

FUTURE SCOPE

This complete system schematic includes the 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. Moreover, it ensures maximum continuous power at full load and simultaneously pollution free and noiseless maintenance.

Furthermore 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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