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# A SOLAR CELL-BASED INVERTER WITH IMPROVED BATTERY LIFE FOR INDUCTION MOTOR

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**Abstract**

*This paper deals with the design and prototype development of an inverter to feed AC power to an induction motor coupled with a submersible pump. In this type of load, input power is proportional to the cube of the speed. The inverter is fed from a 48 V rechargeable battery, which is charged through the solar panel. Four numbers of the solar panel each of 165 W, 12 V rated are used for charging the battery. The basic intention of this research work is to start an induction motor with lower voltage and lower frequency, keeping v/f constant, such that the starting current is low. This concept can be utilized to run a submersible pump in a remote area where there is no electric power supply or where there is a problem in the distribution system. Submersible pumps are normally operated for a small interval (60 to 180 min). This energy can be supplied by a 48 V, 75 Amp-Hour Lead Acid type rechargeable battery. The experiment has been conducted with a Lead acid battery but the Lithium Ion battery gives better performance.*

*The solar panel (cell) is used to charge the battery for around 8 hours from morning and with the fully charged battery, the pump is run through an inverter for a time of around 150 min.*

*An inverter has been designed to run a 1 hp induction motor coupled with a submersible pump. The motor is started with low voltage with v/f control. Gradually the full voltage is applied and the motor runs at the rated speed. After an operation of a preset time, the motor is stopped.*

*With VVVF drive the battery life has increased compared to a Direct online starter.*

**Keywords:** Lead acid battery, Li-Ion battery, V/f control of IM, Starting torque, Energy stored in battery.

## I. Introduction

A prototype solar panel-based inverter has been developed to feed AC power to a pump or any medical equipment and other inductive loads. The design is most suitable for a remote area where there is non-availability of electrical power or there is a blackout of electrical power. Electrical power is required for the basic need of human life. The AC power generated can be utilized for running a pump, medical equipment, refrigerator, mobile charging, emergency irrigation, and lighting. This paper demonstrates the application of a submersible pump used for drinking water.

The inverter is fed from a 48 V (12 V battery, 4 nos in series) rechargeable lead acid battery, which is charged through the solar panel. The basic intention of this research work is to run emergency equipment in a remote area where there is no electric power supply or where there is a problem in the distribution system. The motor or any inductive load will be run through a VVVF inverter. Starting the motor at low voltage and low frequency requires less starting current. The inrush current drawn by the motor will be low and battery life will improve.

In a remote area where there is non-availability of electric power, it is often required to run a pump for drinking water or any emergency medical equipment. A diesel generator set is not an ideal solution as this is not environmentally friendly and requires running expenditure. A system has been designed and developed using a solar panel, a battery as a storage element, and an inverter with V/f control. A lead acid battery has been chosen to store the electrical energy which shall be used to drive the pump. The battery shall be charged throughout the day using a solar panel. The operating period of the pump/high-power equipment shall depend on the charge stored on the Lead Acid type rechargeable battery. For efficient operation, the solar cell shall be kept on the rooftop, and a battery with an inverter can be kept near the equipment. In this particular experiment, the rechargeable battery chosen is 48 V, 75 AH. With this battery, a 1 hp pump can be operated for 150 min efficiently. The loads are suitable for 180-240 V power supply, 50 Hz, single phase. The inverter is also suitable for 60 Hz generation for special medical equipment. We have chosen a lead acid battery as this type of battery can supply high surge current which is required for starting the induction motor. Another advantage of a lead acid battery is that it is easily available in remote places (A car battery or a motorcycle battery can also be used in an emergency situation to run the pump).

## II. Design Consideration

The schematic diagram of the system is shown in Fig.1. The integrated system consists of a solar panel, Lead Acid rechargeable battery, a Microcontroller board, a Voltage regulator to supply 5 V from 12 V to the microcontroller board, a Power amplifier, Centre tapped transformer and squirrel cage induction motor. The subsystems are as described below;

**Solar panel:** The solar panel used for this experiment is having an approximate dimension of 670 mm X 1490 mm. Four such panels are used. The power developed by each solar panel in normal sunlight is 165 W. The open circuit voltage for this solar panel is 52 V and the short circuit current of 5 Amps. When the solar panel is under operation for charging the battery, switch S1 shall be closed and switch S2 shall be open.

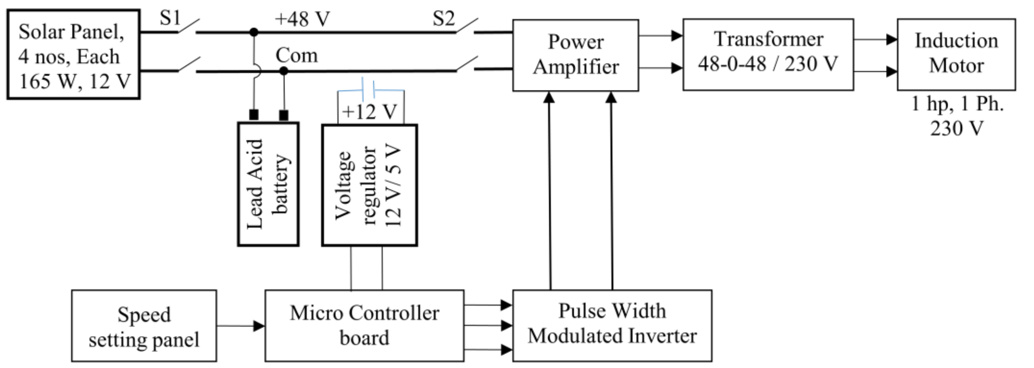


Fig. 1- Schematic diagram of the inverter for driving pumps

**Lead Acid Battery:** The battery used in this experiment is 12 V, 75 AH. Four such batteries are connected in series. The Amp-Hour capacity of the battery is selected in such a way as to run a 1 hp motor for around 150 min. A 1 hp capacity, capacitor start capacitor run squirrelly cage induction motor operated at 230 V, with a power factor of 0.7 shall draw 4.63 A of current. With motor loading and considering other losses, we consider steady-state motor current to be 6 amps. Thus, at the 48 V level, the current drawn from the battery shall be (6 *230/48) = 28.75 Amps. Therefore, the battery can supply this current for (75/28.75)*60 min = 156 min. On the safer side, we can thus operate the pump for 150 min. The battery used is shown in Fig-2.

Fig. 2- Rechargeable battery for the experimental set up

**Control panel**: A control panel has been designed through which we can start the pump with low speed and gradually we can increase to full speed. Starting with a lower speed is an advantage as the initial inrush current drawn by the motor shall be less. Normally, starting current of an induction motor is 5 to 7 times the full load current. A high starting current of the motor shall give rise to a voltage dip in the battery. To reduce the high starting current of the induction motor, we have adopted to start the motor at a lower voltage and then gradually we can increase the voltage to the rated voltage. Initially, during starting, the magnetizing component of the current flowing through the stator is proportional to the applied voltage and is independent of the load. These facilities are programmed in the microcontroller and depending on the situation; we can adopt a starting method.

We have selected a 48 V DC supply to reduce the cable size from the battery, w.r.t 12 V supply.

## III. Inverter for AC Power Generation

The PWM inverter consists of four sub-modules as under;

***A. PIC Microcontroller*:** The pulse width modulated inverter is designed around a PIC microcontroller 18F4520. PIC refers to Peripheral Interface Controller. The device has 32 KB Program memory. The microcontroller is having an inbuilt PWM module which is used directly in this application.

***B. Voltage regulator***: This microcontroller operates on 5 V DC. This 5 V DC power is obtained from a 12 V DC supply through a voltage regulator. This 12 V supply is from a battery. The regulator is built up around the IC LM 7805. This is a 3-pin IC, where the input is 7-35 volts and the output is 4.8 to 5.2 volts. It can supply an output current of 1.5 A which is most suitable for microcontroller operation. The complete circuit diagram is shown in Fig 3.

***C. Transistor driver***: Two complementary low-voltage transistors (BD 139 and BD 140) has been used as push-pull configuration to process the microcontroller output. Transistor output feds the base of MOSFET.

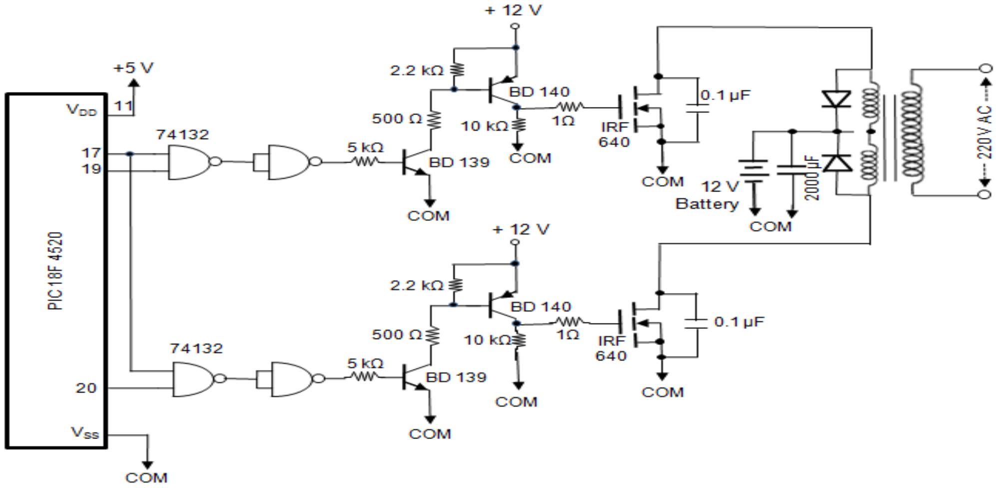


Fig. 3- Detailed circuit of the experimental setup

***D. Power Amplifier*:** The power amplifier is designed around power MOSFET, IRF640. This transistor can supply a continuous drain current of 18 A at 25ºC. At 110ºC, its drain current shall be 11 A. For design consideration, we consider a drain current of 15 A at 40ºC. Since at 48 V level, we require 28.75 A of current, we have to connect 2 such MOSFET parallel to supply 28.75 A of current. All the MOSFETs are mounted on the heat sink.

***E. Transformer:*** A center-tapped transformer with a primary of 48-0-48 V and a secondary of 230 V has been used for increasing the voltage from 48 V AC to 230 V AC. The transformer VA rating should be 1380 VA. The designed value should be taken as 1500 VA. The primary winding shall carry a current of 28.75 A and accordingly the copper wire size and transformer size is calculated

## IV. Experimental Result

The experiment has been conducted to generate AC power with variable voltage and variable frequency. During running with an inductive load and resistive load, the waveform of the AC output has been observed and stored in an oscilloscope as shown in Fig 3. The basic Pulse Width Modulated output from the microcontroller and final AC output across the motor terminal is shown in the waveform. The typical AC voltage output is shown in Fig-4.

| Sl. No. | Applied voltage to the motor (RMS) | Frequency (Hz) | Starting current (A) | Steady-state current (A) |
|---|---|---|---|---|
| 1. | 106 | 23 | 3.0 | 1.5 |
| 2. | 172 | 37 | 5.0 | 2.3 |
| 3. | 230 | 50 | 7.0 | 3.0 |

With a full charge of the battery, the operation time of the pump has increased by 10% with VVVF control.

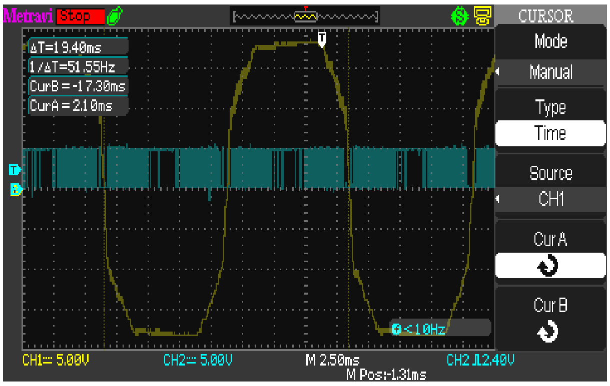


**Fig. 4.** Typical output voltage waveform

## V. Conclusion

With the above experiment, we can conclude that it is possible to run a submersible pump and emergency medical equipment using a solar-based inverter in places where there is no electric power distribution or there is a blackout of electrical power. This equipment shall be fed from a lead acid battery with an inverter. The lead acid battery shall be charged using a solar panel. With the calculation given in this paper, it is possible to run a 1 hp load for 150 min using a 75 Amp-hour battery. With VVVF control and operation time of the pump, the operation has increased by 10% compared to conventional direct online starting. The importance of this work is to generate 230 V AC power with variable voltage variable frequency to reduce the starting inrush current.

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