SOLAR PUMPING

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Abstract

India is a predominantly an agricultural country with a capability of producing three crops a year if proper irrigation facilities are provided. Because of inadequate rainfall and also due to power generation limitations, irrigating crops is becoming a major problem. In this present work a solar based irrigation pumping system is designed and developed. The output from solar panel is fed to an MPPT circuit, followed by a DC-DC converter and then to a 3-phase variable frequency inverter, powering the motor. The designed details are provided.

Key words: *Photo voltaic cells, maximum power point tracking, DC-DC converter, 3-phase inverter, Microcontroller*

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1. INTRODUCTION

Every day we damage our climate by using fossil fuels (oil, coal and gas) for energy and transport. Climate change already has an impact on our lives and eco systems and it will get worse. We need to reduce our greenhouse gas emissions significantly. We have already experienced a global mean temperature rise of 0.6º C during the last century. Apart from this, the pressure on grid due to restricted production of power using fossil fuels and non-availability of hydraulic power is pushing the agricultural usage of power to a corner, thus affecting the production of food grains. To overcome this solar power can be used efficiently and thereby reducing the demand on the grid.

The benefits of solar power are compelling: environmental protection, economic growth, job creation, diversity of fuel supply and rapid deployment, as well as the global potential for technology transfer and innovation. The underlying advantage of solar energy is that the fuel is free, abundant and inexhaustible. The total amount of energy irradiated from the sun to the earth's surface is enough to provide for annual global energy consumption 10,000 times over.

Producing electricity from the energy in the sun's rays is a straightforward process: direct solar radiation can be concentrated and collected by a range of Concentrating Solar Power (CSP) technologies to provide medium- to high temperature heat. This heat is then used to operate a conventional power cycle, for example through a steam turbine or a Stirling engine.

The second method of using the solar energy is by means of photo voltaic cells. The photovoltaic effect is described in Encyclopedia Britannica as "a process in which two dissimilar materials in close contact act as an electric cell when struck by light or other radiant energy". In other words, a photovoltaic cell is a diode optimized to absorb photons from (usually) the sun and convert them into electrical energy.

In the present project, a photovoltaic cell converter based inverter is developed, which can cater to the needs of small organizations, or domestic applications. The photo voltaic cell output is used to drive a 3-phase induction motor, where each photo voltaic cell output is extracted through a maximum power point tracking system. The output from three panels is connected in series and applied to a DC-DC converter, where the output is raised to 440V DC, when the radiant light is at its peak. This DC voltage is used to drive a high efficiency variable frequency inverter, to provide an output to drive the 3-phase induction motor. The frequency and voltage output of the inverter is dependent on the voltage generated from the photo voltaic panels. The output from the photo voltaic cell is monitored by the program and the output from the inverter is varied accordingly, so that constant output torque is maintained. In the present project due to paucity of funds a ¼ th HP, 3-phase induction motor is used. In order to increase the power output, it is required to increase the photo voltaic panel size.

2. HARDWARE METHODOLOGY

The basic building block of solar electric technology is the solar "cell." solar electric cells are wired together to produce a solar electric "module," the smallest solar electric component sold commercially, and these modules range in power output from about 10 watts to 300 watts. A solar electric system running an agricultural pump consists of one or more solar electric modules connected to an inverter. The inverter changes the system's direct-current (DC) electricity to alternating current (AC), which is compatible with the 3-phase induction motor. The basic block diagram of the system is as shown in the Fig.1

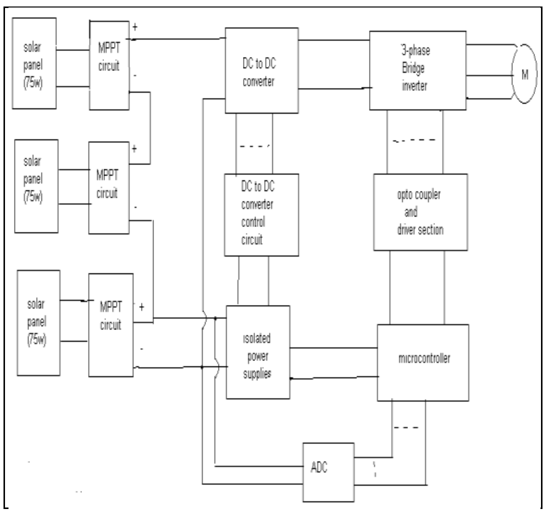

Fig.1 Block Diagram of Photo Voltaic agricultural pump

In the block diagram there are three solar panels, each can provide a maximum of 75Watts, when irradiated properly. It is not possible to achieve maximum efficiency all the time, as the sun orientation with the module changes, apart from this the solar panels may have shadows on them even after taking proper precautions. It is not possible to acquire maximum power for the given conditions, without using Maximum power point tracking (MPPT) circuit. For this reason, the output from each panel is provided to a MPPT circuit, which will see that maximum power is drawn from the module for the given conditions. The MPPT circuit is designed using a Microcontroller and is discussed later in the section. The outputs from the MPPT circuits are connected in series, so that the summation of the three outputs is provided to the DC- DC converter circuit.

Apart from this the output from one solar panel is used for providing the required power supplies for all the control modules. The output from the solar panel has to develop the required isolated power supplies to various modules of the total system. The isolated power supplies are required to drive the inverter elements, and the step up chopper switching element, and also to provide the power to the microcontroller. This is a self oscillating very small inverter with many numbers of secondaries to meet the requirements of the circuit.

The DC supply from the solar panel is elevated to high voltage dc (approximately 450V) supply by means of a step up DC-DC converter, and after this the high voltage DC supply is converted into 440 V three-phase AC supply. This way the circuit efficiency can be improved, and also the size of the whole equipment can be reduced. The DC voltage from the solar panel is applied to the step up DC-DC converter, and the output voltage of the step up DC-DC converter is elevated to 450Vdc.

The output voltage from the step up DC-DC converter is fed to the three phase bridge inverter. The inverter elements are driven by the pulses derived from the microcontroller. These pulses from the microcontroller determine the output frequency and voltage. These pulses cannot be used directly, and they need to be isolated from one another by using opto isolators. These isolators receive the pulses and are isolated due to the isolated power supplies and these pulses are applied to the inverter power switches, meeting the requirements of the driver circuit. The inverter circuit provides variable frequency sinusoidal modulated output to drive the three phase induction motor.

The microcontroller circuit provides the required PWM pulses for the three-phase bridge inverter switching elements. These pulses can be derived from the micro controller with the embedded soft ware and the output pulses can be used to drive the inverter switching elements. Different switching elements can be used in the inverter, but power MOSFETS are preferred as the output voltage is limited to three phase 440V AC. The DC-DC converter power switches are driven by a control circuit and are powered from the isolated power supply block.

It is not possible to achieve a 60V output from the three solar panels, as the solar irradiation and shadows change throughout. With the DC-DC converter the voltage even if it is elevated also cannot reach a maximum of 450V as is desired to have a 440v three phase output. The inverter input voltage itself proportionately reduces. In order to overcome this situation and in order to keep the load torque as constant, a proportionate speed reduction is proposed.

Fig.2 shows the isolated power generation circuit. The transistorized circuit is basically an Astable Multivibrator. The frequency generated by the circuit is of the order of 10 KHz. At these high frequencies, it is very convenient to use ferrite cored transformers, whose efficiency is very high and also occupies minimum space, when compared to ordinary CRGO laminated transformer, which works at low frequencies of the order of 50Hz.

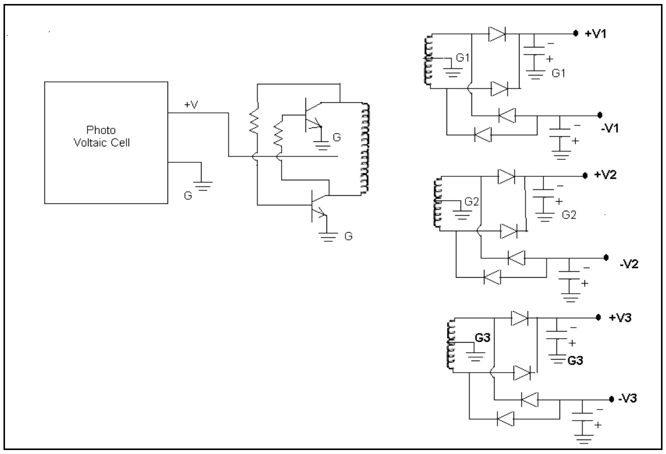

Fig.2 Generation of isolated power supplies

The circuit diagram of the DC-DC converter is shown in the fig.3. The circuit basically consists of a ferrite core based high frequency transformer, with a center tapped primary and a secondary winding, with a turns ratio that can boost the primary voltage by eight times. The primary winding center terminal is connected to 60V DC supply from the solar panels. The two end terminals of the primary winding are connected to two IGBT collector points. The two IGBT emitters are connected to the negative terminal of the solar panels. The two IGBTs are driven by a driving circuit designed around IC555 timer IC and a CMOS JK flip-flop IC. The IC 555 timer IC works as an astable multivibrator, whose frequency is decided by the external resistors and capacitor connected to the IC. In the present design the frequency can be adjusted from 10 KHz to 40 KHZ, with the preset provided in the circuit. The preset can be adjusted so that maximum efficiency can be achieved from the circuit. The astable multivibrator output is rectangular pulses and the duty cycle is not exactly 50%. As the duty cycle is not 50% these pulses cannot be used to drive the IGBTS. Thus the output from IC 555 is applied to a CMOS JK flip-flop. The JK inputs are connected to logic "HIGH" and the output from 555 is connected as clock input to the flip-flop. This makes the JK flip-flop to work as divide by two counters. Thus, the frequency from the 555 is divided by two, and the outputs from JK flip-flop both Q and Q^1 are of 50% duty cycle. When Q is HIGH Q^1 is LOW and vice-versa. The Q and Q^1 outputs are meant for driving the two IGBTs. With this when one IGBT is made ON the other one is kept OFF. Similarly, when the first one is kept OFF the second one is made ON. Thus, alternatively both of them are made ON and OFF. This applies high frequency square pulses to be applied at the primary of the ferrite cored transformer. To avoid spurious triggering, a resistor is connected between the IGBT gate and emitter.

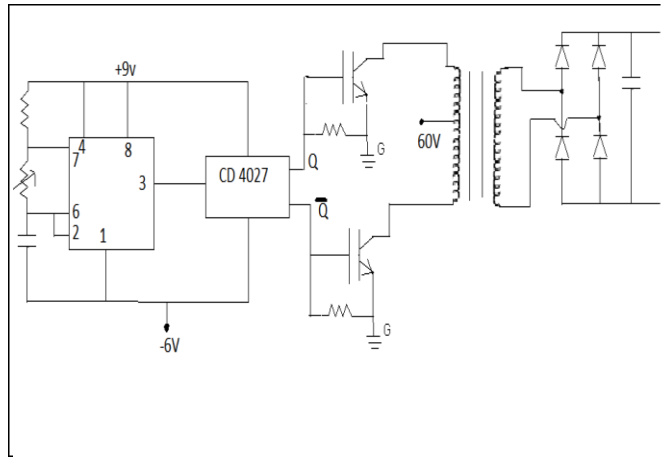

Fig.3 DC-DC Converter circuit

d In order to control the three phase bridge inverter, a micro controller is required. The micro controller is interfaced to ADC in order to read the solar panel output voltage. Based on the solar panel output voltage, the micro controller has to adjust the output frequency, so that the V/F ratio of the inverter output is maintained constant. To perform all these operations, a micro controller is required. In the present project the micro-controller is used for one purpose. That is, the micro-controller provides pulses to the three phase bridge inverter. These pulses are provided by the micro-controller continuously, from the point when the power is applied, to the point when the power is removed. These pulses are applied to the IGBT through an Opto-coupler. These pulses are applied to the photo diode of the Opto-coupler through a current limiting resistor driven by a bus transceiver IC 74LS245. The micro controller as it is not having enough driving capacity to drive the opto-coupler inputs. On the phototransistor side an isolated DC voltage is applied. For driving the top power devices an independent power supplies are required. To drive all the bottom devices one single power supply is sufficient. This is possible just because that all the devices are connected to same reference point.

The maximum power point tracking circuit is built around the micro controller R8C-1A. The microcontroller has built in ADC channels and is used to read the voltage and current values from the solar panel. The product of the two is calculated, and the program looks for maximum power output by varying the duty cycle of the power MOSFET. The circuit diagram of the MPPT is shown in the Fig.4

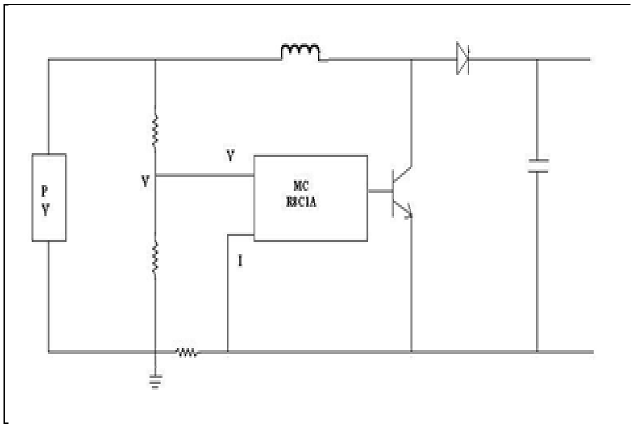

Fig.4 MPPT Circuit

3. SOFTWARE METHODOLOGY

The ATMEL 89C52 micro controller is used to control the 3-phase inverter. The micro controller reads the analog voltage from the solar panel, based on the solar panel voltage; the program increases the frequency or decreases the frequency. Based on the frequency selected the micro controller provides the control signals, (the trigger pulses) to the power MOSFETS, through appropriate isolation circuits. The necessary program is developed for this, and the flow chart is as indicated in Fig.5.

When the micro controller power supply is switched on or when manually 'Reset' button is pressed, the flow chart 'START' thing is initiated. In this 'START' block, the CPU actually brings the starting address 0000H into the program counter, where actually the program starts. The first instruction, whenever the CPU is entering into the main program, is to disable all the interrupts. This is done by using the instruction DI.

After the interrupts are disabled, the ports are initialized; the program transfers 00H on the port-0 and also on port-1. So that all the power MOSFETS are kept in OFF mode. The program also initiates the frequency to 10-Hz, and the corresponding time delay is loaded in to timer-0, and the timer-0 interrupt process is enabled. The program also loads timer-1 with appropriate value, which is used to provide the PWM frequency. Now the program initiates the look-up table address, and reads the same and provides on the power MOSFETS control ports. This makes the corresponding power MOSFETS to go ON based on the look-up table first value contents, and waits for the interrupt. On the arrival of timer-0 interrupt the program jumps to the interrupt service subroutine.

In the interrupt service subroutine the program increments the look-up table address and reads the same and provides the same on the power MOSFETS control ports, which effects the next step condition. After this, the program checks for the end of look-up table, in that case the program initiates the address for the next cycle, with starting address. Thus initiating the operation for next cycle.

Whenever the program loops back for the next cycle, the program increments the cycle counter and once 10 cycles are finished the program reads the solar panel voltage to upgrade the fresh value from the solar panel, so that the frequency can be altered as per the voltage. If any deviation, the program makes the necessary alterations in the value loaded into timer-0 which affects the time gap between the interrupts. While modifying the timer-0 value the program also alters the value of timer-1 from the look-up table, which alters the duty cycle of the PWM, thus varying the output voltage. The timer-1 look-up table is created in that manner. While altering the timer-0 value the program also checks for the maximum and minimum limits of the frequency selected. The program continuously works and varies the frequency based on the solar panel output voltage. The flow chart is shown in the Fig.5.

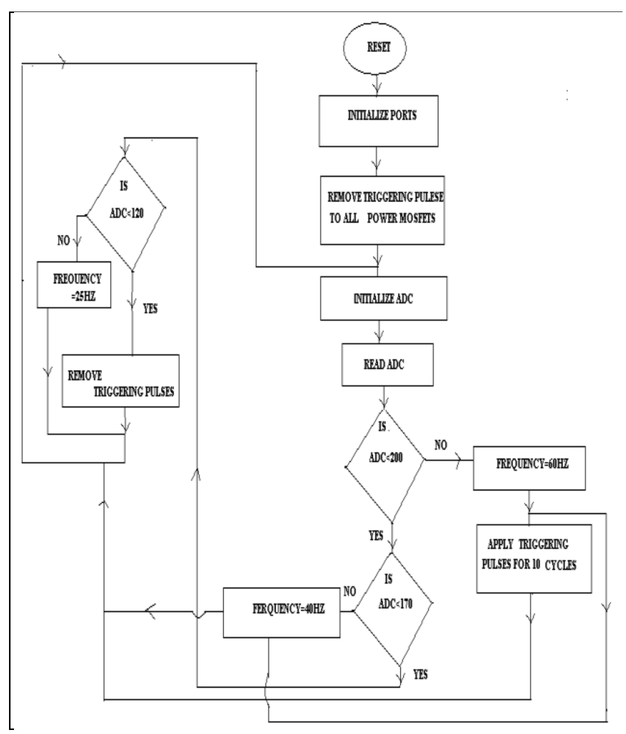

Fig.5 Three phase Inverter Flow Chart

For implementing MPPT algorithm a different micro controller is used. It is required to incorporate three independent micro controllers, one for each solar panel. The three circuits are similar. The micro controller used is R8C1A from Renesas. The micro controller has four channels ADC with 10 bit output capability, and the PWM facility, with which it is very easy to incorporate variable duty cycle operation. The operation of the program is provided in the flow chart, which is provided in the Fig.6. The micro controller on power up gets reset and initializes all the ports and initializes the ADC for reading two input channels. The variable previous product ($product_{prev}$) is made equal to zero. The program selects the minimum duty cycle. Now the program reads both the input channels and performs the multiplication of the two to achieve the power. This value is compared with $product_{prev}$, if it is less the duty cycle is adjusted in such a manner so that the power output increases. Similarly, if it more the opposite action takes place, and also $product_{prev}$ value is updated with new value and the process is repeated so that the process is continuous. Thus the duty cycle is continuously adjusted to procure maximum power output from the panel with the given irradiation.

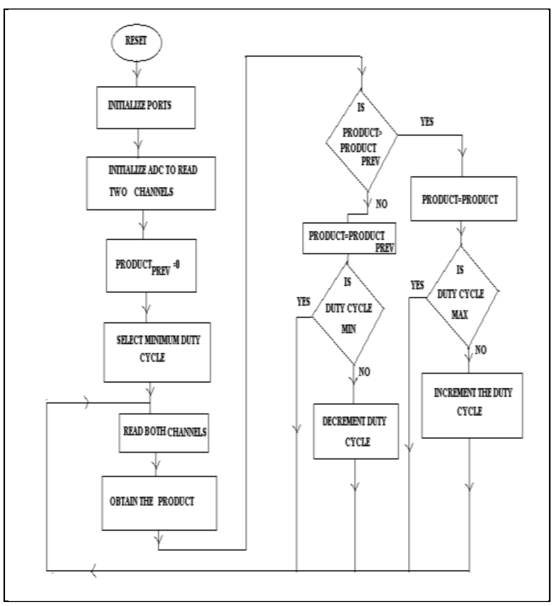

Fig.6 MPPT Flowchart

4. RESULTS

The developed solar panel inverter for driving a fractional power three-phase Induction Motor drive is working satisfactorily for the features it has been designed for. The inverter output frequency is adjusted in such a manner, so that the V/F ratio is maintained constant.

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