PV based Smart Energy Efficient Hybrid Model for Irrigation using Sensorless BLDC Motor

Md Sagar Khan, Sujitha S, Kulshrestha Utkarsh Alok, Karthika M, L Ashwini B, Vivek Ranjan

Department of Electrical & Electronics Engineering,

New Horizon College of Engineering, Bangalore. Karnataka, India-560103

Abstract.

At present, in the farming world there are many problems, one among them is irrigation. The existing solar pumps used for irrigation operates using Induction Motor which have certain flaws i.e., they are less efficient, they also have water wastage issue, this pumps also requires more current which results in increase of the electricity bill and also there is noise problem in the existing structure. So, to overcome these issues the proposed system is introduced with Sensorless Brushless Direct Current (SLBLDC) motor so that the efficiency can be increased. In the proposed system the concept of tank for the storage and usage of water whenever required is introduced to get rid of water wastage problem. The given system is not only solar based but also it is smart and automatic for irrigation on the agriculture field. This system is a hybrid model which can work on solar power or can also operate using direct single-phase Alternating Current (AC) supply.

Keywords. Arduino, Battery, MPPT, Pump, RTC Module, Sensorless BLDC motor, Solar Panel, Solenoid Valve, Tank, Water Level Indicator.

1. INTRODUCTION

India is an agricultural country, which is also known as the global agricultural powerhouse. In India around 17-18% to country's GDP comes from agriculture. As per the records approximately 50% of total personnel of India works in agricultural sector. Report says that due to poor management around 70% of irrigation water is wasted. As the country is progressing towards new and advanced technologies the traditional way i.e., at a fixed time the water will be provided for farmers and at that duration only farmer have to make use of that water with the help of plough cut design on the farming land is reducing and farmers are using their individual pumps for irrigating water in their farmlands. As country is taking several steps towards smart systems there is also advancement in the technology of irrigation system from past few years. Now a days the motor used in pumps for irrigation purpose is Induction motor or Synchronous motor [1]-[6]. But due to recent advancement of Brushless Direct Current (BLDC) motors they are replacing Induction motor or Synchronous motor in the water pumps. So, in simple words, the BLDC is taking over Induction motor or Synchronous motor in pumps [1]. As because the fact is known that BLDC motors are more efficient than the Induction or Synchronous motor [1]. SLBLDC motor is Sensorless BLDC motor, as compared to the sensored BLDC motor this motor is light weight, less complicated, less expensive, less noisy and less prone to failure also its high-speed performance is excellent [3] [4]. So, the initiated model is introduced with SLBLDC motor.

The proposed system is a novel smart energy efficient irrigation system using hybrid SLBLDC motor which is integrated with several types of technologies embedded in one unique block. This energy efficient model is introduced with the concept of off-peak, on-peak, valley filling, load shifting terminologies by using timers, relays etc [3]-[5]. The

performance of the motor is based on the water level indicator connected to tank and also the timings provided to turn on/off the motor [7]. The term Hybrid in the proposed model is suggested because of the use of hybrid source with the motor i.e., the motor can operate using solar power or also the motor can start with the help of direct single-phase AC supply [5]. This hybrid model is also used to achieve energy conservant and energy efficient model.

2. PROPOSED SYSTEM

This hybrid model is an energy efficient model which is proposed to save electrical energy and to do the water irrigation in the agricultural field as well as this model is also useful for household usage [5]-[8]. This model is an automatic control system for solar PV pump applications.

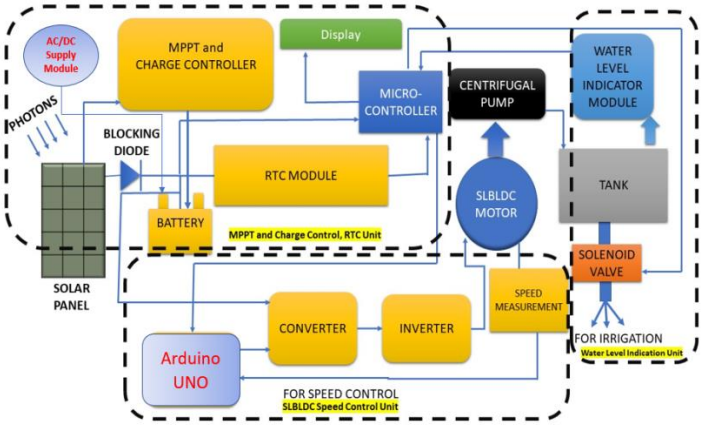


Figure 1. Proposed Block Diagram

This smart system does all the work automatically. A Real Time Clock (RTC) module is introduced in this system to control the indication of water level, which means the tank is empty i.e., without water the motor will start by itself as introduced by the water level indicator module and when the water is up to the mark in the tank than automatically the motor will stop filling the tank with water and the signal will be sent to the timer to on the valve, the valve used here is solenoid valve to prevent water wastage the valve will be started at a particular time and for a fixed interval to irrigate water in the agricultural field by itself. Fig. 1 depicts the block representation of the proposed model [8].

2.1. MPPT and Charge Control, RTC Unit:

The charging of the battery is done with the help of solar panel. After the battery is charged, the stored energy is used to power on or run the SLBLDC motor the SLBLDC motor is also given an option to run on the single-phase AC supply. Since there can be two supplies given as per the requirement so the motor is called hybrid SLBLDC motor [4]. At the specific time that is set in the RTC module unit the motor runs accordingly as required with Solar charge battery or with single-phase AC supply [8]-[10]. The RTC module provides real time and the model is started as per the time which is required to run the system [6]. The Maximum Power Point Tracking (MPPT) is an efficient tracking technique used to track point of maximum sunlight fall on the solar panel with the help of certain MPPT algorithm

set. The microcontroller used is Arduino Uno which is used for the controlling of MPPT and Charge Control and RTC Unit this is depicted in Figure 1.

2.2. SLBLDC Control Unit:

In this part of the SLBLDC control unit here the action performed is the speed control of SLBLDC motor. This system proposes a PI controller with the help of Arduino Uno to control the working in this section as seen in Figure 1. Basically, this section is for the speed control of the SLBLDC motor. In this the actual speed is tally with the reference speed and the error produces a pulse called gate pulse for the converter [1][4]. This speed control of SLBLDC motor is useful for the motor to run at the desired rate so that the proper use of the SLBLDC can be avail in this application.

2.3. Water Level Indication Unit:

This unit is used to indicate the condition of the water tank in this application model. It helps to indicate whether the tank is empty or full. When the water level indicator unit indicates the tank is full as per the convenient the signal is sent to the controller in this case it is Arduino Uno and also the signal from the RTC module is also taken and as per the desired timing set in the RTC module the Arduino Uno as per the signals starts irrigating water with the help of Solenoid valve [8]. And after the duration is over which is provided in the Arduino Uno the irrigation will stop i.e., the solenoid valve will stop. As per the condition of the tank provided by the water level indicator the tank starts to fill itself again automatically if the tank is empty or with less water [6]-[8]. The water level indicator will send signal to the Arduino Uno regarding the condition of the tank weather the tank is full or empty or partially full and according to that signal or indication the Arduino Uno will take the decision whether to start the motor and pump set-up to fill the tank or no actions are required if the is full or up to the mark.

The signal from the RTC module is send to the microcontroller on the other hand the water level indicator also senses the condition of the tank and accordingly sends the signal to the microcontroller [6]-[8]. After getting both the signals the microcontroller decides whether to on the SLBLDC motor or not. The process is done automatically as per the instructions set in the microcontroller. Table I. shows the condition of the motor at different stages.

TABLE I. State of SLBLDC motor/Pump at different signals

SI.No.	***Water level indicator signal***	***RTC module signal***	***Condition of SLBLDC motor/Pump***
1.	Tank empty	At set time	Motor on, pump on filling of tank starts
2.	Tank full	When set time over	Motor off, pump off, filling of tank stops

Due to the water wastage problem in the agricultural field with the help of the timer and the water level indicator the solenoid valve for the purpose of irrigation is switched on/off automatically as per the requirement set [6]-[8]. TABLE II. Shows the condition of the solenoid valve at different stages.

TABLE II. State of Solenoid valve at different signals

SI.No.	***Water level***	***RTC module signal***	***Condition of Solenoid Valve***

	indicator signal		
1.	Tank full	At set time	Solenoid valve opens for irrigation
2.	Tank empty	When set time over	Solenoid valve stops

The energy from the battery which is connected to solar panel provides supply to the converter and from the converter the supply goes to the inverter, inverter converts DC supply to AC and thus the motor starts [1] [2].

After that the supply starts the motor and the centrifugal pump connected to the motor will also start doing its work simultaneously for the duration of time set in the RTC module and the pump will start storing the water in the tank [5]-[8]. And after the duration set in the RTC module the pump stops filling water in the tank.

The proposed system is smart real time energy efficient and water preserving system with the joint venture of several types of technology embedded in one single unit. The best advantage of this smart system is the unique and advance approach of irrigation in the agricultural field.

3. SIMULATION OF PROPOSED SYSTEM

The simulation of the proposed system was carried out successfully on a simulation platform named as on ProteusProfessional 8. The entire system as per the block diagram is divided into three different simulation model.

A. MPPT and Charge Control, RTC Unit
B. SLBLDC Control Unit
C. Water Level Indication Unit

3.1. MPPT and Charge Control:

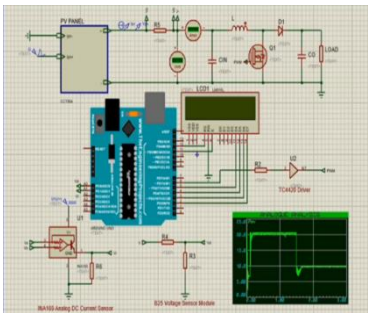


Figure 3.1. MPPT and Charge Control, RTC Unit

The MPPT and Charge Control, RTC Unit which is shown in Figure 3.1. is a part in which the specific algorithm is set as required to obtain the maximum efficiency from the solar panel it is use to set the solar panel at a point where the maximum solar light falls on the panel to store maximum energy in the battery to supply it to the required area [5]-[8]. To keep the track of the battery and to charge the battery charge control is used. The RTC unit is for the real time control of the SLBLDC motor and for the irrigation purpose in the agricultural field.

3.2. SLBLDC Control Unit:

This SLBLDC control unit shown in Fig. 4 is for the speed control of the Sensorless BLDC motor. Here for speed control of Sensorless BLDC motor PI controller unit is used with the help of microcontroller Arduino Uno in this case [2]. The microcontroller is given the pulse by comparing the actual speed and the reference speed and according to the error the Arduino Uno sets the speed of the Sensorless BLDC motor.

3.3. Water Level Indication Unit:

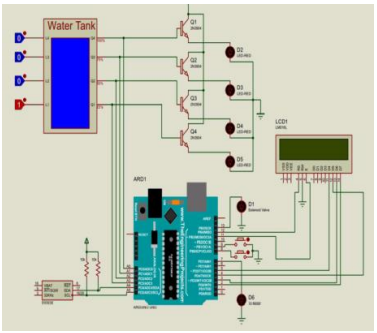


Figure3.3. Water Level Indication Unit

The water level indicator shown in Figure 3.3. is for the indication of the level of water available in the tank. The LED's connected in the water level indicator shows the level of water and the RTC module gives information of the time set in the module. Also, the solenoid valve is connected for the irrigation purpose as per the signal send by the water level indicator the microcontroller (Arduino Uno) switches on/off the solenoid valve as required for irrigation.

4. SIMULATED OUTPUT OF THE PROPOSED SYSTEM

The simulated output of the proposed system is given through the software named as Proteus Professional 8 which is as follows

4.1. Output of MPPT and Charge Control:

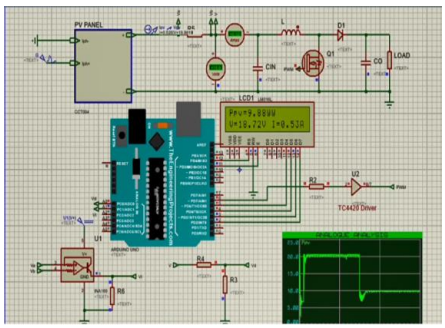


Figure4.1. Output of MPPT and Charge Control

Figure 4.1. shows the output of MPPT and charge control. The LED screen shows the Ppv(t) value and also the current and voltage measured by current sensor and voltage sensor respectively is shown by the LED successfully. The graph in the output shows the Ppv(t) curve.

4.2. Output of SLBLDC Control Unit:

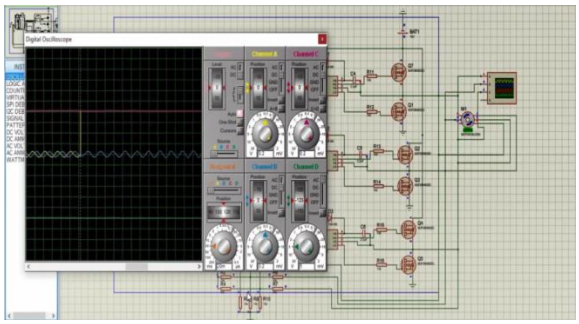


Figure 4.2. Output of SLBLDC Control Unit

The output of the SLBLDC control unit is shown by the Figure 4.2. Here the graph in the digital oscilloscope shows the working of the sensor less BLDC motor. The controller used for speed control is PI controller in which the microcontroller part is changed by Arduino Uno.

4.3. Output of Water Level Indication Unit:

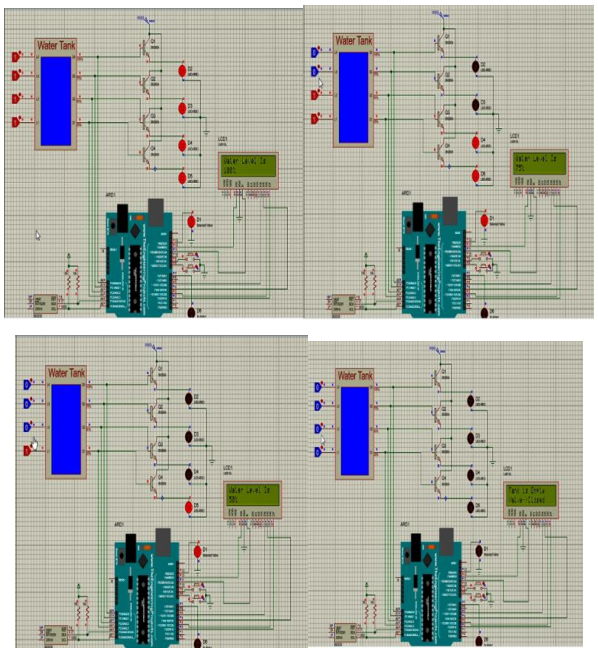


Figure 4.3. Output of Water level indicator at different phases of water in a tank

The output of water level indicator at different phases of water filled in the tank is shown by Figure 4.3. In this Figure 4.3. it is shown the working of water level indicator. When the tank is full the LED will show the message “Water Level Is 100%” and all the LEDs will glow at once. When the water level decreases i.e., when two LEDs glow the message shown is “Water Level Is 75%”. When only one LED glow “Water Level Is 50%” is shown by the LED panel. And when the tank is fully empty no LEDs will glow and the message will come is “Tank Is Empty Valve-> Closed” and the solenoid valve will stop irrigation in the field. The whole process will take place vice-versa when required.

The signal from RTC module and water level indicator module helps the Arduino Uno to decide when to irrigate the field or when to open the motor to fill the tank with water.

5. RESULTS AND DISCUSSIONS

When the time comes as set in the RTC module, it sends signal to the microcontroller (Arduino Uno) and the signal is then sent to sensorless BLDC motor. And accordingly, when the conditions are meet the motor starts.

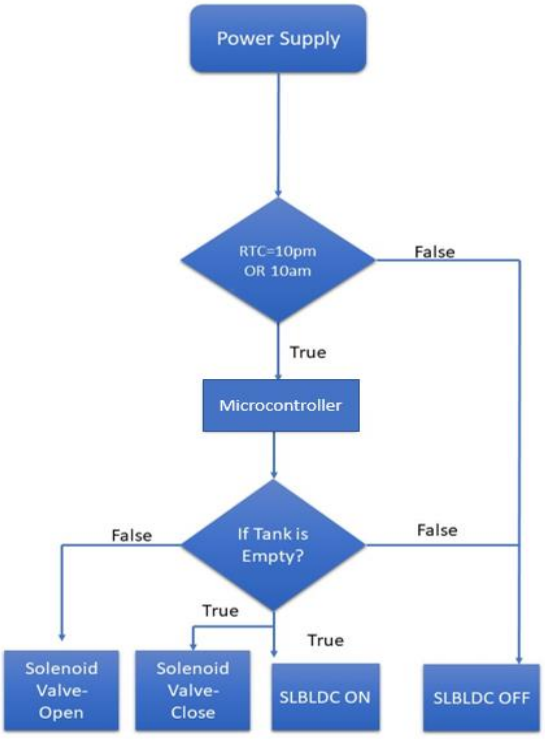


Figure 5.1. Flow Chart of Proposed Model

After getting the supply the motor starts and the centrifugal pump connected to the motor will also start doing its function simultaneously during that interval of time which is set in the RTC module and the water will get stored or irrigate through solenoid valve in the tank

or in the agricultural field respectively. And if the duration that is set in the module is over the tank stops filling or the irrigation stops in the agricultural field as shown in Fig. 6.

The proposed system is simulated, tested and the results are analyzed in Proteus Professional 8 software. A 24V, 100W solar panel is used for the supply of energy to the 24V, 250W sensorless BLDC motor. A RTC module is used to send the signal to the microcontroller (Arduino Uno) and the signal from the water level indicator is utilize to operate the sensorless BLDCmotor so that the tank can be filled according to the requirement and also the water can be irrigated through solenoid valve in the agricultural field.

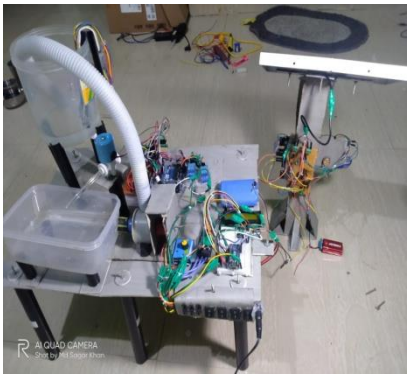
Table III. Status of Switches and LED in tank

Switches/Transistor state	***LED***	***Water level of the tank***
All transistors are OFF	All LEDs OFF	No water inside the tank
Two transistors are ON and Two transistors are OFF	Two LEDs are ON and Two LEDs are OFF	Water tank is partially filled with water
All transistors are ON	All LEDs ON	Water tank is completely filled with water

Table III. gives the information about the condition of the tank with the help of switches/transistors and LEDs

6. CONCLUSION

The model proposes a system which uses water as per the requirement in a smart and efficient manner. The motor in the proposed system will start at the night time or at the time which is required by the farmers so to fill the tank at that time mostly at night time. This will reduce the electricity bill since the load is operated during off-peak time and hence if more electricity consumed also the electricity bill will be less as compared to morning time as morning time is the on-peak time when the load is operated even for a short time also the electricity bill will come more. In this way this system is more convenient and efficient as compared to other conventional systems.



7. FUTURE SCOPES

This system can be made more intelligent by introducing the concept of IoT. More than two sources can also be introduced in future, more sensors, Bluetooth modules, Node MCU, etc. can be introduced, so that one can sit at home and control all the functions from his home sitting at one place. Speed control method for BLDC motor with the help of PIC microcontroller using python, Arduino using python, etc. can also be introduced. Complete integration with Python is only possible using Raspberry pi.Using Raspberry pi the entire system can be connected to cloud. So that the entire system can be operated through internet. Internet operation will make the entire system to be controlled from anywhere in the World.

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