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Design and Implementation of Arduino Based Control of Solar Powered DC Motor Pump Load

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Abstract : An investigation into the design of a stand-alone Photo Voltaic (PV) water pumping system for supplying rural areas is presented. The work is about increasing energy extraction by improving maximum power point tracking (MPPT) to provide continuous water supply to their needs. The PV source output power and the speed of the DC pump motor are used as input variables. Arduino controller is used for generating the signal and the relay to operate. MPPT technique is used for the maximum power generation with respect to atmospheric condition. By this technique, maximum power is obtained for the process and also for battery storage. Thus there is no need to depend on other sources. MPPT technique extracts maximum power with faster dynamic response and also eliminates oscillations around the MPP under steady-state conditions and it is a suitable optimization tool for locating MPP regardless of atmospheric variations This work enhances the usage of renewable energy to perform energy saving and to reduce the pollutions created by some other resources.

I. Introduction

Water is essential for life and for most activities of human society. Most of the human activities and needs rely upon ready access to adequate water supplies such as; ensuring food production, and protecting health, energy and the restoration of ecosystems. All societies require water for social and economic development and for sustainable development[1]. However, the UN World Water Development Report in 2003 provided an estimation of the number of people, who have no access to the water sources in forty-eight countries and it was found that, two billion people are affected by water shortage, and 1.1 billion do not have sufficient drinking water[2]. Also, in the UN World Water Development Report 2014, it has been estimated that 3.5 billion people do not have their right to water satisfied and 2.5 billion people lack access to improved water supply[3]. Water pumping has throughout history been a technical challenge. There has always been a need to supply drinking water and satisfy regular agricultural demands throughout the development of civilization in human societies[4]. There is a great and urgent need to supply sustainable energy for the provision of drinking water at very low financial and environmental cost, especially in relatively poor, arid, rural regions.

In the rural areas, pumping systems are needed to pump the water for domestic usage, to irrigate crops, to water cattle and animal stocks, etc. Hence a source of power is needed to operate the pumping system[5]. An AC powered system would be economic and takes minimum maintenance when the AC power is available from

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the nearby grid. However, in many rural areas, water sources are spread over many miles of land and the located too far away from the existing grid lines. Installation of a new transmission line and transformers at isolated locations is extremely expensive. Windmills have been installed traditionally in such areas but because of the lack of proper maintenance and age, many of them are not operating now. There are many internal combustion engines that are used for a stand-alone water pumping systems nowadays. These systems have the same advantages, such as: they are portable and easy to install but they require frequent site visits for refueling and maintenance, and in addition, the diesel is expensive and not readily available in rural areas of many developing countries and even the fuel is available within the country, transporting the fuel to remote, rural villages because there are no roads or supporting infrastructure in most of the remote villages[6]. The consumption of fossil fuels also has an environmental impact; it is considered the major cause of climate change due to their polluting effects. The problem associated with CO2 emissions can be solved through the application of renewable energy technologies, which are already cost competitive with fossil fuels in many situations[7]. Therefore, the use of renewable energy is a very attractive for water pumping systems in the rural areas of many developing countries.

Solar energy generation via PV cells is a very attractive renewable source. Its advantages include relatively light-weight, low-complexity structural requirements, although systems may extend over large areas; free and sustainable fuel source; noise free operation due to the absence of large rotating machinery or engine parts other than slow sun-tracking mechanisms; Photovoltaic energy, has gained a lot of attention in recent years because it is environmentally friendly and sustainable compared to traditional energy sources[8].

In this work, a stand-alone photovoltaic water pumping system is presented. It also investigates in detail the maximum power point tracker, a power electronic system that extracts the maximum available power from a PV source for use in the load. To increase the system efficiency, different maximum power point tracking techniques have been investigated and improved MPPT techniques are proposed. The utilization of PV water pumping systems helped both in improving the living conditions in remote areas and keeping the environment clean.

II. Methodology

A. Solar Cell

A solar cell, or photovoltaic cell (previously termed "solar battery"), is an electrical device that converts the energy of light directly into electricity by the photovoltaic effect, which is a physical and chemical phenomenon. It is a form of photoelectric cell, defined as a device whose electrical characteristics, such as current, voltage, or resistance, vary when exposed to light. Solar cells are the building blocks of photovoltaic modules, otherwise known as solar panels.

B. Servo Motor

A servo motor is an electrical device which can push or rotate an object with great precision. If you want to rotate and object at some specific angles or distance, then you use servo motor. It is just made up of simple motor which run through servo mechanism. If motor is used is DC powered then it is called DC servo motor, and if it is AC powered motor then it is called AC servo motor.

C. Arduino Mega 2560

The Arduino Mega 2560 is a microcontroller board based on the ATmega2560. It has 54 digital input/output pins (of which 14 can be used as PWM outputs), 16 analogy inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Mega is compatible with most shields designed for the Arduino Duemilanove or Diecimila.

D. Transformer

The purpose of a transformer is to change electrical voltage to a different value. A transformer is used to lower the voltage from 480 V to 120 V for the lighting circuit, A clear understanding of how transformers

work is necessary in order to wire them properly in an electrical system. Understanding input and output current and grounding are particularly troublesome.

E. Diode

A diode is a device which only allows unidirectional flow of current if operated within a rated specified voltage level. A diode only blocks current in the reverse direction while the reverse voltage is within a limited range otherwise reverse barrier breaks and the voltage at which this breakdown occurs is called reverse breakdown voltage. The diode acts as a valve in the electronic and electrical circuit. The most common function of a diode is to allow an electric current to pass in one direction (called the diode's *forward* direction), while blocking current in the opposite direction (the *reverse* direction).This unidirectional behavior is called rectification, and is used to convert alternating current (AC) to direct current (DC), including extraction of modulation from radio signals in radio receivers—these diodes are forms of rectifiers.

F. Capacitor

Unlike the resistor which dissipates energy, ideal capacitors and inductors store energy rather than dissipating it. In both digital and analog electronic circuits a capacitor is a fundamental element. It enables the filtering of signals and it provides a fundamental memory element. The capacitor is an element that stores energy in an electric field.

G. Voltage Regulator

A voltage regulator is designed to automatically maintain a constant voltage level. A voltage regulator may be a simple "feed-forward" design or may include negative feedback control loops. It may use an electromechanical mechanism, or electronic components. Depending on the design, it may be used to regulate one or more AC or DC voltages. Voltage regulators find their applications in computers, alternators, power generator plants where the circuit is used to control the output of the plant. Voltage regulators may be classified as electromechanical or electronic.

H. Heat Sink

A heat sink is an electronic device that incorporates either a fan or a peltier device to keep a hot component such as a processor cool. There are two heat sink types: active and passive.Active heat sinks utilize the power supply and are usually a fan type or some other peltier cooling device. Passive heat sinks are made of an aluminum-finned radiator that dissipates heat through convection. For passive heat sinks to work to their full capacity, there should be a steady airflow moving across the fins.

I. Lcd Display

The term liquid crystal is used to describe a substance in a state between liquid and solid but which exhibits the properties of both. Molecules in liquid crystals tend to arrange themselves until they all point in the same specific direction. This arrangement of molecules enables the medium to flow as a liquid. Depending on the temperature and particular nature of a substance, liquid crystals can exist in one of several distinct phases

J. Relay Module

Relays are used as interface modules. They perform different tasks depending on the version and are used to switch circuits on, off, and over. Switching devices that are susceptible to faults compromise the availability of machines and systems. Thanks to the wide range of products from Phoenix Contact, cost-effective solutions are available that meet all the requirements of modern system concepts.

K. Transistor

A transistor is semiconductor device used to amplify or switch electronic signals and electrical power. It is composed of semiconductor material usually with at least three terminals for connection to an external circuit. A voltage or current applied to one pair of the transistor's terminals controls the current through another pair of terminals. Because the controlled (output) power can be higher than the controlling (input) power, a transistor can amplify a signal.

L. DC Motor

DCM Series Wound DC Motors have the armature and field windings connected in a series circuit. These type motors normally drive loads that require precise speed regulation. Starting torque developed in series motors normally ranges between 300% and 375% of full load, but can be as high as 800% of full load torque. These motors can easily be configured in 2 & 3 speed, as well as reversible models. DCM Permanent Magnet DC Motors produce high running torque, and provide a relatively simple, high efficiency DC drive as compared to wound field motors. High efficiency and a linear speed torque curve are primary advantages of a DCM Permanent Magnet DC motor. These motors are easily reversed by changing polarity.

M. Motor Pump:

Pumping systems are the single largest type of industrial end-user of motor-driven electricity in the United States, accounting for 25% of industrial motor energy usage. 36 Also, pumping systems account for nearly 20% of the world's demand for electric energy.37 While pumps typically operate to serve various chemical process support equipments such as chillers, cooling towers, material transfer, etc., pumping is considered an individual process separate from the processes of the aforementioned equipment. A pump is a device used to raise, compress, or transfer fluids. The motors that power most pumps can be the focus of many best practices. It is common to model the operation of pumps via pump and system curves. Pump curves offer the horsepower, head, and flow rate figures for a specific pump at a constant rpm. System curves describe the capacity and head required by a pump system.

N. Solenoid Valve:

Most solenoid valves operate on a digital principle. They therefore possess two distinct states, which are (1) when the coil is activated by an electrical current, and (2) when the valve is resting (without electricity). Valve functions are defined from the resting position. The force produced by the solenoid plunger, which is mechanically coupled to the main closure device, opens this type of valve. The sequence starts with the solenoid opening the pilot seat. This relieves the pressure on the main closure device, bringing it into balance so the solenoid force can lift it into the open position. When the pilot seat is closed, bleed orifices allow a force to build upon the closure device that pushes it down into the closed position on the valve seat. These valves are preferred for use where the differential pressure is very low or zero.

O. Moisture Sensor:

This sensor can be used to test the moisture of soil, when the soil is having water shortage, the module output is at high level, else the output is at low level. By using this sensor one can automatically water the flower plant, or any other plants requiring automatic watering technique. Module triple output mode, digital output is simple, analog output more accurate, serial output with exact readings.

P. LDR (Light Dependent Resistor):

A light dependant resistor also know as a LDR, photo resistor, photoconductor or photocell, is a resistor whose resistance increases or decreases depending on the amount of light intensity. LDRs (Light Dependant Resistors) are a very useful tool in a light/dark circuits. LDRs can have a variety of resistance and functions.

III. Implementation

The block diagram of Arduino controlled solar powered DC motor pump load is shown in Figure 1.

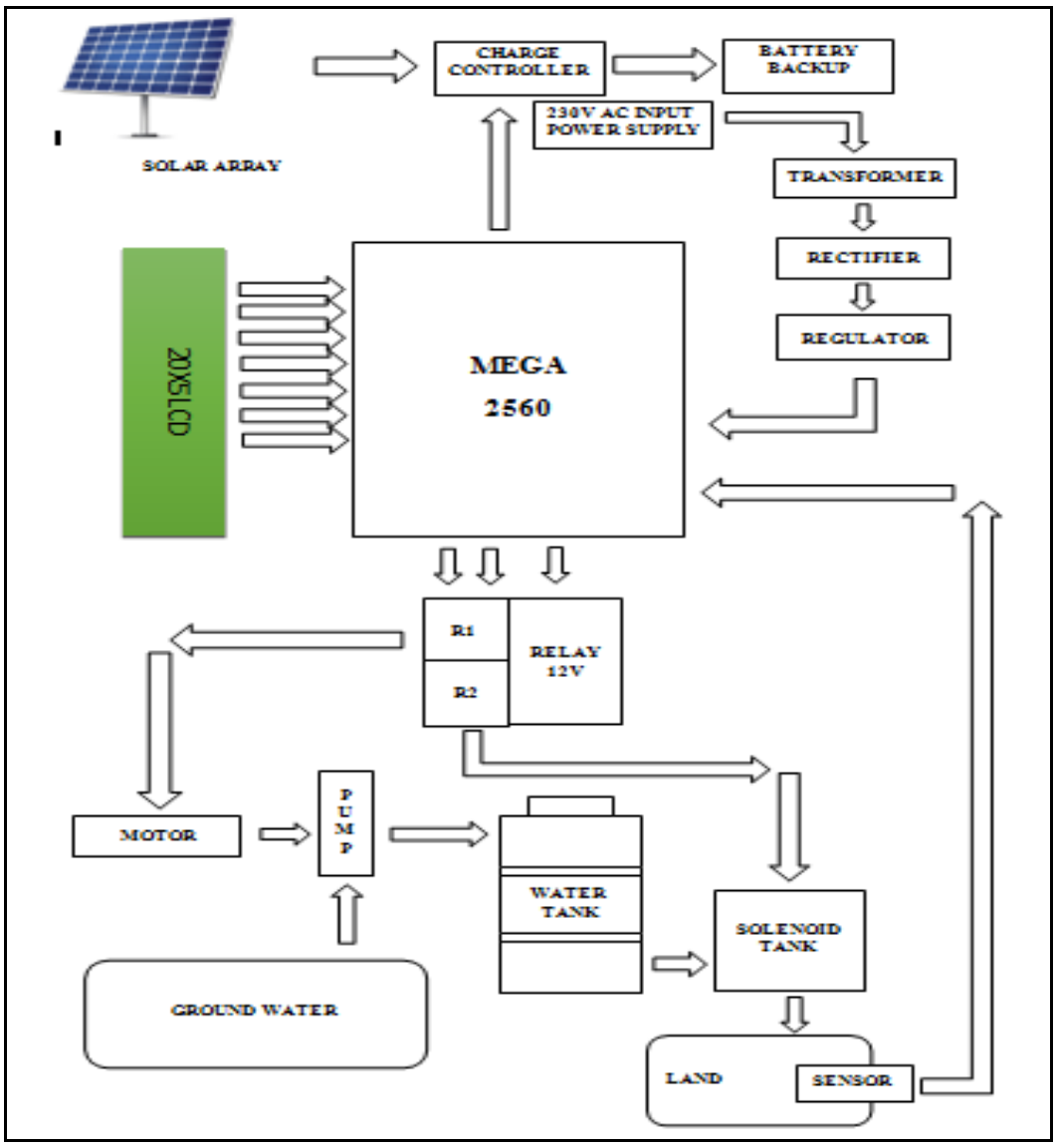

Figure 1. Block Diagram of Solar Powered DC Motor Pump Load

Solar power is given to the Arduino Controller, which checks the status of the Moisture level and gives the signal to the relay to operate the motor. Then the water is pumped from ground water and stored in a water tank. When water is stored, the solenoid valve is OPEN to drain the land, which is sensed by moisture sensor. After this process, again Arduino gives the signal to trip the relay and motor stops.

Figure 2. Hardware implementation

Solar power is given to the charge controller. when it is not used for motor ,then the power is used for battery charging. In this Process, 230v is stepdown, rectified and regulated to provide signal to Arduino controller. Arduino checks the status of the moisture level and then relay operates.

A. Low Moisture Sensor:

As per the scenario 1 from the Table 1,when the moisture level is low, Relay 1 operates to fill the water tank and Relay 2 operates to open the Solenoid valve, which is used to drain the water to the land. In this condition, battery is not charged.

Table 1. Performance of the proposed work when the Moisture level is LOW and HIGH

Condition	Scenario 1	Scenario 2	Scenario 3
Low Moisture Level	Solar Power-ON Distribution Supply-OFF Battery Storage-OFF	Solar Power-OFF Distribution Supply-OFF Battery Storage-ON	Solar Power-OFF Distribution Supply-ON Battery Storage-OFF
High Moisture Level	Solar Power-OFF Distribution Supply-OFF Battery Storage-ON		

As per the scenario 2, When the Moisture level is LOW, Solar Power and Distribution Supply is OFF and the Battery Storage is ON. Then the Solar power is used for charging. As per the Scenario 3, when the moisture level is LOW, Solar power and Battery Storage is OFF and Distribution Supply is ON. For the insufficient battery power, power is taken from the 230v AC mains supply.

B. High Moisture Sensor:

As per the scenario 1 from the Table 1, When the Moisture Level is HIGH, Solar Power and Distribution Supply is OFF and Battery Storage is ON. Since the land is drained, then the power is used for the battery storage.

IV. Conclusion

Arduino controlled solar powered DC motor pump load has been successfully designed and implemented. In this work, a stand-alone photovoltaic water pumping system is presented to supply the water in remote location areas with a clean and sustainable source of energy. The main focuses of this work is how to improve the total system efficiency by implementing an efficient MPPT techniques to transfer the maximum available power to the load especially under rapidly changing atmospheric conditions. During the atmospheric condition, MPPT tracks the maximum power, which is used to operate the motor and the water is pumped from the land and stored in water tank. This method is beneficial to farmers to utilize insufficient water for agriculture. Since it is a renewable resources, there is no need to depend on other sources and water is efficient to their need.

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