Solar Water Pumping System Using IOT Monitoring System

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Abstract - The Photovoltaic (PV)-powered water pumps have received considerable attention because of major developments in the field of solar-cell materials and power electronic systems technology. The motors available for the PV water pumping applications: dc motors and ac motors. AC motors are coupled to the solar panels through inverters. In solar powered PV pumps as input solar energy is freely available so it is desired that total water to be pumped out over the day, is to be maximized. Objective of the proposed system is to maximize the speed of pump and AC motor for a particular isolation (G) and temperature (T), in order to maximize the water to be pumped out. Field current speed control method is to optimize the speed of the AC motor at any value of isolation (G) and temperature (T). The dc– dc converter can be used to keep the PV-panel output voltage constant and to help in operating the solar arrays close to the maximum-power point. The proposed system is monitoring of motor speed, voltage and current range of the circuit by using IOT system.

Keywords: solar panel; converter; motor; isolation; IOT.

I. INTRODUCTION

Photovoltaic (PV) panels are often used for agricultural operations, especially in remote areas or where the use of an alternative energy source is desired. In particular, they have been demonstrated time and time again to reliably produce sufficient electricity directly from solar radiation (sunlight) to power livestock and irrigation watering systems. A benefit of using solar energy to power agricultural water pump systems is that increased water requirements for livestock and irrigation tend to coincide with the seasonal increase of incoming solar energy. When properly designed, these PV systems can also result in significant long-term cost savings and a smaller environmental footprint compared to conventional power systems. The volume of water pumped by a solar powered system in a given interval depends on the total amount of solar energy available in that time period. Specifically, the flow rate of the water pumped is determined by both the intensity of the solar energy available and the size of the PV array used to convert that solar energy into direct current (DC) electricity. The principle components in a solar-powered water pump system (The Internet of Things (IOT) refers to the ever-growing network of physical objects that feature an IP address for internet connectivity, and the communication that occurs between these objects and other Internet-enabled devices and systems. The Internet of Things extends internet connectivity beyond traditional devices like desktop and laptop computers, smart phones and tablets to a diverse range of devices and everyday things that utilize embedded technology to communicate and interact with the external environment Solar energy is widely available throughout the world and can contribute to minimize the dependence on energy imports. In 90 minutes, enough sunlight strikes the earth to provide the entire planet's energy needs for one year. Solar PV entails no greenhouse gas (GHG) emissions during operation and does not emit other pollutants. Solar has many benefits like system-friendly deployment, improved operating strategies, like advanced renewable energy forecasting and enhanced scheduling of power plants and also investment in additional flexible resources, comprising demand-side resources, electricity storage, grid infrastructure and flexible generation, all via the internet.
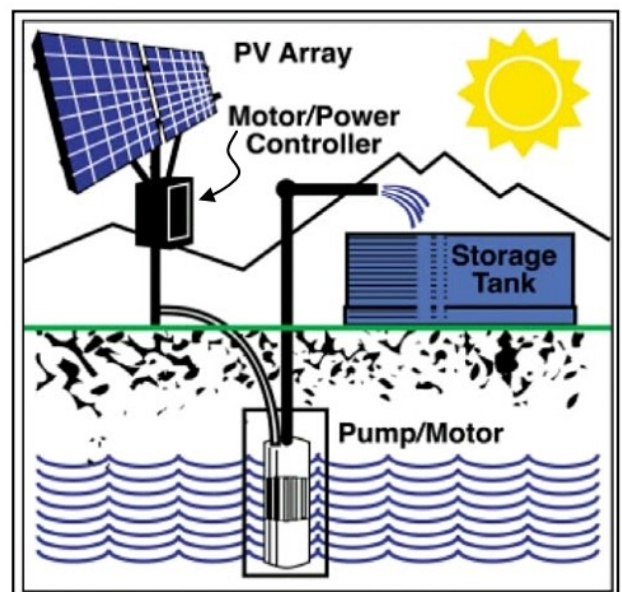

Fig 1.   A typical solar-powered water pump system, which includes a solar array, controller,pump and storage tank.

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The PV array and its support structure, an electrical controller, and an electric-powered pump. It is important that the components be designed as part of an integrated system to ensure that all the equipment is compatible and that the system operates as intended. It is therefore recommended that all components be obtained from a single supplier to ensure their compatibility. The following information is required to design a PV-powered pump: The site-specific solar energy available (referred to as "solar isolation").The volume of water required in a given period of time for livestock or irrigation purposes, as well as for storage. (A storage volume equal to a three-day water requirement is normally recommended for livestock operations as a backup for the system's safety features and cloudy days.) The total dynamic head (TDH) for the pump. The quantity and quality of available water. The system's proposed layout and hydraulic criteria. The following sections will first provide an introduction to the basic concepts involved in solar-powered pump systems, then descriptions of and design considerations for the previously mentioned, individual system components.

II. SOLAR RADIATION, SOLAR IRRADIANCE, AND SOLAR INSOLATION

To design a solar-powered water pump system, you will need to quantify the available solar energy. It is therefore important for you to be familiar with the definitions and distinctions between the three related terms "solar radiation," "solar irradiance," and "solar insolation." Solar radiation is the energy from the sun that reaches the earth. It is commonly expressed in units of kilowatts per square meter (kW/m^2). The earth receives a nearly constant 1.36 kW/m2 of solar radiation at its outer atmosphere. However, by the time this energy reaches the earth's surface, the total amount of solar radiation is reduced to approximately 1 kW/m^2 . The intensity of sunshine (i.e. solar radiation) varies based on geographic location. A good analogy to describe this variation is the different conditions that can be found on the north slope of a mountain versus its south slope[1]. The intensity of sunlight also varies based on the time of day because the sun's energy must pass through different amounts of the earth's atmosphere as the incident angle of the sun changes. Solar intensity is greatest when the sun is straight overhead (also known as solar noon) and light is passing through the least amount of atmosphere. Conversely, solar intensity is least during the early morning and late afternoon hours when the sunlight passes through the greatest amount of atmosphere. In most areas, the most productive hours of sunlight (when solar radiation levels approach 1 kW/m^2) are from 9:00 a.m. to 3:00 p.m. Outside of this time range, solar power might still be produced, but at much lower levels. Solar irradiance, on the other hand, is the amount of solar energy received by or projected onto a specific surface. Solar irradiance is also expressed in units of kW/m2 and is measured at the surface of the material. In the case of a PVpowered system, this surface is the solar panel. Finally, solar insolation is the amount of solar irradiance measured over a given period of time. It is typically quantified in peak sun hours, which are the equivalent number of hours per day when solar irradiance averages 1 kW/m^2 . It is important to note that although the sun may be above the horizon for 14 hours in a given day, it may only generate energy equivalent to 6 peak sun hours. Figure 3, right, demonstrates how peak sun hours are determined for any particular day. The entire amount of solar irradiance (indicated by the blue arc) is divided by 1 kW/m2 , which equals the total number of peak sun hours for that day (indicated by the white rectangle). Another term that is synonymous with peak sun hours (solar insolation) is "equivalent full sun hours." Occasionally, the term "solar radiation" can also be used to describe equivalent full sun hours (in addition to the definition above). Two important considerations when determining solar insolation values are the latitude of the project site and the proposed tilt angle of the PV array. (the angle of the panel relative to horizontal where 0° is horizontal and 90° is vertical. Latitude is discussed in Section 2.0). An example of monthly solar insolation values for North Bend, Oregon (latitude 43 degrees) for a fixed tilt angle. Additional solar insolation (solar radiation) values are provided for nine locations in Oregon[5].

a) Electromagnetic nature of solar radiation - Here we give an introduction to physics of solar radiation and solar insulation. The complete concept of harnessing solar energy to generate electricity is based upon the phenomenon of **solar radiation**.It is this radiation from the sun, together with a few more factors, which is the reason why life exists on earth. Solar radiation is **electromagnetic**in nature and is the radiant energy emitted from the sun.The total frequency spectrum of this electromagnetic solar radiation covers visible light and near visible radiation (**UV Rays, Infrared Rays, X-Rays**, etc.). The visible light and heat supports life on earth while much of the near visible harmful radiation is deflected away by the earth's atmosphere.

b) Solar radiation - The source of never ending energy Sun produces its energy by the, never-stopping, **nuclear fission reaction**, which converts approximately 700 million tons of hydrogen to helium per second.This process creates massive amounts of **heat** and it is due to this heat that photons are emitted. Each emitted **photon** travels a very short distance before being absorbed by another molecule, which by a similar process, emits another photon. This process of absorption and re-emission continues and the photons keep moving forward, finally being able to reach the outer space at the sun's surface.

Direct Normal Irradiance (DNI) is the amount of solar radiation received per unit area by a given surface that is always held perpendicular to the incoming rays.The amount of irradiance can be maximized by keeping the receiving and electricity-generating surface – the PV module – on optimal track with the movement of the sun and thus of the sun rays.

The journey from sun's core to sun's surface typically takes around 100,000 years. When in the outer space, the photon is radiated and incepted by planets as light. This

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journey from the sun's surface to the earth's surface typically takes around eight minutes.

The total energy emitted by the sun is 63,000,000 W/sq. m. The intensity of solar radiation striking the earth is determined by the Inverse Square Law.

This means that the total radiant energy striking the earth's surface is inversely proportional to the square of the distance. For double the distance, this energy reduces to a quarter of the original energy.Only about 40% of the solar energy which is intercepted by the earth is passed through the atmosphere and is available for solar applications[1].The total radiation is composed of the following three components:Direct Radiation (the radiation which comes directly from the sun)Diffused Radiation (the radiation which is diffused by the sky, layers of atmosphere and other surroundings)Reflected Radiation (the radiation which is reflected back by the lake, seas and other water bodies).
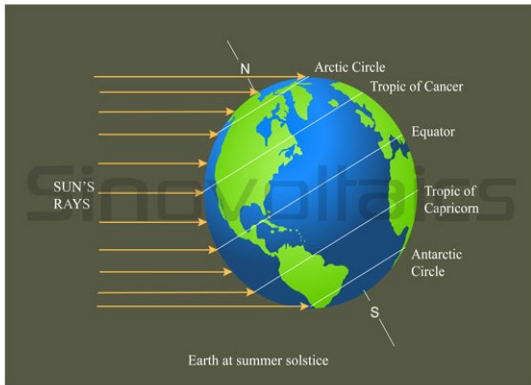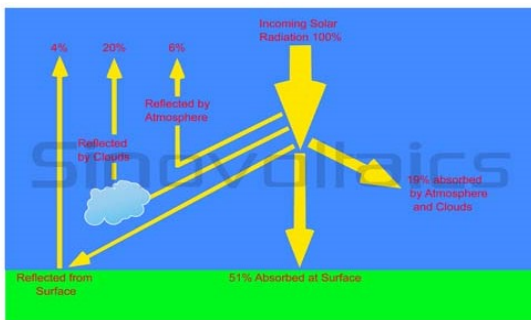

Fig 2.   Solar radiation

Fig 3.   Solar radiation – atmospheric effects

The total ground reflection is a sum of all the above three components. Although the sun's energy output is fairly constant, the total solar radiation falling on the earth's surface varies and depends on a lot of factors, including but not limited to:

1. **Atmospheric Conditions** (Cloud Cover, Ozone layer condition, etc.)

2. **Earth's Rotation** (time of the day, solar activity, etc.)

3. **Earth's Revolution** (distance between earth and sun, seasons, angle of inclination of earth's surface, etc.)

During the process of nuclear fusion, the sun produces energy that in form of electronicmagnetic waves (**radiation**)[4].Solar insolation is affected by factors such as **atmosphere**, **angle of the sun** and **distance**. The thinner the atmosphere in which the sun is passing through, the more the insolation.Insolation is also at its highest when the sun is directly overhead in an area. This is also the shortest distance between the sun and an area. When the angle of the sun to an area increases, the distance increases, and a lot of energy is lost through reflection.**Insolation** refers to the quantity of solar radition energy received on a surface of size X m² during an amount of time T.In the **photovoltaic industry** it is commonly expressed as **average irradiance** in kilowatt per square meter (kW/ m²) or – taking into account the time factor – kilowatt hours per year per kilowatt peak $kWh/(kW_p*year)$.

III. PHOTOVOLTAIC (PV) PANELS PV

Panels are made up of a series of solar cells, as shown in Figure 3.1, below. Each solar cell has two or more specially prepared layers of semiconductor material that produce DC electricity when exposed to sunlight. A single, typical solar cell can generate approximately 3 watts of energy in full sunlight. The semiconductor layers can be either crystalline or thin film. Crystalline solar cells are generally constructed out of silicon and have an efficiency of approximately 15%. Solar cells that are constructed out of thin films, which can consist of a variety of different metals, have efficiencies of approximately 8% to 11%[2]. They are not as durable as silicon solar cells, but they are lighter and considerably less expensive. PV panels may be arranged in arrays and connected by electrical wiring to deliver power to a pump (see Section 3.0 for more details). PV panels must meet all NRCS required specifications, both for power production and structural integrity (including resistance to hail), as described in the following sections. 3.0 PV Panel Electrical Characteristics PV panels are rated according to their output, which is based on an incoming solar irradiance of 1 kW/m^2 at a specified temperature. Panel output data include peak power (Watts [Pw]), voltage (Volts [V]), and current (Amps [A]). Under conditions of reduced solar radiation, the current produced is decreased accordingly, but the voltage is reduced only slightly. Example electrical characteristics for a solar panel is as follows. Multiple panel arrays should be wired in a series and/or parallel so that the resulting voltage and current are compatible with the controller and pump motor requirements. Example PV Solar Panel Electrical Characteristics Characteristic Value Units Peak Power 117 Watt [Pw] Power Tolerance ±5 % Max Power Voltage 35.5 Volts [V] Max Power Current 3.3 Amps [A] Open Circuit Voltage 40.0 Volts [V] Short Circuit Current 3.5 Amps [A] Figure 5 – Solar cell, PV solar panel, and PV panel array. (Source: "Guide to Solar

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Powered Water Pumping Systems in New York State.")
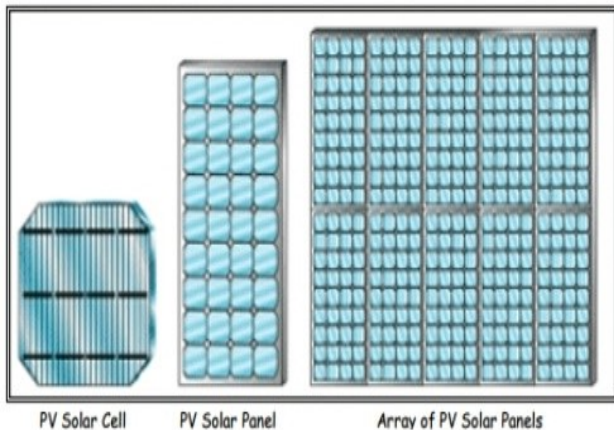PV Solar Cell PV Solar Panel.

Fig 4.   Solar cell, PV panel array

Solar photovoltaic modules are where the electricity gets generated, but are only one of the many parts in a complete photovoltaic (PV) system. In order for the generated electricity to be useful in a home or business, a number of other technologies must be in place.

a) Mounting Structures

PV arrays must be mounted on a stable, durable structure that can support the array and withstand wind, rain, hail, and corrosion over decades. These structures tilt the PV array at a fixed angle determined by the local latitude, orientation of the structure, and electrical load requirements. To obtain the highest annual energy output, modules in the northern hemisphere are pointed due south and inclined at an angle equal to the local latitude. Rack mounting is currently the most common method because it is robust, versatile, and easy to construct and install. More sophisticated and less expensive methods continue to be developed[6].For PV arrays mounted on the ground, tracking mechanisms automatically move panels to follow the sun across the sky, which provides more energy and higher returns on investment. One-axis trackers are typically designed to track the sun from east to west. Two-axis trackers allow for modules to remain pointed directly at the sun throughout the day. Naturally, tracking involves more up-front costs and sophisticated systems are more expensive and require more maintenance. As systems have improved, the cost-benefit analysis increasingly favors tracking for ground-mounted systems.

b) Inverters

Inverters are used to convert the direct current (DC) electricity generated by solar photovoltaic modules into alternating current (AC) electricity, which is used for local transmission of electricity, as well as most appliances in our homes. PV systems either have one inverter that converts the electricity generated by all of the modules, or microinverters that are attached to each individual module. A single inverter is generally less expensive and can be more easily cooled and serviced when needed. The microinverter allows for independent operation of each panel, which is useful if some modules might be shaded, for example. It is expected that inverters will need to be replaced at least once in the 25-year lifetime of a PV array. Advanced inverters, or "smart inverters," allow for two-way communication between the inverter and the electrical utility. This can help balance supply and demand either automatically or via remote communication with utility operators. Allowing utilities to have this insight into (and possible control of) supply and demand allows them to reduce costs, ensure grid stability, and reduce the likelihood of power outages[3].

c) Storage

Batteries allow for the storage of solar photovoltaic energy, so we can use it to power our homes at night or when weather elements keep sunlight from reaching PV panels. Not only can they be used in homes, but batteries are playing an increasingly important role for utilities. As customers feed solar energy back into the grid, batteries can store it so it can be returned to customers at a later time. The increased use of batteries will help modernize and stabilize our country's electric grid.

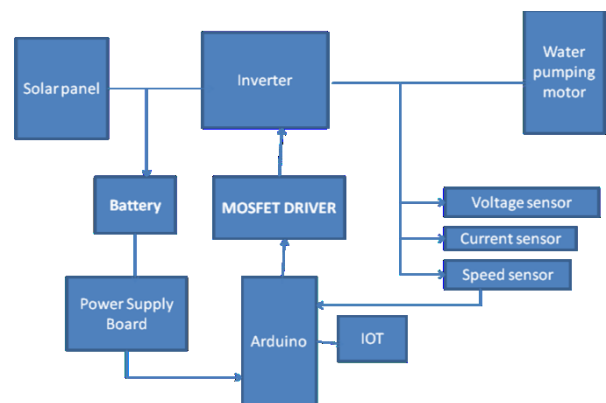## A. PROPOSED BLOCK DIAGRAM

Fig 5.   Proposed block diagram of solar water pumping

B. ARDUINO

Keeping in mind the economic constraints and the simplicity of the system, Arduino Uno has been used which abates the programming complexity. Arduino sense the current and voltage value through Analog pins. With the help of these values, Arduino programing calculates the power and energy.

IV. CONCLUSION

The major aim of our research article has executed the complete design and operation of IOT based automatic water pump controller from the engineering perspective and created an enhanced working model of water pump controller integrated with sensors having significant improvement in moisture sensing which makes the design very unique. Our main objective has been achieved to construct a controlling of water pump using website.
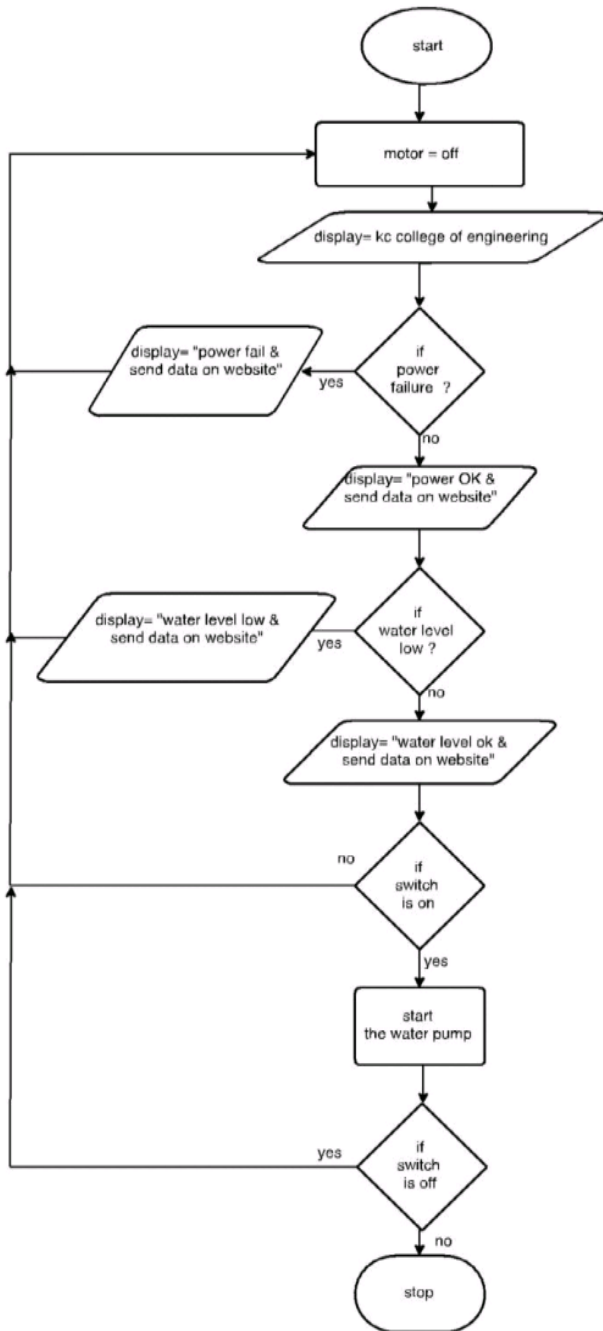
Fig 6.   FLOWCHART

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