Hybrid Powered Auto-irrigation System using Embedded Controller

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Abstract. In this work, the level of moisture in the soil is monitored constantly via a moisture sensor. The output of this sensor is fed to the microcontroller and accordingly, it directs the switching of the water pump. The automatic water flows control using a moisture sensor-driven microcontroller circuit throws a light upon the utility of automation in irrigation and thereby optimizing the water flow in the field. The microcontroller is interfaced with a sensor to check soil moisture and the relay circuit to complete the control loop along with the feedback mechanism. When the sun shines, the LDR sensor via the relay directs the battery to be charged by the solar panel. On the other hand, during the night or cloudy weather, the LDR sensor senses the absence of light and thus via relay switching directs the battery to be charged by the windmill. This allows a sensible way of balancing nature-provided energy as and when available. Integration of the wind systems helps to facilitate the accumulation of wind energy during the night as a backup or rather as an additional system to add on more energy.

Keywords: Green Energy, Hybrid Power, Irrigation, Soil Moisture, Water-saving, Agricultural.

1 Introduction

Manual irrigation of paddy field and due maintenance of moisture level poses a grave challenge to the current-day research fraternity. In the proposed work, an automatic water pump operating module with a soil moisture monitoring system has been designed and fabricated. The developed prototype model includes various microcontrollers to enhance the system performance. Further, the proposed system is powered by a hybrid renewable source of energy comprising wind and solar power. Every sector using solar as the renewable power source is striving hard to utilize wind power (though ample availability) during the nighttime [1-2]. This motivated us to implement the same for the irrigation field whereby large open fields, specifically in hilly terrains, receive high solar radiation during daytime and an appreciable amount of wind energy at night. The introduction of automation in irrigation played a crucial role in water-saving and also unnecessary degradation of plant and field health due to water clogging [3]. Thus automation and renewable power source would lead us to successfully achieve dual goals: conservation of water and energy.

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1.1 Recent Advancements in Irrigation System

Agriculture is considered one of the major occupations in India. Indian population where nearly three-fourth is dependent on agriculture for leading their lives, and it is considered as one of the major occupations in India without a tinge of dilemma [4]. Designing the control system using the internet of things (IoTs) can be used to mitigate the flaws whereby control systems are vulnerable to external interference leading the system to have poor stability. Such a case can be in a control system designed for water lifting irrigation for wind power generation which has an open line communication with auxiliary equipment nearby posing a threat to the system [5]. With the surging reliability of renewable energy sources, a standardized assessment of the suitable sites becomes necessary for the optimal utilization of these resources. Analysis of the present research work shows that 4.13% of the study area (133,874 km^2) and 0.91% of the total area (29,457 km^2) is highly suitable for the deployment of solar plants and wind farms respectively [6].

Pumped hydro storage (PHS) technology has emerged as an economically and technologically viable option for energy storage which possesses to be a key element in the future of renewable energy (RE) systems. Current research focuses on the hybridization of PHS with the other conventional storages which thereby has an impact on off-grid RE systems, increasing the range of services and overall system reliability, shrouding the weakness of each other. Recent studies also confirm the feasibility of hybrid PV and wind systems to support the combined load [7]. Mechanical energy storage systems are among the foremost efficient and sustainable energy storage systems. Selecting the suitable mechanical storage type depends on the requirements of each application such as using the flywheel for short duration applications [8-9]. While photovoltaic water pumping (PVWP) and wind power water pumping (WPWP) systems for irrigation represent two significant verticals of innovative solutions in irrigation, if we take into account the average specific costs both for PVWP and WPWP systems, it has been concluded that the most cost-effective solution for irrigation is site-specific with the PVWP systems winning with better performances in terms of matching between water supply and IWR (Irrigation water requirement) compared to the WPWP systems [10].

In [1], authors have reviewed site feasibility of solar based irrigation. Then, in the year of 2015, a group of researchers have suggested low cost solar based drip farming [2]. In continuation with it, the holistic micro-irrigation based on water pumping from local resources has been presented in [3]. A study has been conducted for farming at remote rural place based on energy harvested from sunlight [4]. The sustainability of solar based irrigation across the regions of Sub-Saharan Africa has been reviewed in [11]. Then, solar based agriculture possibility has been checked in one of the region in China [12]. Similarly, a solar- diesel hybrid irrigation viability has been studied across one of the Australian regions [13]. However, recently in [14], Selmani et al., have presented cyber physical based agricultural management concepts. Rizi et al., have briefed financial aspects of irrigation pumping system for various regions in Iran [15]. In [16]., a tuning based stand-alone PV irrigation system has been studied as a large scale power system. Nikzad et al., have evaluated viability of rice irrigation system based on solar energy in a province of Iran [17]. Thereafter, in [18], an IoT based irrigation and farming has been introduced. Then, a boost converter based solution has been adopted irrigation [19]. Furthermore, Kumar et al., have applied a solar based greener approach for farming [20]. However, an irrigation system based on thermo electric generator has been adopted [21]. In Bangladesh, an irrigation system for rice farming has been analyzed [22]. In its continuation, the drip irrigation for vegetable cultivation has been studied [23]. Whereas, Lefore et al., have adopted solar power irrigation system for small agriculture scale [24]. A hybrid irrigation system for farming has been studied with Oman Falaj [25]. Then a drive of variable frequency has been applied for irrigation of palm trees [26]. Then after, a single axis based solar powered irrigation system has been tested [27]. An effective management of apple farms with rainwater irrigation has been adopted in [28]. Here with, Kurulekar et al., have taken small hydro based turbine system for ease in irrigation [29]. Alongwith, it, Zhang et al., have proposed farming in a microgrid while using electricity from wind power and pump storage [30].

Table 1 Parameters for irrigation water pumping systems

Sl.	Dimensions particulars	Specifications
1	Pipe Diameter	50 mm
2	Pipe Length	40 m
3	Pipe Inlet Pressure	745 kPa
4	Pipe Outlet Pressure	97 kPa
5	Flow Rate at Horizontal Position	0.0027 m^3/sec
6	Flow Rate at Inclined 15° Upward	0.00235 m^3/sec
7	Flow Rate at Inclined 15° Downward	0.00322 m^3/sec
8	Density of Water	997 kg/m^3
9	Dynamic Viscosity of Water	0.890 kg/m·s

The current paper has been covering six sections, which are as follows after the introduction: Section-II: Mathematical Formulation; Section-III: Formulation for Hybrid System Integration; Section-IV: Hardware Integration; Section-V: Simulation Results; and at the end Section-VI: Conclusion.

1.2 Motivation behind present Study

- Over Irrigation and under irrigation.
- Water logging and drainage problems in villages, agricultural lands, and along roads - with mostly negative consequences. The increased level of the water table can lead to reduced agricultural production.
- Farmlands & fields situated miles away from your home. Thus, extensive travel is required, someday several times to start & stop the irrigation water pumps.
- Land is more, we need more manpower so the shift towards automation is a wise option
- Diesel/kerosene-based water pumps are not so eco-friendly.

1.3 Dual Goals - Conservation of Water and Energy

- Keeps the moisture availability in the soil to an acceptable limit
- Conserves energy by aiming towards the use of renewable energy-driven water pumps
- When the Sun shines, pumping process is a sensible way of solar energy to be used throughout the summer, as the water need is highest.
- Pumped water should be sufficient to meet seasonal plantation. The design of the solar system would be such that it would collect maximum solar energy that is converted into electrical energy which in turn is used to power the irrigation system.

Along with that, here, the wind solar-hybrid power means facilitate effective utilization of green energy round the clock. The irrigation pumping system has been briefed in Table 1.

2 Mathematical Formulations

Basic formulae related to proposed work is explained in succeeding sections. Irrigation water pumping by PV pump can be formulated as (1) [10],

$$P_{pvW} = \frac{0.0027 \times \mathrm{TDH}}{f_m \eta_p} \max_{m} \frac{IWR_{t,m}}{E_{wm}} \quad m = month... \tag{1}$$

where, TDH : total dynamic head, f_m : matching factor, η_p : pump efficiency, IWR :irrigation water requirement, $IWR_{t,m}$: total monthly average daily IWR (m3/ha/day); E_{wm} : monthly average daily energy yield of the WT (kWh/day per kWr).

Energy generated at wind velocity *v* can be formulated as in (2) [10],

$$E_w = t\int_{vi}^{vr} P_v f(v)dv + tP_r \int_{vr}^{v0} f(v)dv \tag{2}$$

where, *t*: time period, V_0 , V_r , V_i : cut out, rated and cut in speed, respectively.

Then, benefits in terms of carbon foot print could be related from (3) [2],

$$\text{Carbon footprint}\,(\mathrm{kgCO_2 - eqkWh^{-1}}) = \frac{\mathrm{EF(kgCO_2 - eqkWh^{-1})}}{\text{Effeciencyof Pumping System}} \tag{3}$$

where, EF: emission factor.

Techno-economic viability of any project depends on its life cycle assessment. This life cycle cost of the proposed system can be evaluated using (4) [2],

$$\text{Present worth} = C\left\{\frac{(1+i)}{(1+d)}\right\}^{n} \tag{4}$$

where, *i* : relative inflation rate and *d*: discount rate /year and *n*: duration (year)

3 Hybrid Irrigation System Simulations

At present, instead of only solar PV-based irrigation, a hybrid of PV and wind systems is more promising. Along with it, automatic water flow controller is using a moisture sensor. The irrigation pump can be controlled in two modes namely: Automatic mode and Manual mode. The LDR sensors would help an efficient shift over of capturing energy, wind, or solar according to availability. Apart from soil moisture sensors, it would be better to introduce multiple monitoring parameters like temperature and humidity via control logic which would enhance irrigation even more. This is the combined system that we have designed and proposed for hybrid-powered auto irrigation (refer to Fig. 1).

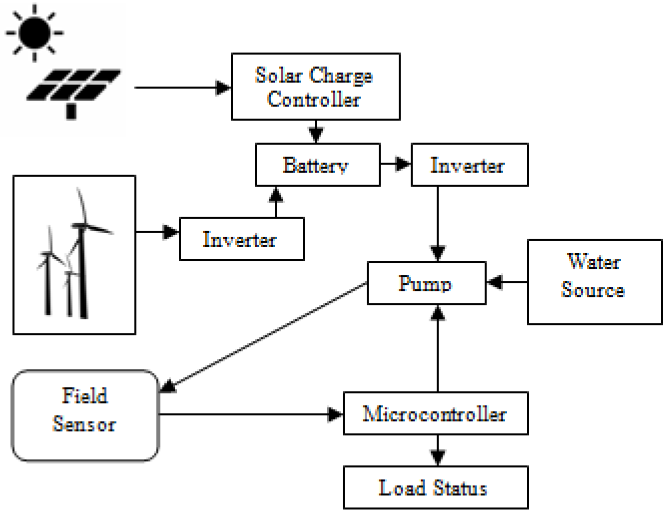

Fig. 1 Basic block diagram for the proposed system

The system here, in the case of wind turbine and generator, has been shown for a practical 3 phase system, however, due to modeling; we have used a small dynamo to generate dc power. However, the entire PSIM design has been done considering real-time, large-scale scenarios. Despite such differences, if our model is replicated on large scale, it is not expected to give much of a varied output. It has been used multiple software to get varied view points for the same model. PSIM model was specifically built to get a detailed idea about the solar system works. Followings are the prospective work scope:

- GSM can be added for sending SMS to the concerned person in case of any problem.
- Pesticides and fertilizers can also be added automatically to the water.
- Wireless sensor application.
- Image processing can be introduced to detect the picture of particular plants and crops and water them necessarily since different crops have different needs. This will allow personalization while using it for a mass of crop or plant.
- This concept in the future can be enhanced by adopting DTMF technology. This project is basically dependent on the output of the sensing arrangement. Whenever there is a need for excess water in the desired field then it will not be possible by using sensing technology.

4 Hardware Integration of the Proposed System

The proposed system hardware integration has been carried out as follows (shown in Fig. 2):

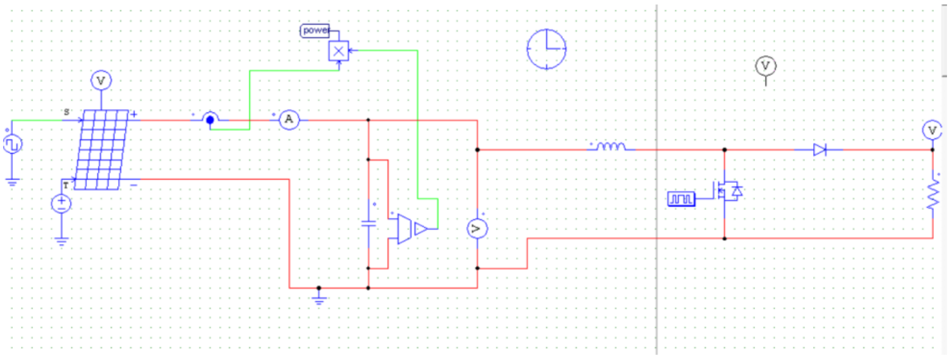

Fig. 2 Solar module with boost converter.

4.1 Design of PV System

The Arduino with the temperature sensor LM 35, humidity sensor, and soil sensor LM393 has been simulated. These sensors will indicate the conditions like temperature and humidity of the atmosphere and the moisture sensor will indicate the soil moisture condition and the requirement of water in the field. The soil moisture sensor works with the principle of change of capacitance value across the sensor probes. The values of change in temperature or moisture will be displayed in the LCD (e.g Dry/Wet) which is connected with the Arduino and motor on/off is directed accordingly as shown in Fig. 3.

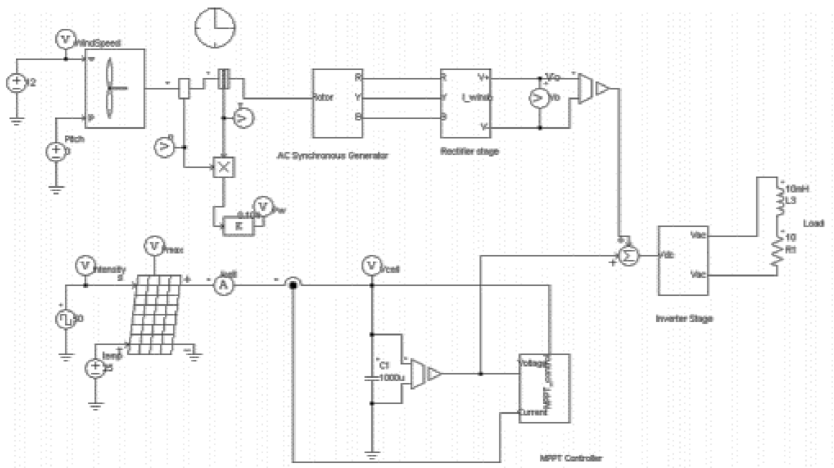

Fig. 3 Model design for block in PSIM

A control program has been developed to indulge in more input parameters based on Arduino programming. Apart from this, another set of Arduino block and control circuits is used and a program is developed based on the LDR sensor, whereby sensing of light by LDR sensor would turn on the solar charging circuit or the wind charging circuit as presented in Fig. 4.

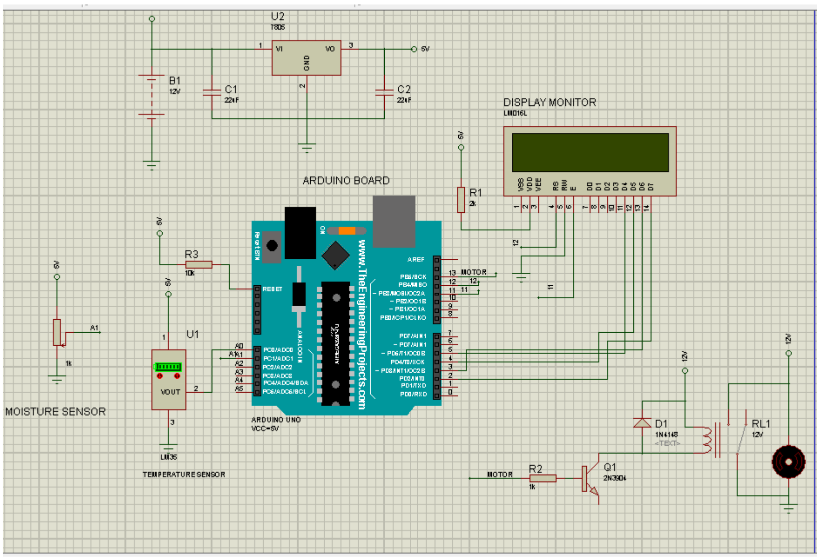

Fig. 4 Control circuit of the automatic irrigation designed in proteus

(a). Arduino with soil moisture (b). System integration

Fig. 5 Complete set up with irrigation platform

4.2 Design of Wind Turbine

They can produce electricity in any wind direction. A strong supporting tower is not needed because the generator, gearbox, and other components are placed on the ground. The production cost is also low as compared to horizontal axis wind turbines. Vertical axis wind turbines, as shortened to VAWTs, have the main rotor shaft arranged vertically. The main advantage of this arrangement is that the wind turbine does not need to be pointed into the wind. This is an advantage on sites where the wind direction is highly variable or has turbulent winds. With a vertical axis, the generator and other primary components can be placed near the ground, so the tower does not need to support it, which also makes maintenance easier. As there is no need of pointing turbine in wind direction to be efficient so yaw drive and pitch mechanism are not need. Easy installation as compared to another wind turbine (refer to Fig. 5(a)-(b)). Low risk for humans and birds because blades move at relatively low speeds. They are particularly suitable for areas with extreme weather conditions, like in the mountains where they can supply electricity to mountain huts. The monthly energy savings is presented in Table 2.

Table 2 Energy saving on monthly basis for irrigation

Period	Unit (kW/month)	Period	Unit (kW/month)
Jan	640	Jul	800
Feb	460	Aug	620
Mar	300	Sep	480
Apr	340	Oct	240
May	500	Nov	400
Jun	720	Dec	580

5 Simulation Results

From the simulation result, it can observe that though the voltage and current output takes some time to stabilize, the power output is stabilized within a very short span of time which is a good performance indicator (refer to Fig. 6(a)-(b)).

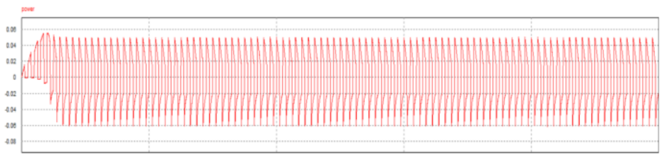

Fig. 6(a) Power output with respect to time.

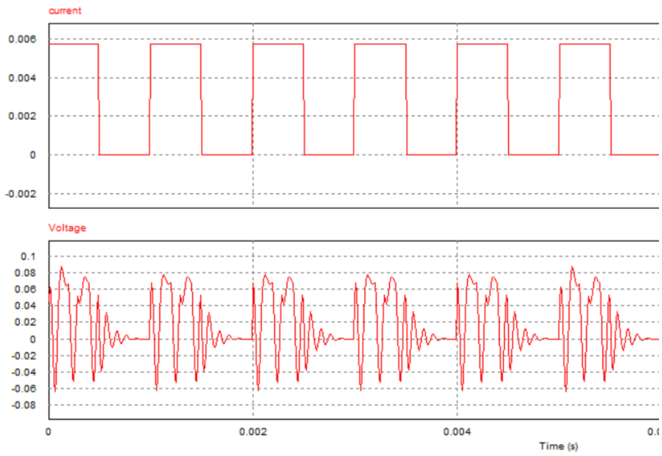

Fig. 6(b) Voltage and current output with respect to time

6 Conclusions

The proposed solution is effective in serving rural farming, where access to the grid is not that economical. And it also helps effective water management for uniform irrigation. A variety of other advanced systems can be incorporated along with hybrid systems in order to increase their efficiency and productivity. Many of these systems are now working as standalone systems but can be incorporated in the future. Some of these probable systems are discussed below the incorporation of which is kept for developing highly sound systems in the future.

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