# Solar Energy in Irrigation: Innovation for Water and Energy Efficiency

**Mrs. SHRIMATHI.G.H**
**Sr/Gr Lecturer**
Department of Electrical & Electronics Engg.,
DACG Government Polytechnic Rg Road,
Chikmagalur

***Abstract: This paper presents the development of a solar-powered automatic irrigation system designed to minimize human intervention and optimize water usage in agriculture. The system employs a soil moisture sensor to continuously monitor the moisture content in the soil. When the moisture level drops below a predefined threshold, the sensor transmits the data to a PIC microcontroller, which in turn activates a water pump to irrigate the crops. The system ensures that only the required amount of water is supplied, maintaining optimal soil conditions for plant growth while conserving water. Powered entirely by solar energy, this setup promotes sustainable farming practices by leveraging a renewable energy source. A 4x4 keypad interface allows users to select different crop types, enabling crop-specific irrigation control. The proposed system enhances efficiency in agricultural operations, reduces the dependency on manual labor, and contributes to environmental sustainability.***

***Keywords****: Solar Power, Automatic Irrigation, Soil Moisture Sensor, PIC Microcontroller, Water Pump, Sustainable Agriculture, Renewable Energy*

## 1. Introduction

Due to decreasing rainfall and growing water scarcity in agricultural regions, implementing an efficient irrigation strategy is essential. Crop fields largely depend on the availability of water in the soil, and continuous extraction of groundwater leads to a decline in soil moisture levels. To tackle this, a well-regulated irrigation method is necessary [1]. However, conventional irrigation systems often result in significant water wastage.

To address this issue, an automated irrigation system powered by solar energy and equipped with a humidity sensor is proposed. This system uses photovoltaic (PV) cells to convert solar energy into electricity, removing dependence on conventional electric power sources. The proposed setup includes a soil moisture sensor embedded in the soil to monitor moisture levels. The system is controlled by a PIC microcontroller, which manages the operation of the irrigation pump.

When the soil moisture drops below a certain threshold, the sensor detects the dry condition and signals the microcontroller to activate the pump via a relay mechanism. Once adequate moisture is restored, the motor is automatically switched off [2]. These motor states—ON in dry conditions and OFF in moist conditions—are also displayed on a 16x2 LCD.

### Photovoltaic (PV) Cell

A photovoltaic cell, commonly known as a solar cell, converts sunlight directly into electricity. These cells are used in both basic devices like calculators and advanced systems that power water pumps, communication tools, lighting, and home appliances. In this model, a grid of PV cells collects solar energy and powers the irrigation pump. The generated electricity can also be stored in batteries for later use.

While PV panels generate electricity, solar thermal panels are designed to heat water for domestic and industrial purposes [3]. Solar collectors play a central role in active solar thermal systems by converting sunlight into thermal energy, which can reduce electrical consumption.

There are several types of solar collectors, including flat-plate, evacuated-tube, concentrated, and transpired air collectors—each tailored to specific temperature and environmental conditions.

In this proposed system, solar energy powers the water pump, and soil moisture levels guide irrigation. Different crops require specific moisture levels, and failure to meet these can lead to crop failure and reduced yields. The system ensures plants receive water based on their individual moisture requirements through the use of soil moisture sensors, promoting efficient irrigation and improved productivity [4].

## 2. Literature Review

Cost-effective solar energy has emerged as a viable solution to address the energy needs of the Indian agricultural sector. One promising innovation is the **solar-powered intelligent irrigation system**, which integrates a solar-driven water pump with automated soil moisture monitoring. This technology minimizes reliance on grid electricity and conserves water through precision irrigation [1].

A **SCADA-based automated irrigation system** utilizing PLC controllers, powered by adaptive solar arrays, has been developed for broader industrial applications including agriculture, oil, and gas sectors. The system employs four sensors—two for soil moisture and two for water level detection—and operates solenoid valves accordingly. While solar systems offer lower operational costs, challenges remain regarding high installation and emission-related expenses [2].

A **low-cost solar-powered drip irrigation model** was proposed, utilizing photovoltaic (PV) panels to deliver pressurized water effectively. The project spanned 1,000 square meters and supported over 100 trees. It incorporated Systems Modeling Vocabulary to simulate and evaluate overall system performance [3].

**Photovoltaic water pumping systems** are considered a sustainable alternative for irrigation due to their adaptability to temporal and spatial water distribution patterns. They reduce manual labor, conserve water, and support socioeconomic development in rural regions [4]. Studies, particularly in Sub-Saharan Africa, suggest that solar PV and solar thermal technologies are increasingly adopted due to rising fuel prices and improvements in PV affordability.

Comparative analysis shows that **solar-powered pumps perform comparably or better** than conventional systems. For example, while traditional systems yielded an average flow rate of 69 LPM, solar pumps achieved 65 LPM with higher efficiency and economic viability through Maximum Power Point Tracking (MPPT) [5].

Another study proposed a **solar-powered wireless sensor network (WSN)** framework for real-time irrigation management. It comprises three units: Base Station Unit (BSU), Valve Unit (VU), and Sensor Unit (SU), facilitating precise water control. This setup not only reduces water stress and salinity risks but also enhances freshwater utilization [6].

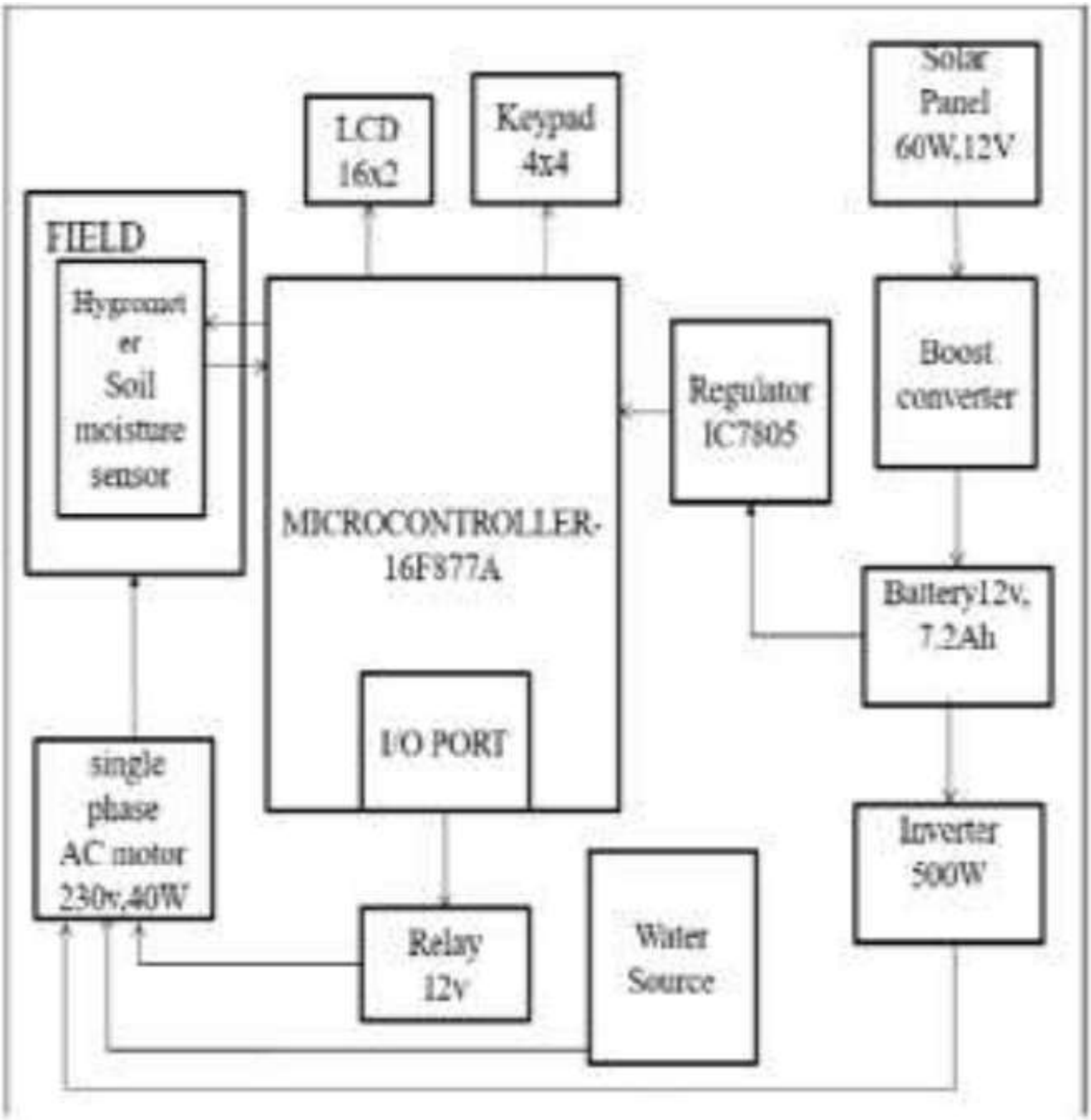


**FIGURE 1: Irrigation system design**

# 3. Methodology

The proposed solar-powered irrigation system integrates multiple components to enable automated, energy-efficient water distribution based on soil moisture levels. The key elements include a **solar panel**, **boost converter**, **battery**, **PIC16F877A microcontroller**, **soil moisture sensor**, **relay**, **water pump**, and a **4x4 matrix keypad** for crop selection.

**System Overview**

The primary energy source is a **12V solar panel**, which supplies power to a **boost converter**. This converter increases the panel's output voltage, especially during low solar irradiance, ensuring sufficient energy is delivered to charge the battery. The charging controller regulates voltage and current, optimizing battery life and preventing overcharging.

The **boost converter** operates in switch-mode, using a transistor, diode (IN4007), and inductor (100µH) to raise the voltage. When the switch is closed, energy is stored in the magnetic field of the inductor. When opened, the magnetic field collapses, releasing energy that increases the output voltage delivered to the battery.

**Power Supply Regulation**

To power the microcontroller and associated components, a **voltage regulator (IC 7805)** is used to step down the 12V DC to 5V DC. A **500W inverter** converts the 12V DC to 230V AC to operate the water pump. Capacitors (100µF and 1000µF) and resistors (330Ω) are used to stabilize voltage and reduce ripple.

**Microcontroller Operation**

A **PIC16F877A microcontroller** (40-pin) governs the system. It receives input from a **soil moisture sensor**, which is embedded in the soil to monitor moisture levels. Crop-specific moisture thresholds are preprogrammed and can be selected using the **4x4 matrix keypad**. Once a crop is selected, the microcontroller references the stored moisture threshold to determine if irrigation is needed.

When the sensor detects moisture below the preset threshold, the microcontroller sends a signal to a **12V relay** to activate the water pump. When the desired moisture level is reached, the pump is turned off. The system status and moisture levels are displayed on a **16x2 LCD** for user feedback.

**Hardware Simulation**

The simulation environment includes the PIC microcontroller connected to an LCD, relay, keypad, and other components. The moisture sensor sends real-time humidity values, which are compared against programmed crop-specific data. The microcontroller processes the data and actuates the pump accordingly.

**Component Details**

- **Boost Converter**: Regulates voltage to the battery during varying sunlight conditions. Ideal for charging SLA, gel cell, and flooded lead-acid batteries [7].

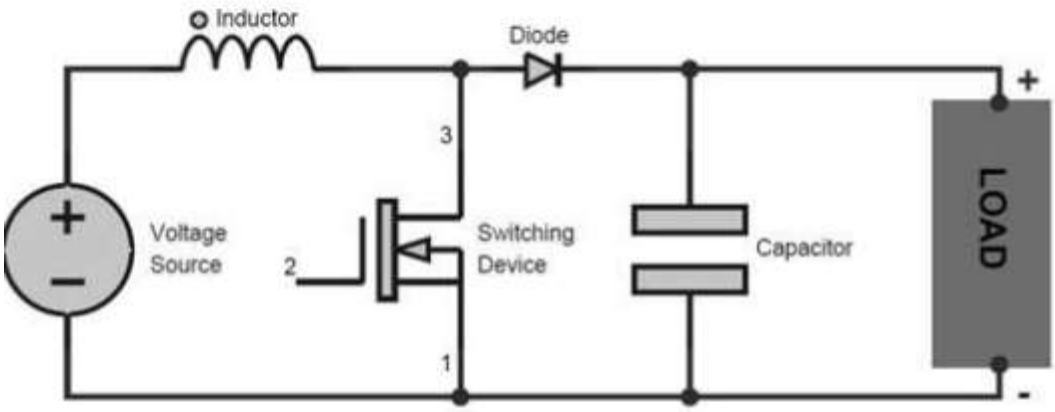


**FIGURE 2: Boost Converter.**

- **Regulator (IC 7805)**: Converts 12V DC from the battery to 5V DC required for the microcontroller and sensors [8].

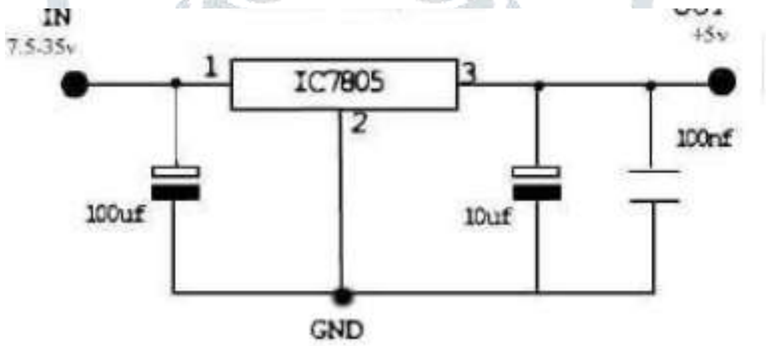


**FIGURE 3: IC 7805**

- **4x4 Matrix Keypad**: Crop selection interface, controlled using MCP23X08 IC with input/output and interrupt-on-change features [9].

**Proposed System Summary**

- **Input**: Soil moisture level, crop selection.
- **Processing**: PIC microcontroller logic based on stored crop-specific moisture thresholds.
- **Output**: Automatic water pump activation/deactivation.
- **Power**: Entire system powered via solar energy, with regulated supply for each component.

This design significantly reduces human intervention, ensures efficient use of water, and leverages renewable solar energy for sustainable agricultural practices.

## 4. Conclusion

When this program is introduced, the program proposed benefits the farmers. And with solar panel energy also useful to the government, addressing the energy crisis is a challenge. This automatic irrigation system is implemented when soil needs water is indicated by the sensor. Then the various crops also got irrigated by turning on the button with this device. The irrigation system measures the crop's humidity level according to the pressed button. For example, soil moisture content in Wheat, Paddy, Sugarcane crops is automatically detected and irrigated. Automatic irrigation system is utilized to maximize water usage by reducing waste and reducing human activity. Solar panel gives the energy needed to the water pump and control system. Small grid solar panels which can generate excess energy. By using solar energy it reduces the issue of the energy crisis. The device needs minimal maintenance and care, as they start themselves. Tracking arrays may be implemented to further enhance the daily pumping rates. This device shows the feasibility and application of using solar PV to provide energy for the sprinkler irrigation pumping demands. While this system needs more investment but after a long run of this system it solves more irrigation problem.

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