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Development of "AgroVolt X"

A Renewable Energy-Based Irrigation System for Rural Farming

Sujal Choudhary[1] , Deeksha Yaduwanshi[1] , Prof. Preeti Singh[2]
Department of Electrical Engineering
Medicaps University
Madhya Pradesh (Indore), India

[1] Students, Department of Electrical Engineering, Medi-Caps University, Indore-453331, India
[2] Faculties, Department of Electrical Engineering, Medi-Caps University, Indore-453331, India

Abstract: Finding dependable and affordable energy sources for irrigation is still a major problem in many rural and agricultural areas. By using solar energy to power agricultural water pumps, AgroVolt X offers a sustainable solution. The main goal of this project is to design and install a water pumping system for small to medium-sized farms that is powered by solar photovoltaics (PV). A submersible or surface water pump is used in the system to extract water from available sources, like wells or ponds, after solar panels transform sunlight into electricity. By reducing reliance on traditional diesel or grid-powered pumps, AgroVolt X seeks to minimize environmental impact and operational costs. The study illustrates the viability and effectiveness of using renewable energy for irrigation through site-specific design, cost analysis, and performance evaluation. The project supports energy access in off-grid areas, encourages environmentally friendly farming methods, and advances the larger objectives of rural development and sustainable agriculture.

1. Introduction

Many developing countries, including India, where a large share of the population depends on farming for survival, depend on agriculture as their backbone. Among the most important needs in agriculture is access to dependable and reasonably priced irrigation systems. Traditionally, farmers have drawn water from wells, canals, or rivers using grid-connected or diesel-powered pumps. These traditional techniques, though, have some drawbacks including high running expenses, environmental damage, and reliance on uneven power supply, especially in rural or remote areas where grid access is either unreliable or non-existent.

Adopting renewable energy sources in farming is becoming more and more necessary as the world moves toward sustainable development and clean energy. Particularly solar energy has become a feasible and environmentally friendly substitute because to its abundance, particularly in tropical nations such as India, where sunlight is accessible for most of the year. Powering water pumps with solar photovoltaic (PV) systems presents a possible way to solve the two problems of sustainable irrigation and energy access.

This study presents AgroVolt X, a solar-powered water pumping system meant particularly for agricultural use. By using solar PV technology, the project offers farmers a steady and reasonably priced water source,

so lessening their reliance on expensive diesel fuels and unpredictable power grids. Included in the system are solar panels, a controller, an inverter (if required), and a locally suited water pump.
By encouraging clean energy use, AgroVolt X not only helps to solve the technical and financial issues farmers have but also helps to preserve the environment. The system lowers greenhouse gas emissions, increases crop yields by means of timely watering, and encourages the effective use of natural resources by using solar power for irrigation.

The goal of this study is to:

- Design and put into operation a solar-powered water pumping system for farm irrigation.
- Study the system's performance and financial viability.
- Investigate how such systems affect sustainability and rural farming practices.

The present study also addresses the current body of work on renewable energy-based irrigation systems, the approach taken in creating AgroVolt X, system design criteria, performance assessment, cost analysis, and the possible scalability of the project for general use in rural areas.

2. Literature Review

Solar-powered irrigation systems have been extensively researched for their capacity to replace diesel pumps and lower dependence on grid power. [Jain and Mehta (2018)]'s study underlined the environmental and financial advantages of solar PV systems in irrigation, therefore stressing their long-term cost savings and reduced carbon emissions.

A case study by [Patel et al. (2019)] revealed the efficiency of a 1 HP solar pump in Gujarat, indicating it could meet irrigation requirements for small-scale farms with little maintenance. [Sharma and Singh (2021)] also investigated hybrid systems combining solar and grid power, discovering that although they provide more dependability, they raise complexity and cost.

Although these studies have been helpful, small farmers still lack low-cost, region-specific solutions. AgroVolt X solves these problems by providing a reasonably priced, efficient, practical solution for agricultural irrigation tailored to local circumstances.

3. Methodology

The AgroVolt X project's method is a methodical one comprising the design, selection, integration, and testing of a solar-powered water pumping system customized for agricultural irrigation. The project was conceived to provide rural farmers with an energy-efficient, affordable, and environmentally friendly irrigation solution. The main actions taken are as follows:

3.1 System Design Overview

The AgroVolt X system consists of the following core components:

- **Solar Photovoltaic (PV) Panels**
- **Charge Controller**
- **DC or AC Water Pump**
- **Inverter (if using an AC pump)**
- **Pipes and Water Storage Tank (optional)**

The design was done with cost limits in mind, solar availability in the area, and the water needs of small to medium-sized farms in mind.

3.2 Component Selection

1. **Solar Panels**
    - The average daily water need and solar availability guided selection of solar **PV** panels.
    - For instance, a **1 HP (Horsepower) DC submersible pump** typically requires around **1000–1500 Wp** of solar power.
    - High-efficiency **monocrystalline** or **polycrystalline** solar panels were considered.
2. **Water Pump**
    - To improve efficiency and direct compatibility with the DC output of solar panels, a **DC submersible pump** was selected.
    - The pump is capable of lifting water from a depth of up to **20–30 meters**, making it suitable for bore wells or small ponds.
3. **Charge Controller**
    - A **Maximum Power Point Tracking (MPPT)** charge controller was used to maximize energy extraction from the solar panels and regulate voltage.

4. **Inverter**
    - If an **AC pump** is used instead of a DC one, a **solar inverter** is installed to convert DC electricity from the panels to AC.

3.3 System Integration

- The components were interconnected as per the designed block diagram.
- To guarantee optimum sun exposure all year round, the solar panel array is installed at a tilt angle depending on the geographic area.
- To stabilize voltage and prevent overcharging or deep discharge, the charge controller links the solar panels and the pump.
- Piping and water outlets are installed based on the layout of the agricultural field.

3.4 Site Selection and Installation

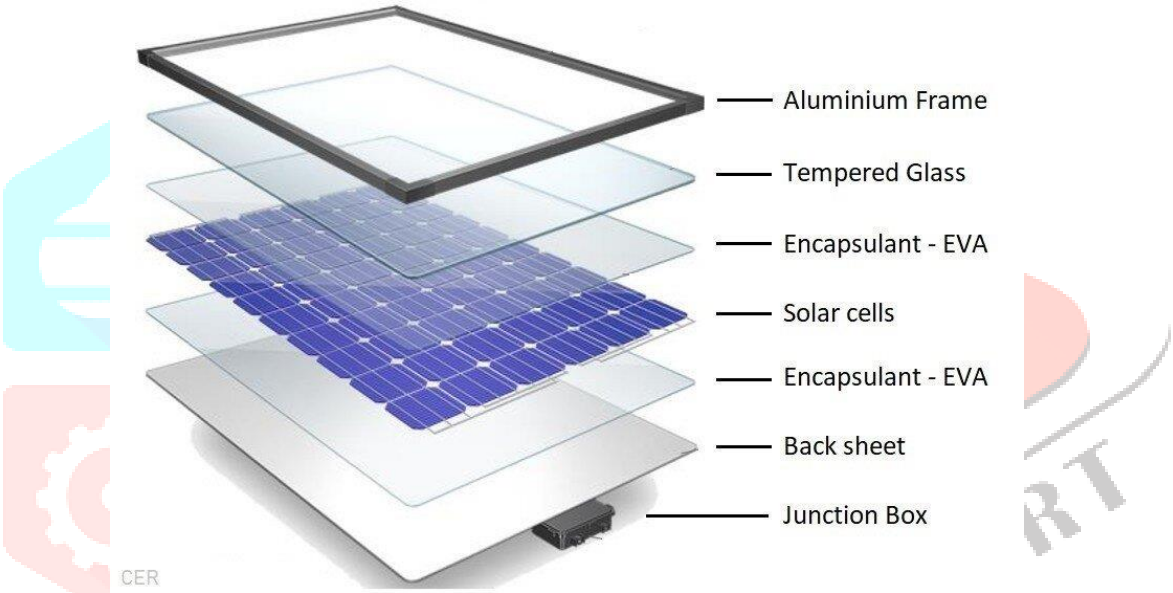
- A small-scale farm plot was chosen for practical implementation and testing.
- Soil, water source proximity, and sunlight availability were taken into account for installation.
- Proper earthing and weatherproofing were ensured to safeguard the electrical components.

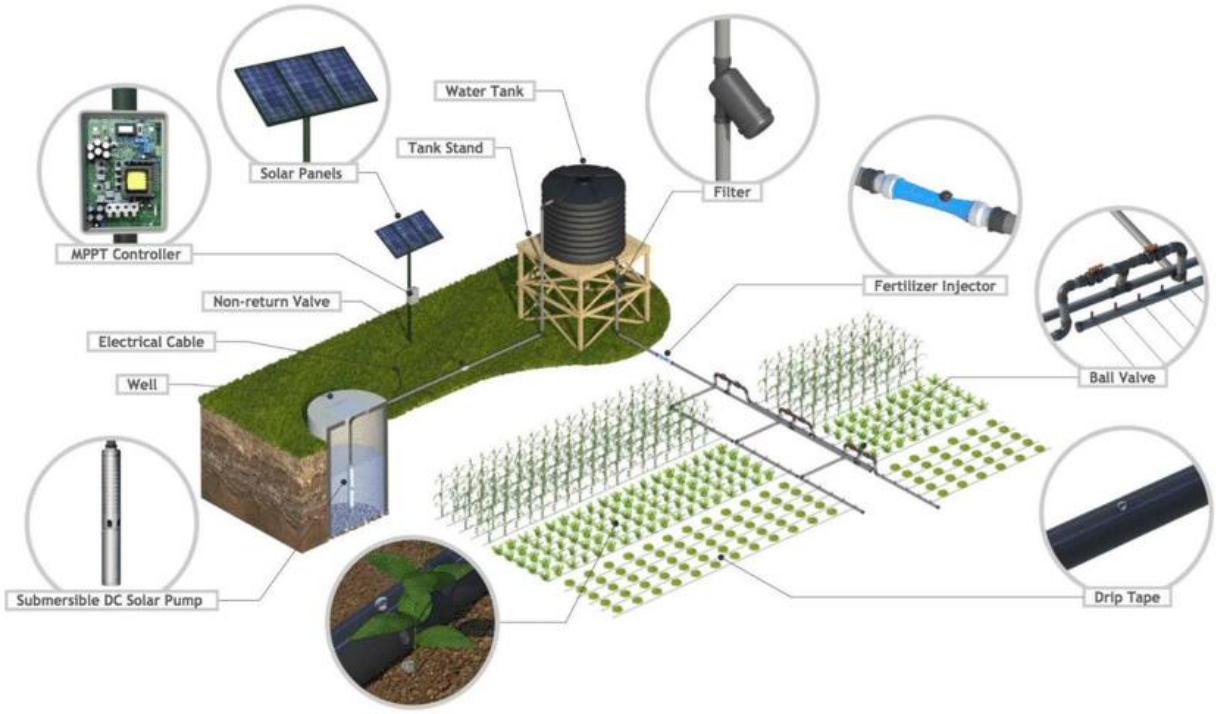
3.5 Testing and Performance Evaluation

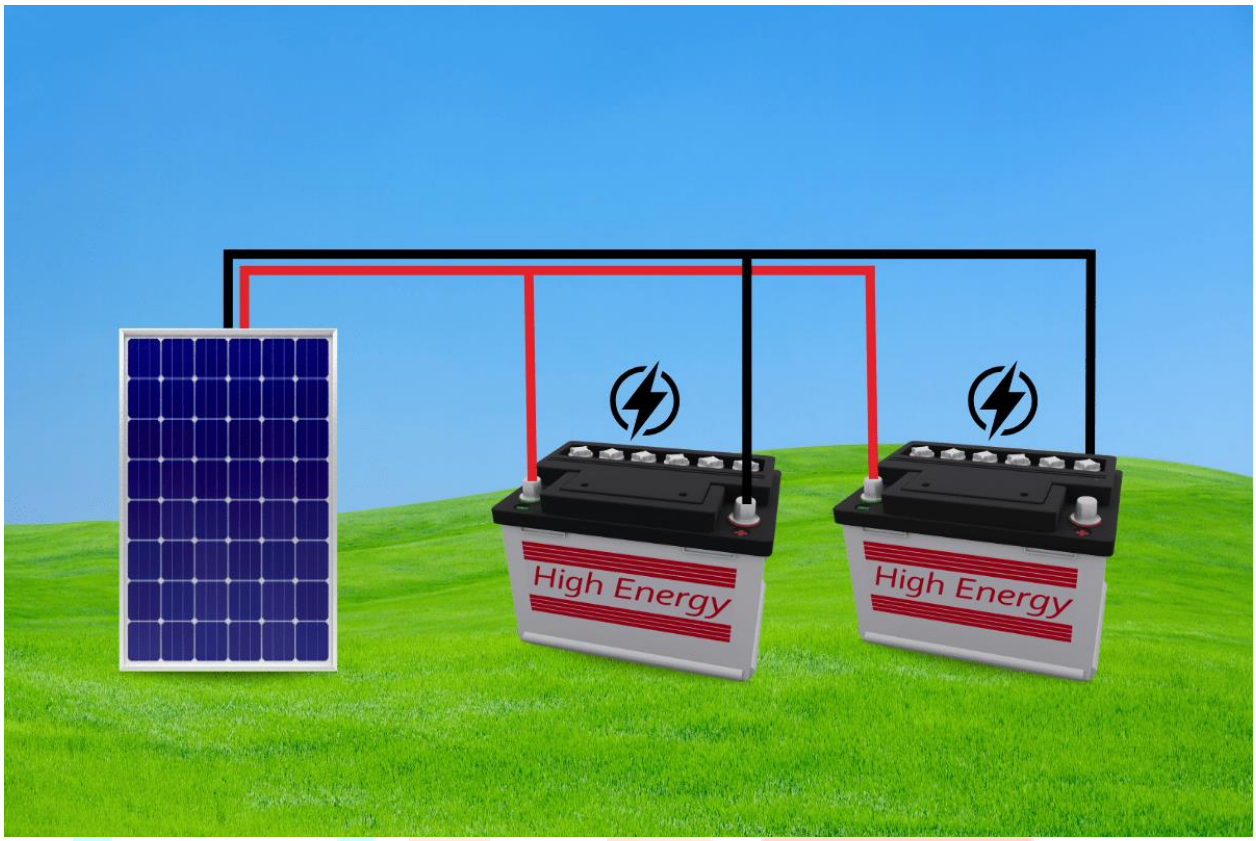
- The system was tested under different weather conditions (sunny, cloudy) to assess:
    - **Pump discharge rate**
    - **Energy efficiency**
    - **Water delivery time**
    - **Reliability and operational continuity**
- Observations were recorded and compared with conventional diesel/electric pump performance.

3.6 Cost and Feasibility Analysis

- A cost-benefit analysis was conducted to evaluate:
  - **Initial setup cost**
  - **Operating costs (zero for solar)**
  - **Return on investment (ROI)**
  - **Payback period**
- Feasibility was further assessed based on system maintenance needs and farmer acceptance.







4. Conclusion

By using solar energy to power water pumps, the AgroVolt X system offers a strong and sustainable solution for agricultural irrigation, therefore lowering the reliance on expensive and ecologically damaging diesel-based pumps. The project included the design, execution, and testing of a solar-powered water pumping system tailored for small to medium-sized agricultural farms. Results showing the system's capacity to satisfy the irrigation demands of rural farmers while supporting sustainable farming practices helped to evaluate its technical viability, cost-effectiveness, and environmental advantages.

Economically speaking, the system offers a notable return on investment (ROI) via its low running expenses and little maintenance needs. The study also showed that, when compared to traditional fuel-based irrigation systems, the payback time for the first investment is rather short, which makes it a practical choice for farmers with constrained funds. The system's scalability also allows it to be suitable for many different agricultural uses, from small home farms to bigger commercial operations.

All things considered, AgroVolt X is a hopeful renewable energy-based solution tackling several issues farmers face, such high operating expenses, inconsistent energy access, and environmental worries. The system has the potential to greatly affect agricultural production, lower energy costs, and support sustainability in farming practices by offering a reasonably priced, efficient, and environmentally friendly option. Larger-scale implementation of such systems could be instrumental in attaining energy security for rural areas and promoting sustainable agriculture worldwide.

Future studies will aim at improving the system design, broadening its relevance, and investigating hybrid systems combining solar energy with other renewable energy sources, therefore increasing the dependability and scalability of solar-powered irrigation.

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