Integrated Solar PV and Canal Based Micro Hydro Power Generation System

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Abstract - Agriculture in rural India faces significant challenges due to unreliable irrigation and inconsistent electricity supply, particularly in regions dependent on canal-based irrigation systems. Frequent power outages and irregular water flow reduce irrigation efficiency and increase dependence on diesel-powered pumps. This paper proposes a hybrid renewable energy system integrating solar photovoltaic (PV) and canal-based micro-hydro power to ensure reliable and continuous electricity for agricultural irrigation. Solar PV generates power during daylight using an MPPT controller, while a micro-hydro turbine harnesses canal water flow to supply energy during water availability. Both sources are coupled with a battery storage system to support uninterrupted pump operation. Experimental results demonstrate improved power reliability, reduced dependence on grid and diesel energy, and enhanced irrigation efficiency. The proposed system is cost-effective, eco-friendly, scalable, and effectively utilizes existing canal infrastructure, making it suitable for sustainable rural agricultural development

Key Words: Solar PV, Micro-Hydro Power, Irrigation, Battery Storage, MPPT

1. INTRODUCTION

Agriculture plays a vital role in India's rural economy, employing nearly half of the population and contributing significantly to national GDP. However, agricultural productivity is often limited by inefficient irrigation systems and unreliable electricity supply, particularly in canal-dependent regions such as North Karnataka. Canal irrigation networks frequently suffer from irregular water release, lack of flow monitoring, and inefficient distribution, resulting in poor water utilization and reduced crop yield. In addition, frequent power outages hinder the operation of irrigation pumps, forcing farmers to rely on expensive and polluting diesel generators.

Solar photovoltaic (PV) energy has emerged as a clean alternative for rural electrification but is constrained by weather dependency and nighttime unavailability. Meanwhile, the kinetic energy of flowing canal water remains largely untapped. To address these challenges, this paper proposes an integrated Solar PV and canal-based micro-hydro power generation system for agricultural irrigation. The system combines solar power during daylight with micro-hydro energy generated from canal flow, supported by battery storage for uninterrupted operation. By integrating renewable energy generation with canal infrastructure and flow-rate monitoring, the proposed system improves irrigation reliability, optimizes water usage, reduces dependence on grid and diesel power, and offers a sustainable, cost-effective solution for rural agricultural development.

2. BODY OF PAPER

1. **D. Sharma, S. Mishra, and J. Nanda, "Micro-Grid Operation and Control of Photovoltaic Power with Canal-Based Small Hydro Power Plant," IEEE Trans. Sustain. Energy, 2021**.
   This system integrates a canal-based micro-hydro turbine with solar PV panels using a coordinated control strategy. The hydro unit uses a governor to regulate turbine speed, while the PV system uses MPPT to extract maximum power under varying sunlight. In real-time, the system can balance the instantaneous load between hydro and PV sources, providing a stable micro grid operation.
   Limitation: Although effective for power stability, it does not fully consider battery storage management, sudden drops in canal flow, or intermittent solar irradiance, which can lead to temporary supply deficits

2. **Kumar and R. Singh, "Feasibility Study of PV–Micro Hydro Hybrid Systems for Electrification," IEEE Access, 2020**
   This study evaluates hybrid PV–micro-hydro systems for rural electrification, analyzing the complementary nature of solar and hydro resources. In simulations, hydro compensates for low solar output during cloudy periods, while solar assists when water flow is insufficient. **Limitation:** The work is mostly simulation-based and lacks practical real-time validation. Dynamic control of the system under variable load conditions and seasonal canal flow variations is not fully addressed.

3. **P. Wandhare, S. Thale, and H. Muchande , "Integrated Solar PV-Battery and Micro-Hydro Based Low-Voltage Autonomous DC Microgrid," Proc. IEEE ICPE, 2019.**
   This system implements a low-voltage DC microgrid combining PV, micro-hydro, and battery storage with hierarchical energy management. Real-time operation prioritizes sources based on availability, ensuring continuous supply to the load. The battery acts as a buffer to handle

transient mismatches between generation and demand. **Limitation:** While effective for small DC loads, scalability to higher load applications or handling variable canal flows in real-time is not fully tested

4. **J. Xue and B. Ning, "Improvement of Inverter Efficiency in Hydro–Photovoltaic Hybrid Power Station Using PSO," IEEE Trans. Power Electron., 2020.** Focuses on optimizing inverter efficiency in PV–hydro hybrid systems using Particle Swarm Optimization (PSO). In real-time, the inverter adjusts conversion parameters to minimize losses, improving overall system efficiency. **Limitation:** Real-time load variations, battery management, and dynamic integration with micro-hydro units are not addressed, limiting practical deployment for continuous operation.
5. **M. Patel and K. Deshmukh, "Hybrid Energy Model (PV–Hydro–Wind): MATLAB/Simulink Based Modeling," Proc. IEEE ICRES, 2020.** Uses MATLAB/Simulink to model PV–hydro–wind hybrid systems, predicting energy production, storage, and supply under different environmental conditions. The model demonstrates resource complementarity and energy sharing between sources in real-time scenarios. **Limitation:** Purely simulation-based; lacks prototype validation. The effect of fluctuating canal water flow, sudden shading, or MPPT response in real-time conditions is not evaluated.
6. **P. Cazzaniga, M. Rosa-Clot, and G. Tina, "Integration of Floating Photovoltaic Systems with Existing Hydropower Plants," Renewable Energy, 2021.** Studies PV panels installed on water surfaces integrated with hydro plants. In real-time, floating PV can contribute additional power without affecting hydro turbine operations. The approach improves land use and can smooth daily power fluctuations.
   Limitation: Focused on large-scale hydro; micro-hydro or canal-based applications are not experimentally tested. Small-scale real-time energy coordination is not addressed.
7. **Mauludin, R. Syamsuddin, and M. Taufik, "Techno-Economic Modeling of Hybrid PV–Hydroelectric Generator Systems Using HOMER," Int. J. Renew. Energy Res., 2020** Uses HOMER software to evaluate hybrid PV–hydro systems for cost, payback, and economic feasibilty. The model simulates different scenarios of water flow and solar irradiance in real-time to optimize system sizing.

BLOCK DIAGRAM OF THE SYSTEM

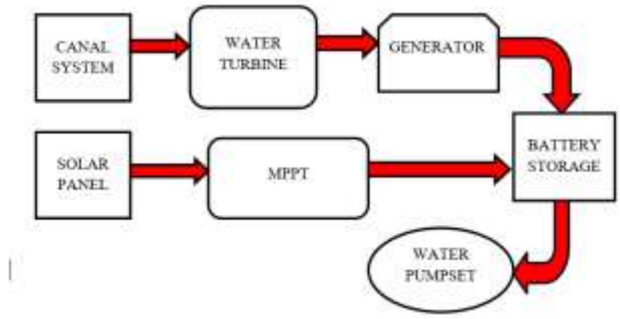

Figure.1: shows the block diagram of the proposed hybrid renewable energy system.

The system consists of a solar PV panel connected to an MPPT controller, a canal-based micro-hydro turbine coupled with a permanent magnet DC generator, a battery storage unit, and a DC water pump load. Both energy sources operate in parallel to charge the battery, which supplies regulated power to the irrigation pump, ensuring continuous operation.

WORKING PRINCIPLE

When canal water flows, it drives the micro-hydro turbine, converting kinetic energy into mechanical energy that is further converted into electrical energy by the generator. Simultaneously, the solar PV panel converts sunlight into DC electrical energy, which is optimized using an MPPT controller. Energy from both sources is stored in the battery and supplied to the irrigation pump, enabling continuous operation.

Table.1: Solar panel output

Condition	Output Voltage (V)	Observed photo
Without Battery Connected	19.17 V	
With Battery Connected	13.32V	

Table.2: Generator output

Parameter	Measured Value	Observed photo
Generator Output Voltage	21.8 V	

Table.3: Combined System Output

S.No	Source Condition	Output Voltage (V)	Remarks
1	Solar Panel Only	12.63 V	Depends on sunlight and angle of incidence.
2	Micro Hydro Generator Only	21.8 V	Achieved at turbine speed ~88.6 RPM.
3	Solar + Hydro (Combined)*	By combining both the output we are getting voltage approx.(34.43V)	Combined charging possible through controller; not tested in prototype.

DISCUSSION & ANALYSIS OF RESULT

The experimental results obtained from the prototype of the Integrated Solar PV and Canal-Based Micro Hydro Power Generation System clearly demonstrate the effectiveness of combining two renewable energy sources to achieve a stable and enhanced power output.

1. Solar Panel Performance:

The voltage generated by the solar panel without a battery was 13.32 V; with a battery, it was 19.17 V.

The increase in voltage with the battery shows good charging capability and better load regulation.

This shows that the solar PV unit can reliably support energy storage and compensate during low-light conditions.

2. Turbine Runner Speed Performance:

The turbine speed increased significantly from 48.8 RPM without pressure to 88.6 RPM with pressure.

This therefore confirms the importance of water pressure in increasing mechanical rotation, leading to increased power generation.

Even at small-scale, the canal-based flow effectively drives the micro-turbine.

3. Generator Output:

The generator output was 21.8 V, demonstrating that at prototype scale, the mechanical energy provided by the turbine is well-converted to electrical.

This exemplifies the capability of micro-hydro systems to supplement solar energy, especially at night or during cloudy conditions.

4. Combined Performance Interpretation:

The solar panel provides consistent daytime energy, while the micro-hydro system ensures continuous generation whenever water flow is available.

A water tank guarantees storage and controlled flow, hence improving turbine pressure and stability.

Collectively, the hybrid system enhances reliability, reduces dependence on a single source, and generally improves energy availability.

ADAVANTAGES

- ❖ Provides continuous power during day and night by utilizing solar energy in the daytime and canal-based hydro when water flows, improving overall efficiency
- ❖ Low operating and maintenance costs, with an eco-friendly, pollution-free operation.
- ❖ Efficiently uses existing canal water without requiring new infrastructure.
- ❖ Offers reliable power for irrigation pumps and other small loads.
- ❖ Easily expandable by adding more solar panels or turbines.
- ❖ Reduces dependence on grid electricity, making it suitable for remote areas.

APPLICATIONS

- ❖ **Agriculture & Irrigation:** Powers borewell and surface pumps, as well as small machinery like threshers, sprayers, and dryers.
- ❖ **Rural & Canal-Side Communities:** Supplies electricity to homes, schools, health centres, and community halls near canals.
- ❖ **Energy Storage & Backup:** Charges batteries and renewable energy banks for off-grid or backup use.
- ❖ **Environmental Monitoring:** Powers sensors and IoT devices for water and environmental monitoring.

3. CONCLUSIONS

The integrated solar PV and canal-based micro-hydro power generation system turns out to be a truly reliable, clean, and efficient hybrid energy solution that ensures continuous power supply for irrigation and rural applications through the combination of solar energy with the kinetic energy in flowing canal water.

It reduces dependence on grid electricity, promotes sustainable development, and makes effective use of the existing canal infrastructure. Overall, this hybrid approach presents a cost-effective and eco-friendly method for meeting the energy requirements of agricultural and remote areas.

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