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# Innovation of Solar Powered Irrigation System Based on IoT for Rice Fields in Tempuran Village

## Inovasi Sistem Irigasi Tenaga Surya Berbasis IoT untuk Persawahan di Desa Tempuran

**Rifqi Firmansyah[1]*, Rachmad Syarifudin Hidayatullah[2], Ali Nur Fathoni[2], Muhammad Rafli Fahrezy[4], Nabila Hannunnisa[5], Amelia Rahmi Wibowo[6].**
[13456]Department of Electrical Engineering, Universitas Negeri Surabaya, Indonesia
[2] Department of Mechanical Engineering, Universitas Negeri Surabaya, Indonesia
[1]rifqifirmansyah@unesa.ac.id , [2]rachmadhidayatullah@unesa.ac.id , [3]alifathoni@unesa.ac.id,
[4]rafli.fahrez@gmail.com , [5]nabila.hannun005@gmail.com , [6]ameliarahmi365@gmail.com

### *Abstract*

Tempuran Village, Mojokerto Regency, is a rice production center with a cumulative agricultural land area of approximately 30 hectares. However, productivity is still hampered by irrigation problems, as farmers only have two planting seasons per year due to the high operational costs of diesel pumps and limited fuel resources. In addition, repeated theft of pumps poses an even greater challenge to agricultural operations. These problems cause economic losses, reduced profit margins, and instability in water supply during the crucial period of rice growth. As a policy measure, a solar-powered pump system has been developed that is integrated with renewable energy technology and equipped with a GPS-based security system. The use of solar-powered pumps is estimated to reduce production costs by up to 40% by reducing dependence on fossil fuels, while enabling farmers to increase the frequency of cultivation to three times a year. Based on test results, the power output of solar panels is influenced by the intensity of solar radiation, with a maximum power of approximately 544.6 W and an average daily power of ±342 W, enabling the system to charge batteries and operate water pumps effectively in accordance with agricultural irrigation needs. In addition, this program also includes training for farmers on the use, operation, and maintenance of new irrigation technology to achieve long-term sustainability that contributes to the achievement of SDGs in access to clean energy [x1.1] (SDG 7), food security (SDG 2), and climate change mitigation and adaptation (SDG 13). The use of this technology will not only increase crop yields and farmers' incomes but also be a concrete step towards the modernization of renewable energy-based agriculture.

***Keywords:*** Solar pump, IoT, Agricultural irrigation, Renewable energy, Food security

### Abstrak

Desa Tempuran, Kabupaten Mojokerto, merupakan sentra produksi padi dengan luas lahan pertanian kumulatif sekitar 30 hektar. Namun, produktivitas masih terhambat oleh masalah irigasi, karena petani hanya menjalani dua musim tanam dalam setahun akibat tingginya biaya operasional pompa diesel dan terbatasnya sumber daya bahan bakar. Selain itu, pencurian pompa yang berulang kali menimbulkan tantangan lebih besar bagi operasional pertanian. Masalah-masalah ini menyebabkan kerugian ekonomi, berkurangnya margin keuntungan, dan ketidakstabilan pasokan air selama periode krusial pertumbuhan padi. Sebagai langkah kebijakan, dikembangkan sistem pompa listrik bertenaga surya yang terintegrasi dengan teknologi energi terbarukan dan dilengkapi sistem keamanan berbasis modul GPS. Penggunaan pompa bertenaga surya diperkirakan dapat mengurangi biaya produksi hingga 40% dengan mengurangi ketergantungan pada bahan bakar fosil, sekaligus memungkinkan petani untuk meningkatkan frekuensi kegiatan budidaya menjadi tiga kali setahun. Berdasarkan hasil pengujian, keluaran daya panel surya dipengaruhi oleh intensitas radiasi matahari, dengan daya maksimum mencapai sekitar 544,6 W dan daya rata-rata harian sebesar ±342 W, sehingga sistem mampu mengisi baterai dan mengoperasikan pompa air secara efektif sesuai dengan kebutuhan irigasi lahan pertanian. Selain itu, program ini juga mencakup pelatihan bagi petani tentang penggunaan, pengoperasian, dan pemeliharaan teknologi irigasi baru untuk mencapai keberlanjutan jangka panjang yang membantu pencapaian SDG dalam akses terhadap energi bersih (SDG 7), ketahanan pangan (SDG 2), dan mitigasi serta adaptasi terhadap perubahan iklim (SDG 13). Penggunaan teknologi ini tidak hanya akan meningkatkan hasil panen dan pendapatan petani, tetapi juga menjadi langkah nyata menuju modernisasi pertanian berbasis energi terbarukan.

**Kata Kunci:** Pompa surya, IoT, Irigasi pertanian, Energi terbarukan, Ketahanan pangan

## I. INTRODUCTION

Rural Indonesian farm productivity greatly depends on effective irrigation. Rice cultivation in Tempuran Village, Mojokerto Regency, covers approximately 30 hectares, yet farmers continue to face irrigation challenges. Farmers predominantly utilize diesel pumps, which are expensive to operate due to fuel prices and limited availability of fuel. Thus, farmers end up harvesting only two cropping seasons per year, reducing possible yield and profit margins. In addition, cases of pump theft further increase agricultural risks and financial losses [1][2].

Several studies have assessed renewable energy-powered irrigation systems, e.g., solar-powered pumps, as an alternative to reduce the consumption of fossil fuels [3][4]. Research shows that solar irrigation is also able to minimize operational costs with higher energy sustainability for agriculture [5][6]. At the same time, the use of Internet of Things (IoT) in agriculture has gained attention to enhance efficiency and asset security. IoT-based technologies provide remote monitoring, protection against theft, and optimization of irrigation control [2][7]. The majority of existing research on renewable energy adoption and IoT security is addressed separately but not properly combined with both approaches [8][9]. In addition, the lack of training for farmers often hinders the long-term adoption of new technologies [10].

Based on these conditions, the main problem addressed in this study is the lack of integrated irrigation systems that simultaneously ensure energy sustainability, operational cost efficiency, and long-term usability for farmers in rural agricultural areas. Existing irrigation practices remain vulnerable to high fuel dependence, security risks, and inadequate technical capacity for system operation and maintenance. The study suggests the implementation of a solar-powered irrigation system with an IoT-based security program [3][11]. The system will reduce the cost of irrigation, increase the cultivation cycle to three times a year from two times, and protect against pump stealing through alert messages and GPS tracking. The program also takes into account technological innovation and training of farmers on use and maintenance to ensure sustainability [11] [12].

The objective of this research is to develop and evaluate an irrigation system that is sustainable, enhances farm production, reduces dependency on fossil fuels, enhances the security of agricultural resources, and enhances Sustainable Development Goals (SDGs) achievement in rural areas.

## II. METHODS

Experimental research methodology is utilized in this study to design and test a solar-driven water pumping system. Figure 1 depicts the basic configuration of the proposed system. Hardware development, system design, and experimental testing are the three main phases of the research process.

### 2.1. System Design

The basic power source in the system is solar photovoltaic (PV) panels. The DC from the PV panels is controlled by a charge controller prior to charging the battery [2]. The water pump may be used at night or during low sun radiation hours using stored power. The pump motor receives constant alternating current (AC) supply from an inverter, and the equipment is protected against overcurrent destruction by providing fuses and micro circuit breakers (MCBs) with the supply.

### 2.2. Hardware Implementation

The solar-powered PV panels are the primary source of energy for the system. The direct current (DC) from the PV panels is controlled by the charge controller [8]. The energy generated by the PV modules will be stored in four battery units with specifications of 12 V and 26 Ah each configured in a series-parallel arrangement. This configuration allows two batteries connected in series to produce a voltage of 24 V, while the two series circuits are connected in parallel to increase the energy storage capacity to reach 52 Ah at a 24 V voltage system.

Figure 1. hardware of fotovoltage circuit

The stored energy is utilized to power the water pump at night or during the low solar radiation period.. A steady alternating current (AC) is provided to the pump motor from an inverter, while overcurrent damage is protected against by fuses and micro circuit breakers (MCBs).Various intensities of sun irradiation were used in the testing experiments. The charge controller regulates the energy flow between the battery and the PV module to prevent overcharging or deep discharge [14][15]. A converter in the form of an inverter converts DC power from the battery or PV module to AC power adequate for driving the water pump [5]. In addition, protective devices such as fuses and miniature circuit breakers (MCB) are included to safeguard the system against electrical faults. All the parts are wired according to the block diagram to provide safe and reliable power distribution to the system [11].

### 2.3. Experimental Testing

Voltage and current of the PV panels, battery, and pump were measured at certain parts of the day when the system was under test [16].

Figure 2. testing pump

To define the impact of sun intensity variations on the performance of the system as a whole, the data collected were further analyzed [4]. The data observed were then analyzed to verify voltage stability, current variations, and overall pumping efficiency. This measurement-based method leads to a full picture of the solar water pumping system's electrical behavior.

## III. RESULTS AND DISCUSSION

The solar performance test with solar power at the test facility showed voltage and current fluctuation in the observation day as anticipated with fluctuations in irradiance. In the early morning (05:00), the panels provided only about 8 V with a nearly zero current (0.001 A), which gave nearly zero power output (0.008 W) and contributed virtually nothing to battery charging or load supply.

From 07:30 onward, the panels began to operate in a useful range, with readings of 50.0 V and 7.2 A, generating approximately 360 W of power. This increase indicates that irradiance was sufficient to produce usable energy, enabling effective battery charging and supporting light loads from the PV system. This morning-to-noon transition period is crucial because it determines the duration of battery charging before the midday peak.

At 09:07, readings were 49.0 V and 9.2 A (450.8 W) and at 10:14 48.0 V and 8.2 A (393.6 W). These readings indicate that current (and thus irradiance) is the most responsive reading to changes in weather or position of the sun, and the MPP voltage was reasonably stable at about 48–50 V throughout the readings. The daytime rise in current towards noon accelerates battery charging and increases power supplied to the load by the inverter.

Maximum field values at 15:21 were 50.9 V and 10.7 A, giving almost 544.6 W. This was the day's maximum power point, meaning that afternoon irradiance was adequate to improve PV output, though not to full nominal capacity (4 × 550 Wp = 2200 Wp). Therefore, even with periods of maximum power, the duration of this maximum was quite brief, and thus the daily energy integrated was far below the theoretical module capability.

At 16:30, readings were 50.5 V and 6.0 A (303 W), marking a decrease in current as evening approached. The observed power range throughout the day (from 0 W at dawn to a peak of 545 W) produced an average power of approximately 342 W, which forms a realistic basis for estimating battery charging and runtime under measured field conditions. Based on field implementation, performance data was collected for 7 days by following the same daily observation time interval as presented in this study. The average module current was about 6.88 *A* based on the six measurements. The results are in Figure 2.

Figure 3. graph PV performance

If the system is expected to supply two 350 W pumps (total 700 W), the continuous AC-side energy requirement is 700 W (3.18 A at 220 V). However, on the DC (battery) side, a higher current is needed due to inverter efficiency. Assuming a 90% inverter efficiency, the required DC current is approximately 32.4 A; without accounting for inverter losses, the DC current is 29.2 A. Therefore, a 24 V battery system must be designed to supply tens of amperes when the pumps operate from the batteries.

Battery runtime and charging time estimates indicate operational limitations if only the average PV power from the test day is used. For a battery configuration of 4 × 12 V (series-parallel) with 100 Ah per battery (total 24 V, 200 Ah), stored energy is 4,800 Wh. If the pumps operate solely from the batteries, the theoretical runtime is about 6.2 hours (using 4800 Wh - 777.8 W DC including inverter losses). Meanwhile, full charging of the batteries from empty by using the calculated average PV power (342 W) and total charging efficiency of 85% would require 16.5 hours of equivalent sunshine i.e., several full-sun days are needed to recharge from empty, or the peak PV power should be significantly higher to compensate. When battery capacity is increased (200 Ah per battery → total energy 9,600 Wh), runtime and charging time increase proportionally (runtime 12.3 hours, full charging with average PV 33 hours).

## IV. CONCLUSION

This test managed to convincingly demonstrate that the solar panels are sufficient to supply the pumps with the power required, even though the power output is a function of solar radiance. The highest recorded power was approximately 544.6 W with an average daily power of approximately 342 W, still short of the nominal panel capacity of 2200 Wp. This implies that real operational conditions such as weather and time of the day significantly affect the efficiency of the PV system. However, to power two pumps of cumulative capacity 700 W continuously, the system relies on batteries as an energy buffer. With a battery bank of 24 V and 200 Ah, the pump running time would be around 6.2 hours, while charging the battery to capacity using the mean PV power would require about 16.5 hours of useful sunlight. Therefore, additional solar panels and battery capacity are recommended to make the system operate more economically and sustainably during unfavorable weather conditions.

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## VI. CONTRIBUTION OF AUTHOR(S)

RF and RFH: Methodology, Software, Content analysis, Research, Manuscript writing - Original draft, Manuscript Writing – Review and Editing. ANF and MRF: Conceptualization, Verifying the accuracy of experimental results, Material procurement, Advisory/Supervisory. NH and ARW: Verifying the accuracy of experimental results, Material procurement, Advisory/Supervisory.

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*Corespondent e-mail addres zainalabidin@unisla.ac.id

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# DAFTAR GAMBAR

Figure 1 hardware of fotovoltage circuit

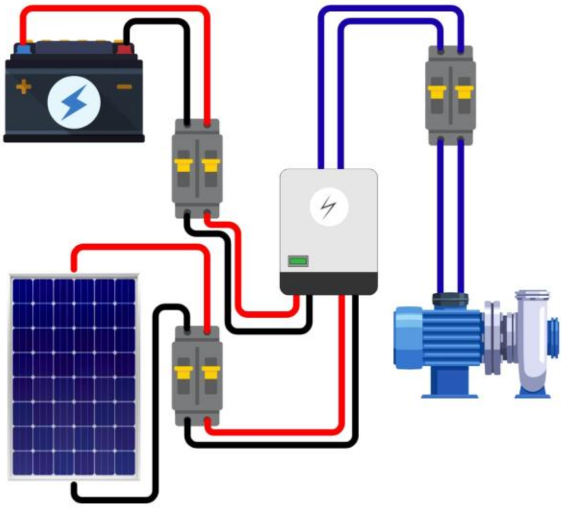

Figure 2 testing pump

Figure 3 graph PV performance