

IoT Monitoring for PV System Optimization in Hospital Environment Application

Kemas Andi^{1*}, Raden Kusumanto², Syahirman Yusi³

Applied Master of Renewable Energy Engineering, Universitas Palembang, Indonesia^{1*}

Electrical and Occupational Safety and Health Section, RSI Siti Khadijah, Indonesia^{1*}

Electrical Engineering Department, Politeknik Negeri Sriwijaya, Indonesia²

Business Administration Department, Politeknik Negeri Sriwijaya, Indonesia³

kms.andi1977@gmail.com



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Abstract

Purpose: The objective of this study is to implement IoT monitoring to remotely monitor PV system output and efficiency to ensure the continuous supply to ventilators and monitors in the ICU Room of RSI Siti Khadijah Palembang.

Methodology/approach: The approach implemented in this study is by installing IoT Monitoring as an automatic transfer switch to ensure the continuous supply for the load.

Results/findings: The IoT monitoring shows the real-time production of PV panels, battery capacity, and inverter output. Hence, the operator can monitor the PV system output and decide whether to keep using sources from PV panels or switch to grid utilities during cloudy/rainy days.

Limitations: The IoT monitoring system has supervised the system's reliability, but it is necessary to improve the output and efficiency of the PV system by adding artificial intelligence algorithms and installing active cooling to prevent overheating.

Contribution: This study shows the effectiveness of implementing IoT monitoring for the On-Grid PV system installed on the rooftop of RSI Siti Khadijah Palembang.

Keywords: *Building Integrated PV, On-Grid PV System, Photovoltaic, Solar Energy*

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1. Introduction

Given Indonesia's depletion of fossil fuel reserves, the application of renewable energy is critical. Indonesia is endowed with numerous renewable energy sources, ranging from solar to tidal, such as wind energy investigated by [Wardhana, Taqwa, and Dewi \(2019\)](#) and [Yuliandi and Dewi \(2018\)](#). Given its tropics location, Palembang, the capital of South Sumatra, has a high potential for solar energy, as explored by [Tresna Dewi et al. \(2016\)](#); [Tresna Dewi, Risma, and Oktarina \(2019\)](#); [Yudha, Dewi, Risma, and Oktarina \(2018\)](#); and [Junianto, Dewi, and Sitompul \(2020\)](#). Solar energy electricity promises long-term sustainability for modern life in the economy, health, and education sectors ([Sasmanto & Dewi, 2020](#)). Solar energy promises a cleaner environment because it produces no CO₂ emissions during its operation. Solar plants on a large scale, a small scale, or even a housing scale can be realized in an urban area or city and used as the primary or secondary source of electricity, which were investigated by [Zhafarina, Dewi, and Rusdianasari \(2018\)](#); [Mases and Dewi \(2021\)](#); and [Putra and Dewi \(2021\)](#). Solar power plants are highly dependent on geographical factors ([Sarwono & Kusumanto, 2021](#)); ([Setiawan, Dewi, & Yusi, 2019](#)), but most of Indonesia has high solar energy potential ([Junaedi, Dewi, & Yusi, 2021](#)); ([Nurjanah & Dewi, 2021](#)); ([Tresna Dewi, Taqwa, Kusumanto, & Sitompul, 2021](#)). Even in a city, the electricity supply is not always stable, so a backup power source is required for critical sectors where a power outage can be fatal ([Edward & Dewi,](#)

2019); ([Hamdi & Dewi, 2019](#)). Hospitals are one of the critical sectors that require a continuous supply.

The government is currently strongly encouraging the health and the renewable energy sector; therefore, merging the application of renewable energy in the health sector will be very beneficial, as mentioned by [IRENA \(2017\)](#) and [Yudiartono, Anindhita, Sugiyono, Wahid, and Adiarso \(2020\)](#). Hence, solar power plants will be highly beneficial to hospitals. Internet technology is rapidly expanding and encompasses all aspects of life, including solar energy.

The current issue of PV system implementation is how to optimize the output and efficiency regardless of the environmental impact of PV panels, such as tropical heat ([Arissetyadhi, Dewi, & Kusumanto, 2020](#)); ([Tresna Dewi et al., 2019](#)); ([Tresna Dewi, Taqwa, Kusumanto, et al., 2021](#)), intermittent irradiance due to shading or partial shading ([Rosyadah, Kusumanto, & Dewi, 2022](#)). However, these limitations do not stop researchers from keeping on integrating PV systems into daily life, such as the possibility of automatic vehicles ([T Dewi, Risma, Oktarina, Taqwa, & Renaldi, 2020](#)); ([Putra & Dewi, 2021](#)); ([Mases & Dewi, 2021](#)); ([Sujati, Dewi, & Rusdianasari, 2021](#)), and ([Septiarini, Dewi, & Rusdianasari, 2021](#)). Another way to ease the PV system users to monitor their panels is by integrating it with internet technology, such as the Internet of Things (IoT). IoT makes it easier for solar energy users to track the output and efficiency of the installed solar power plants ([Taqwa, Kusumanto, & Dewi, 2018](#)).

This research presents the implementation of a PV power plant in hospital environments where an On-Grid PV system is installed as the alternative power source ([Alamoudi, Taylan, Aktacir, & Herrera-Viedma, 2021](#)); ([Ghaleb & Asif, 2022](#)); ([Kim, Cho, & Kim, 2014](#)). This paper discusses the installation of a solar power plant at the Siti Khadijah Islamic Hospital in Palembang. This solar power plant provides backup power in the ICU room. This paper demonstrates the benefits of using solar energy over backup batteries or UPS.

2. Literature review

Solar energy can be an excellent alternative for energy generation as the primary source or the alternative one. The feasibility of harvesting solar energy in Palembang has been investigated by ([Tresna Dewi et al., 2019](#)); ([Arissetyadhi et al., 2020](#)); ([Sasmanto & Dewi, 2020](#)); and ([Harahap & Dewi, 2019](#)). Those research results show that maximum power can be achieved due to the geographical location of Palembang, although the application of solar energy will be more beneficial in highland and remote areas, as presented by ([Sarwono & Kusumanto, 2021](#)).

[Tresna Dewi, Taqwa, Sitompul, and Kusumanto \(2021\)](#); [Tresna Dewi et al. \(2019\)](#); [Harahap and Dewi \(2019\)](#), and [Arissetyadhi et al. \(2020\)](#) optimized the output and efficiency of PV systems installed in Palembang; however, even though there is still a possibility of overheated in some parts of South Sumatra, the downside of the possible overheated panel is negligible compared to the benefits gain by this application. [Tresna Dewi et al. \(2019\)](#) stated that the factors affecting the efficiency and output of solar panels could be overcome by adjusting the panel to the environmental conditions, such as ensuring the application of MPPT (given by [Putra and Dewi \(2021\)](#)). Considering these references, the feasibility of implementing solar energy for hospital environments in Palembang is very high. [Alamoudi et al. \(2021\)](#) present the possibility of a PV system for hospital environments using RSM, and ANFIS approaches.

This paper presents the application of a PV system in a hospital environment, and IoT monitoring is installed to monitor PV system output and ensure continuous supply to ventilators and monitors in ICU Room.

3. Research methodology

This paper presents the implementation of on-grid solar panels in a hospital environment. Figure 1 shows the block diagram of this implementation where the on-grid solar panel is connected to the

solar charge controller to ensure the safety of battery charging; hence, the overcharging or undercharging will not occur, and battery life is preserved. The inverter needs to convert DC output from PV panels to power a Ventilator in the ICU room of RSI Siti Khadijah. The IoT Monitoring receives inputs from current and voltage sensors; therefore, the user can monitor the production of PV panels installed on the rooftop of RSI Siti Khadijah. Exercise

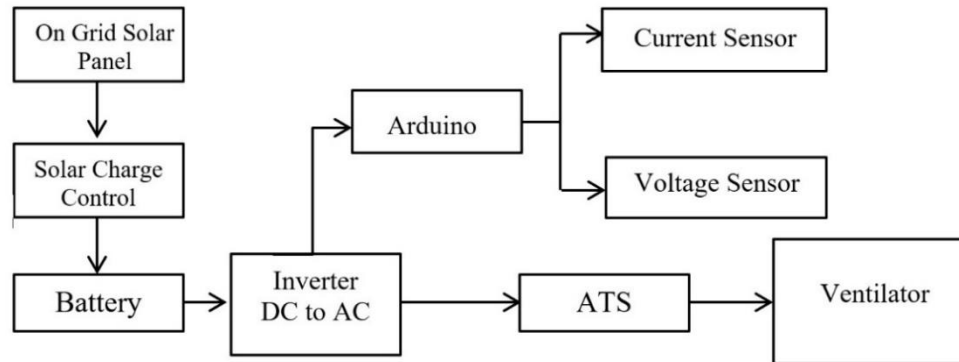


Figure 1. Blockchain distributed ledger technology.

3.1. Output and Efficiency Solar Cell

Figure 2a shows a PV panel modelled as an ideal diode. This model is obtained when the PN junction semiconductor is wired, and electricity is applied. Electrons flow to the positive side, and holes flow to the opposing side. During this motion, the number of electrons and holes in the middle of the junction is the same, forming a neutral barrier (Klaus, Olindo, Arno, Van Swaaij, & Miro, 2014). The generated current (I) is given by

$$I = I_{ph} - I_0 \left(e^{\frac{V + IR_s}{AkT}} - 1 \right) - \frac{V + IR_s}{R_{sh}} \quad (1)$$

where I_{ph} is the photocurrent, R_s is series resistance, R_{sh} is shunt resistance, I_D is voltage-dependent current due to recombination, and V is voltage. The IV curve gives the maximum power produced by a solar cell (P_{MP}) in Figure 2b, which is the function of short-circuit current (I_{sc}) and open-circuit voltage (V_{oc}). The efficiency of a solar panel is

$$\eta = \frac{P_{out}}{P_{in}} \times 100\% = \frac{I_{mp} \cdot V_{mp}}{P_{in}} \times 100\% = \frac{I_{sc} V_{oc} FF}{P_{in}} \times 100\%, \quad (2)$$

where I_{mp} and V_{mp} are the maximum current and voltage, E is the solar energy and is the fill factor.

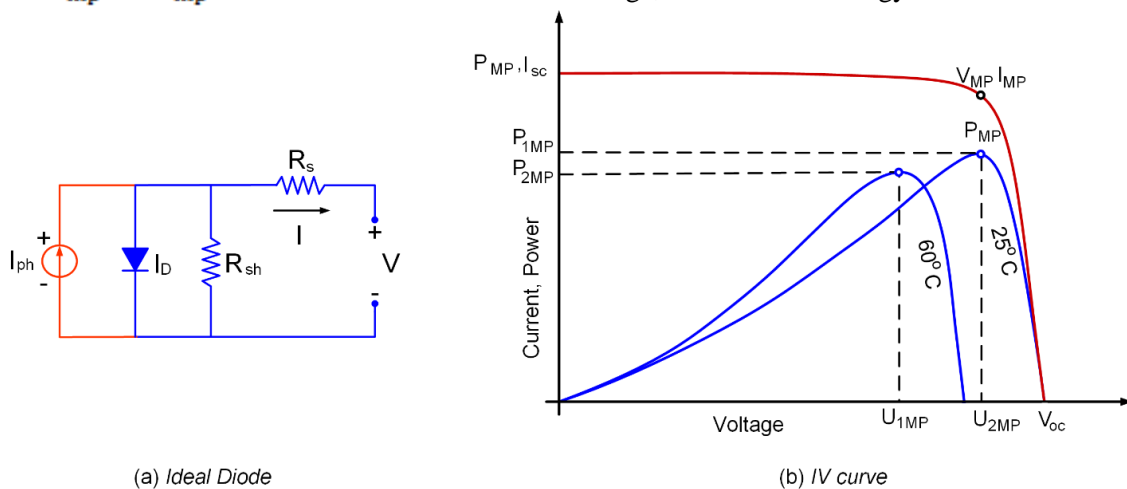


Figure 2. Solar cell modeling as an ideal diode

3.2. IoT Monitoring

The IoT Monitoring installed in this study gets input from voltage sensor ZMPT101B, voltage divider to supply sensor which consists of Resistors $R_1=150\text{ K Ohm}$, $R_2=5,7\text{K Ohm}$, wifi sensor NODEMCU 8266, microcontroller Arduino Nano and shield, and <https://io.adafruit.com/> as IoT interface as illustrated in Figure 3.



Figure 3. IoT monitoring of PV system installed in RSI Siti Khadijah Palembang

3.4. Discussion

This paper presents the On-Grid PV System installed on the rooftop of a hospital building in Palembang, Indonesia, as shown in Figure 4. The PV system consists of 15 120 Wp panels, charge controllers for 4 batteries, ATS for switching to On-Grid utilities, and an Inverter connected to ventilators and monitors in the ICU Room of RSI Siti Khadijah Palembang; and Figure 5 shows the combiner box of the PV system.



Figure 4. IoT Monitoring Result

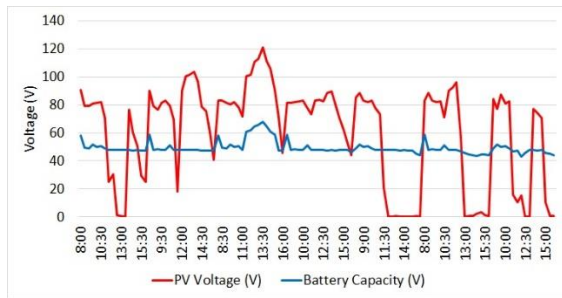


Figure 5. Combiner Box

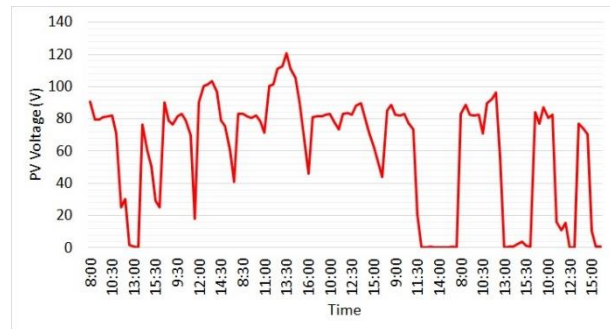
The PV system can produce the maximum power is 1800 Wp as the result of 15 installed panels with 120 Wp each; however, due to the efficiency limitation of silicon-based solar panels, the highest power produced is 300-400 Wp per day. Figure 6 shows the IoT monitoring interface consisting of battery capacity (AKI), inverter input, and power produced by solar panels. The IoT monitoring's objective is to ease PV systems operator to monitor the conditions of PV panels output and whether they should be switched to the utility grid during the cloudy/rainy days or stay using battery charged by the PV system.



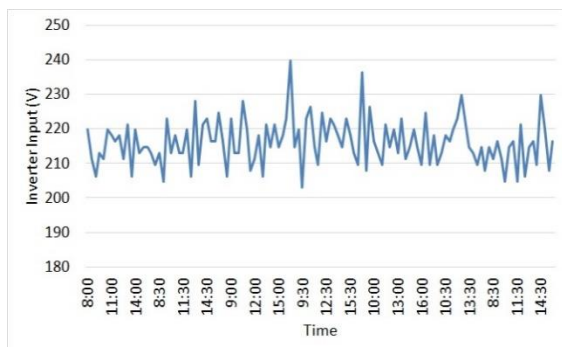
Figure 6. IoT Monitoring Interface



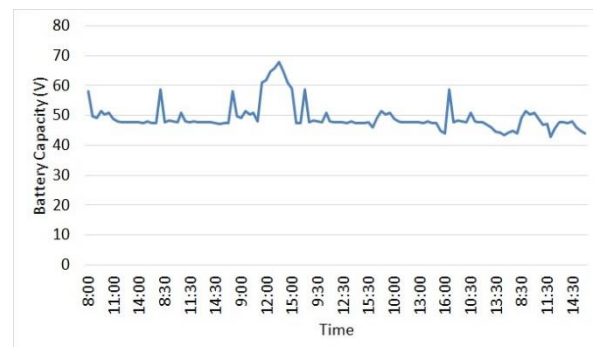
(a)



(b)



(c)



(d)

Figure 7. PV systems output for 7 days

Figure 7 shows the PV systems output for a week, where the data is taken from 08.00 AM to 04.00 PM. Figure 7a shows the PV panels voltage output compared to battery capacity, and Figure 7c shows the inverter output to power ventilators and monitors. Figure 7c illustrates how the voltage is always in the safe range to power the equipment in ICU rooms. The IoT monitoring results show that the proposed method effectively monitors the continuity supply for the load in a hospital environment. Future research is implementing MPPT algorithms and active cooling devices to improve the output and efficiency of the PV system.

4. Conclusion

This paper presents the implementation of IoT monitoring on an On-Grid PV system installed on the rooftop of a hospital environment. The PV system is to power the ventilator and monitors in ICU rooms, which are crucial to a patient's life since any electricity outage can be fatal. The experimental results show that PV systems output is stable to charge batteries and ensure the inverter output voltage is always within the safe range to give continuous power to the load. Applying a PV system is much more beneficial than using the pricey and short-lifetime UPS battery. Future research is implementing MPPT algorithms and active cooling devices to improve the output and efficiency of the PV system.

4.1. Limitation/s and study forward

This study has implemented IoT monitoring to ensure that the PV system is running well, giving continuous supply to ventilators and monitors in ICU rooms. However, the system can be optimized more by implementing MPPT algorithms and active cooling devices to improve the output and efficiency of the On-Grid PV systems installed on the rooftop of RSI Siti Khadijah.

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