A preliminary test of solar roof top in Medan city of Indonesia

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Abstract. A friendly city must be developed with low carbon emission to make it also friendly for climate change. Solar energy resource is abundantly present around the roof. Solar roof top is a promising application to build a friendly city. In this work, a preliminary test of solar roof top in Medan city of Indonesia is carried out. Eight Solar PV modules are installed on the roof of a building in Medan. The specifications of each module are as follows. The rated power and Voltage are 250Watt peak and 30.5 Volt, respectively. The dimension and the weight of each module are 160 mm × 992 mm × 35 mm and 19 kg, respectively. The solar irradiation, voltage and current are measured and recorded. The performances of the system are discussed.

1. Introduction
Ninety-five per cent of the primary energy requirement in Indonesia is met through fossil fuels-oil, gas and coal. It’s has a potential impact on global climate change. Alternative sources such as solar energy and biomass energy are needed to reduce the GHG emissions [1]. Indonesia is potential for solar energy. The amount of energy absorb Indonesia’s location on the equator makes solar radiation can continue throughout the year without experiencing seasonal constraint. Solar energy has become immensely popular as an alternative energy source due to the fact that solar energy is clean, environmentally friendly and secure power source. Generation of electricity through solar photovoltaic (PV) system is clean, reliable and environment friendly. Solar PV system have the potential to become a major source of electricity generation in future due to rapid reduction of fossil fuel. Photovoltaic offer the consumer potential to generate energy in a smooth, quiet and reliable manner [2].

Today’s the introduction of the rooftop PV system in urban regions using the rooftop area of a building is being actively. Having solar panel installed on roofs can more self-sufficient user and reduce the need for additional power generating capacity in the future [3]. A number of research has been conducted on the topic of building rooftop PV installation potential in many countries [4-6]. However, less studies have been reported for urban situations. Alshayeb and Chang reported the differences of PV panel temperature and energy production for those installed over a green roof (2.1 kW) and those installed over a black roof (2.1 kW). Results show that PV panels on a black roof are ranged from 1.1 °C to 2.3 °C hotter than PV panels on a green roof, a PV panel installed on green roof can increase the energy production up to 1.4% for a whole year [7]. Imad ibrik and Fadia hashaika applied solar rooftop photovoltaic system for school in Palestine. The system installed 7.68 kWp on the rooftop of each three schools. Average annual energy produces by each system equal 10.930 MWh/year [8]. Yousef gharbia and Mohammed Anany investigated the technical and economic feasibility of installing PV system on local gas stations rooftop in Kuwait. The Panasonic HIT PV model was chosen based on its system for the available rooftop area of 422 m² [9]. Wang Mudan et al.
explored the potential of urban rooftop photovoltaic (PV) power for reduction emission in Beijing. This paper show that the rooftop PV reduction emission estimated 919.34 g CO$_2$-eq/kWh [10]. Elieser tarigan analysis the rooftop photovoltaic (PV) system on building roofs on the University of Surabaya, Indonesia for electricity power generation. The total capacity of the panel is found about 3.180 MWh per year and could supply up to 80 % of campus energy demand [11].

The aim of this paper is to present results obtained from field performance monitoring of rooftop mounted PV in Medan, Indonesia. The rooftop PV system is described performance evaluation parameters are presented based on collected data. The work would calculate the power rate, voltage, radiation, energy yield and performance ratio. Results obtained give an indication of system performance PV generated electricity and inform policy formulation to promote uptake of the technology in Medan city of Indonesia.

2. Methods

The photovoltaic system was installed at Medan city of Indonesia. Medan is located on the latitude 3° 35’ N and longitude 98° 40’ E, and about 37.5 metres above sea level. The system installation consisted of eight modules covering a total area 13.01 m$^2$ with an installed capacity 2 kW$_p$ within the range of topical domestic installations. The solar PV module were each of 250 Wp capacity and comprised 60 solar cells made of poly-crystalline silicon. The module were fixed, the inclined at an angle of $0^\circ$.

![Figure 1. The PV system installation](image)

| PV module | Specification |
|-----------|---------------|
| Type      | Poly-crystalline silicon |
| Rated Power ($P_{max}$) | 250 W |
| Voltage at Pmax ($V_{mp}$) | 30.5 V |
| Current at Pmax ($I_{mp}$) | 8.20 A |
| Open-circuit Voltage ($V_{oc}$) | 36.0 V |
| Short-circuit current ($I_{sc}$) | 8.86 A |
| Size      | 1640 x 992 x 35 mm |
| Weight    | 19 Kg |
| Cells     | 60 pcs poly-crystalline silicon |
| Standard test condition | 1000 W/m$^2$, AM 1.5, 25 °C |
| Tolerance | +/- 3% |
Table 2. Inverter specifications

| Inverter Mode                  | Specification                  |
|-------------------------------|--------------------------------|
| Rate power                    | 3200 W                         |
| DC input                      | 24 VDC, 15 A                   |
| AC output                     | 230VAC, 50/60Hz, 13.9A, 1φ     |
| AC Changer Mode               |                                |
| AC input                      | 230VAC, 50/60Hz, 13.9A, 1φ     |
| DC output                     | 27 VDC                         |
| AC output                     | 230VAC, 50/60Hz, 13.9A, 1φ     |
| Solar Changer Mode            |                                |
| Rate power                    | 4000 W                         |
| Nominal operating voltage     | 360 VDC                        |
| Max. Solar voltage (VOC)      | 500 VDC                        |
| MPPT voltage range            | 120 to 450 VDC                 |

Table 3. Equation for performance indices [4]

| No | Indices | Expressions |
|----|---------|-------------|
| 1  | Final energy output |
|    | Hourly   | $E_{AC,h} = \sum_{t=1}^{60} E_{AC,t}$ (1) |
|    | Daily    | $E_{AC,d} = \sum_{h=1}^{60} E_{AC,h}$ (2) |
|    | Monthly  | $E_{AC,m} = \sum_{d=1}^{60} E_{AC,d}$ (3) |
| 2  | Energy yields |
|    | Array yield | $Y_A = \frac{E_{DC}}{P_{PV,\text{rated}}}$ (4) |
|    | Final yield | $Y_F = \frac{E_{DC}}{P_{PV,\text{rated}}}$ (5) |
|    | Reference yield | $Y_R = \frac{H_t}{H_R}$ (6) |
| 3  | Efficiency |
|    | Array efficiency | $\eta_{PV} = \frac{100 * E_{DC}}{H_t * A_m}$ (7) |
|    | System efficiency | $\eta_s = \frac{100 * E_{AC}}{H_t * A_m}$ (8) |
|    | Inverter efficiency | $\eta_{inv} = \frac{100 * E_{AC}}{E_{DC}}$ (9) |
| 4  | Losses |
|    | Array losses | $L_A = Y_R - Y_A$ (10) |
|    | System losses | $L_F = Y_A - Y_F$ (11) |
| 5  | Performance ratio | $PR = 1 - L_A - L_F$ (12) |

Definition of symbols: $E_{AC,t}$ is AC energy output at time t (in minutes); $E_{AC,h}$ is AC energy output at hour h; $E_{AC,d}$ is the daily AC energy output; $E_{AC,m}$ is the monthly AC energy output; $N$ is the number of days in a month; $H_t$ is the in-plane solar radiation; $H_R$ is the reference irradiance; $P_{PV,\text{rated}}$ is the PV array rated power; $E_{DC}$ is the DC energy output (kW h); $E_{AC}$ is the AC energy output (kW h); $A_m$ is the
total module area (m²); \( Y_A \) is the array yield; \( Y_F \) is the final yield; \( Y_R \) is the reference yield; \( L_A \) is the array capture losses; \( L_F \) is the system losses and \( PR \) is the performance ratio.

3. Results and Discussions

Potential of rooftop Photovoltaic installation and photovoltaic power generation are presented. This study described the design and implementation of solar rooftop systems, including their monitoring systems, and the experiments to analysis the performance of solar rooftop systems. Performance was based on the energy output, AC power output, and performance ration of the PV panels.

3.1. Performance Analysis

In order to analyse the energy related performance of PV system, some important parameters are to be computed using data collected during its operation in a given location. These parameters include: the total energy generated by the PV system, power output, and performance ratio (PR).

3.1.1. Energy output

The instantaneous energy output was obtained by measuring the energy generated by the PV system after the DC/AC inverter on 1 min intervals. Figure 1 show the total energy generated by the PV system over monitored period. The total energy generated by PV system was 492.303 kW h per day.

![Figure 1. Total energy generated over the monitored period](image)

3.1.2. Power output

Figure 2. Show the total power input affected by solar radiation. The maximum power production was 1.186 kW at 10:44 o’clock and minimum power production was 0.101 kW at 17:30 o’clock. The total calculated solar rooftop energy consumption is 334.902 kW. These solar rooftop could generate 0.557 kW h of electricity.
3.1.3. Performance ratio (PR)

Figure 3. show the performance ratio of solar rooftop PV systems plotted. From this figure, it can be seen that the performance ratio generally, The performance ratio varied between maximum at 99.50% and minimum at 82.36% and the average performance ratio was 89.52%.

Figure 4. Performance ratio solar rooftop PV system

4. Conclusions

A experimental study was carried out to determine the technical performance photovoltaic solar energy of rooftop of Medan, Indonesia. The total average power generated is 0.557 kW h with the availability of solar radiation in Medan with average irradiation of 368.24 W/m². The performance ratio is 89.52% The results of this study would be useful for preliminary consideration solar rooftop in Medan of Indonesia.

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