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Performance evaluation of standalone double axis solar tracking system with maximum light detection MLD for telecommunication towers in Malaysia

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ABSTRACT

This paper is performed to investigate the performance of dual-axis solar tracking system with maximum light detection for off-grid telecommunication towers under weather conditions in Malaysia. The studied system consists of High-efficiency heterojunction intrinsic thin (HIT) film solar modules coupled with state-of-the-art dual-axis maximum light detection (MLD) solar tracking system. The investigation method is based on the analyzed the daily actual data record for both the average power output of the photovoltaic system and the state of charge of batteries in four months under different weather conditions as a function of time. Based on the results obtained the use of HIT solar modules with MLD dual axis solar tracking system has high performance effective under Malaysian weather. The study also presented the detailed investigated system description.

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1. INTRODUCTION

Malaysia has an advanced telecommunication industry with several cellular network operators (CNO) and a high percentage of subscribers. The number of subscribers in 2013 reached 41.9 million [1]. This number increased daily**.** Therefore, CNO is required to build more telecommunication towers (TTs) to cater to the increasing demand for transmission quality and extensive coverage. Typically, in highways, remote and semi-remote locations which are without electrical power or with low power quality, TTs are powered by a diesel generator with a battery as a backup system which caused increases the operating cost, along with the high emission of greenhouse gas. Hence, renewable energy becomes a necessary option to ensure their sustainability and continued availability in the future [2], [3]. Solar energy is one of the renewable energy sources that has become an optimal solution that should be considered, especially in Malaysia because of its high potential sources. It is environment-friendly, has techno-economic viability, and sustainable.

Although Malaysia has the average 8 hours of sunshine every day and a high average of annual solar radiation of 1643 kWh /m^2 [4], due to the reason that the weather is affected by monsoons, the solar irradiation intensity is influenced primarily by the clouds cover. Northern monsoon from November to February, which Characterized by heavy monsoon rains and the Southern monsoon occurs from May to October, which has lesser rainfall than the Northern monsoon. Hence, the primary challenge in the application of solar energy systems is finding a solar system technology provides reliable and cost-effective electrical power for TTs operation, suits the weather in Malaysia.

The photovoltaic (PV) system is a technology that using PV effect to convert light to direct current (DC) electricity. The critical criterion that affects the performance of a PV system is the level of solar irradiance, location, and weather conditions [5], [6]. Therefore, to achieve a high of PV systems performance need high efficiency of the actual cell conversion [7], utility Maximum Power Point Tracking (MPPT) control [8], [9], and installing PV panel on the solar tracking system to track the sun path during daytime and hence increase its efficiency [10], [11]. As well as store energy to supply electricity when there is no sunlight available. So batteries with a high bank storage capacity that covers the power consumed needs [12], [13].

By these previous conditions, solar PV modules with high-efficiency heterojunction intrinsic thin films (HIT) coupled with state-of-the-art dual-axis maximum light detection (MLD) solar tracking system was proposed. This system combines the high efficiency of solar cells and the installation of a solar tracking system, which play a significant role in increasing the efficiency of the system. The MLD function depends on "continuous measurement of intensity and incoming light angle moves the installed PV advantageously, follows up light that is reflected from objects, and diffuses sunlight that penetrates the clouds."

According to some previous studies in various countries with different climates and global solar radiation, the energy production of PV arrays increases with the use of dual-axis solar tracking systems. Mostafa mehrtash et al. [14] investigated the dual-axis tracking system with three PV arrays that are horizontally fixed, tilted fixed, and single azimuth axis tracking in Montreal, Canada. The results showed that the annual energy production of dual-axis tracking was the most significant compared with other systems. In Qeshm Island in Iran, Bazyari et al. [15] analyzed the performance of PV dual and single-axis tracking systems with the PV fixed-axis system regarding solar radiation yield. Results showed that the average energy yield received by the single-axis system was 1.35 times larger than that of the fixed PV system, and the double-axis tracking system was 1.04 times greater than of the single-axis system. In Spain, Simón Martín et al. [16] investigated three different types of PV installation systems, namely, PV fixed axis, PV horizontal axis tracking system, and PV dual-axis system of follow-up. After analysis of the results, the data showed that the performance ratio PR of PV using dual-axis tracking was 3% greater than the horizontal-axis tracking and was approximately 7.5% greater than the fixed system. In Malaysia, J. F. Lee et al. [17] have investigated the performance of dual-axis tracking system compared to using the fixed PV system under the Malaysian climate. The studied results inculcated under Malaysian weather, dual-axis solar tracker gated more excellent performance than fixed PV system. In Malaysia also Ahmad Fudholi et al. [18] have investigated solar tracking PV system for the mobile station under for four days, two cloudy days in December, and two sunny days in January. Although this study was a short duration, the results confirmed that the tracking PV system has high potential to generate electricity for the cellular base stations at remote, rural area Given the results of all the above, PV solar tracking systems can utilize the maximum advantage of solar energy to increase the power produced by PV systems and become more efficient.

The present study aims to present the performance of 12 KWp double-axis solar tracking system with MLD to power TT under the different weather conditions in Malaysia. A computer data acquisition system with wireless data logger were used to log the actual one-second data field measurements in real-time using appropriate sensors. The required measured data are averaged to eliminate the daily variations of data collection and to provide an accurate estimation of PV system performance. The novelty in this study is summarized as follows: (i) the actual data measurements for various factors are used for analysis to obtain accurate investigation results. (ii) Compared to [18], the logged data and its analysis have been done for a long time, for four months under different weather conditions (January and February were rainfall northern monsoon season, and June and July were southern monsoon season characterized by clear sky or and sometimes cloudy with minimal rainfall). (iii) The PV system performance was appraised using the following indices, the actual yield of solar PV modules and the states of charge and discharge of batteries (SOC%) which are significant indicators that reflect the level of PV system performance [19].

2. SYSTEM DESCRIPTION

The primary purpose of Double Axis Solar Tracking System with MLD was to address the annual increase in operational costs incurred by Celcom telecommunication towers, which was previously dependent on diesel generators and reduce the emission of toxic gases associated with the utilization of these generators. Figure 1 shows the photograph of the standalone system. The system is located at the Green Technology and Innovation Park, UKM University in Bangi, Selangor, Malaysia (latitude: 2°56'06.7" N, Longitude: 101°46'53.3" E), as shown in Figure 2.

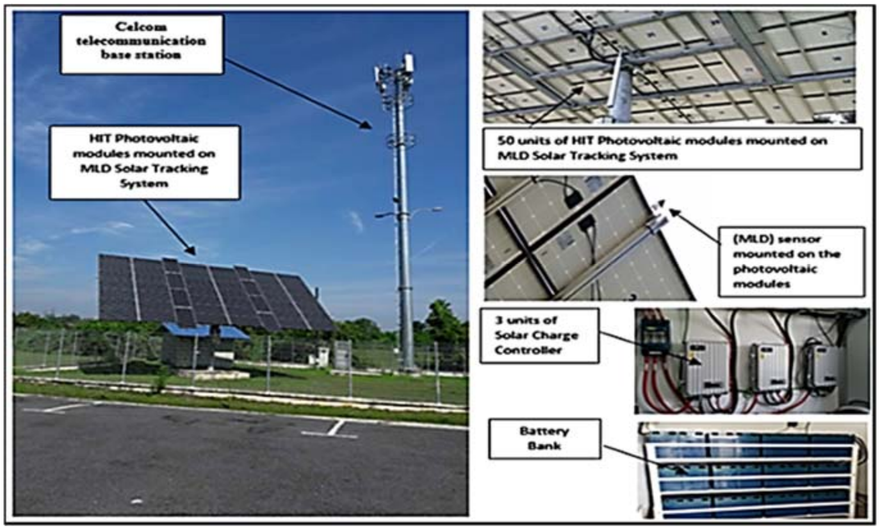

Figure 1. Photograph of 12 kwp standalone double axis solar tracking system with mld

Figure 2. Location of the installed system

This design was the first in Malaysia and could become a potentially massive market for highly efficient HIT PV with MLD solar tracking system in telecommunication towers throughout the Asian region. Figure 3. shows the diagram of this system, and Figure 4. shows the electrical diagram. The standalone system was designed based on the following principal elements:

a. Fifty units of Panasonic solar panel (VBHN240SJ25), Max Power P max = 240 Wp (total = 63.042 m2, 12 KWp) HIT solar PV modules (suitable for Malaysian weather and reducing the area of the conventional solar cell). The PV system consists of six arrays, namely, Arrays 1 and 2 (4.32 KWp), Arrays 3 and 4 (3.84 KWp), and Arrays 5 and 6 (3.84 KWp).
b. Two MLD sensor controllers mounted on PV modules as shown in Figure 3 are used as smart light detection (one MLD sensor controls the azimuth, and the other controls the elevation tilt of the solar tracker). Intelligent light sensor controllers operate with a solar tracking system to sense the brightest point of the sun’s radiation and automatically move the solar tracker toward it in real-time.
c. 24 units of 2 V/2000 Ah high-capacity valve-regulated lead-acid batteries as bank storage. It is needed to supply electricity when there is no sunlight available.
d. Three units of solar controllers with maximum power point tracking (MPPT) that have 48 V/64 A to give more potential to produce maximum output power.

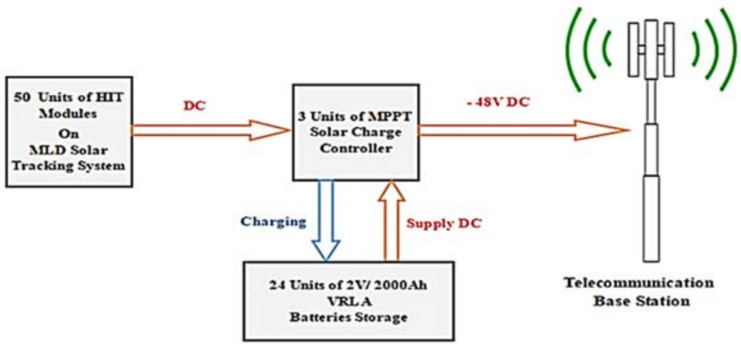

Figure 3. Block diagram of the 12KWp standalone high efficiency HIT modules with MLD solar tracking system and battery bank for telecommunication base station

2.1. Hit solar modules

Solar cells are still actively developed as an alternative energy source. "HIT is one of the advanced commercial technology" [20]. This technique has been widely used in many applications because of its high efficiency [21]. The designed system is based on an advanced solar cell technology that uses highly efficient multi-junction PV cells that can withstand high ambient temperature in Malaysia. The efficiency of HIT solar modules is 19.4%, which is the highest among upper commercial production solar modules. The high efficiency of HIT solar modules minimizes the conventional solar cell area. This issue should be considered when using the solar tracker system. Therefore, HIT solar cells have a low-temperature coefficient of −0.29%°C, and they can maintain higher efficiency than a conventional silicon solar cell, especially at elevated temperatures. The electrical diagram of the 12 kwp standalone pv system as shown in Figure 4.

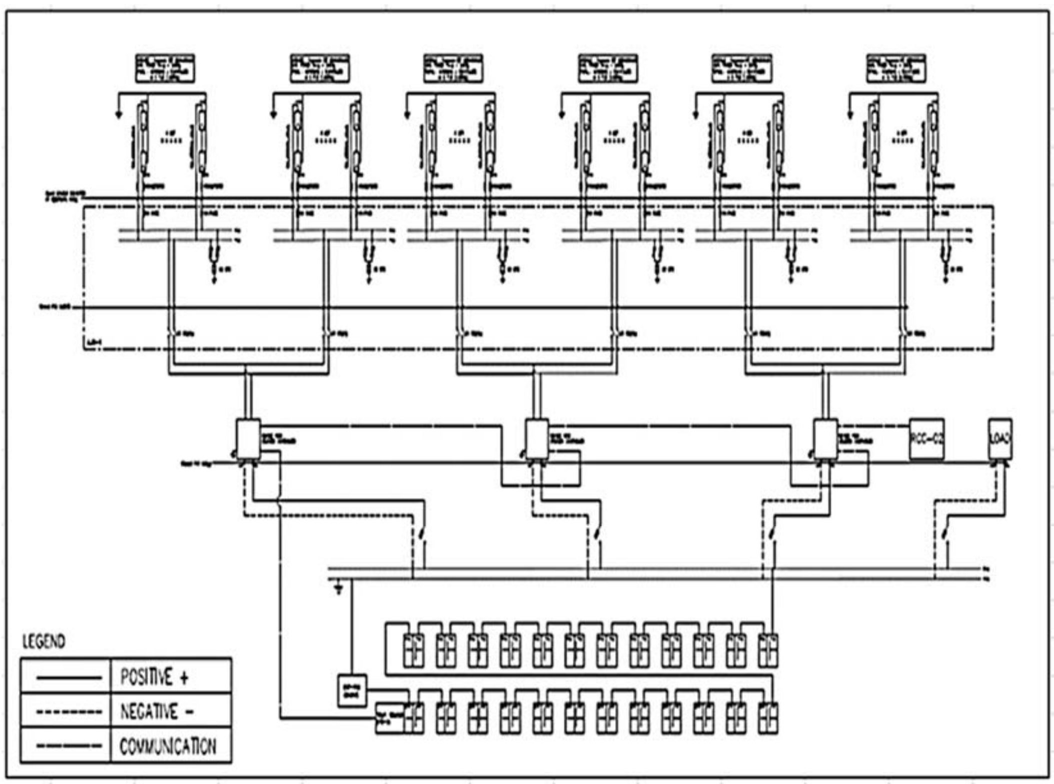

Figure 4. Electrical diagram of the 12 kwp standalone pv system

2.2. Dual-axis MLD solar tracking system

The solar tracker system tracks the sun to minimize the incidence angle between the incoming sunlight and PV panel surface [22]. The PV panel surface is directly facing the sun, and solar irradiation reaches the panel in a vertical angle of 90° or close to it. In Malaysia, the intensity of solar radiation is primarily influenced by clouds. This condition should be considered when deploying a smart control system to respond to the states in a real-time situation. The advanced technology of the dual-axis MLD solar tracking system become the best solution. It is an intelligent solar tracking system that tracks the actual conditions of the sky. The smart control module continually measures the intensity and incoming light angle and moves the installed solar modules in the advantageous positions. The intelligent solar sensors and control system consider solar irradiation and also the light reflected by the reflective roof and floor materials and water reflection. In this case, solar radiation obscures and generates diffused light under cloudy conditions. Thus, the MLD sensor cannot determine the brightest light point because it is intercepted. MLD provides the signal to move the solar tracker system into a horizontal position. This position allows the system to capture the diffused light that penetrates the clouds, as shown in Figure 5 and Figure 6. [23]. The dual-axis MLD solar tracking system recorded a 47% increase in energy generation output compared with the fixed PV installation. Moreover, MLD technology recorded 27% higher than the conventional astronomical solar tracking system.

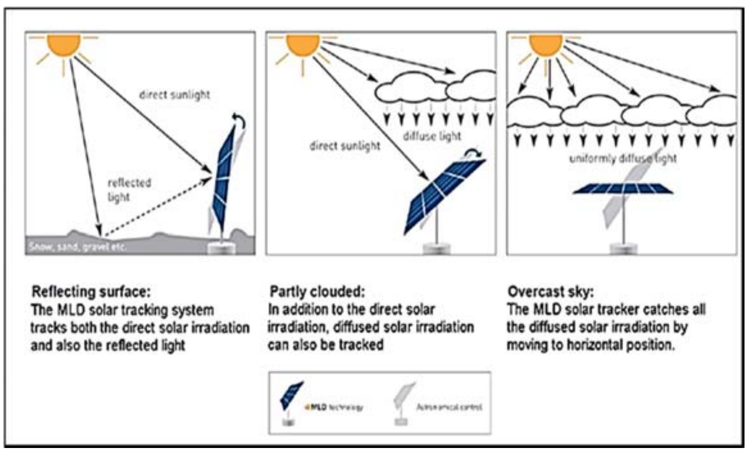

Figure 5. Dual-axis mld solar tracking system [23]

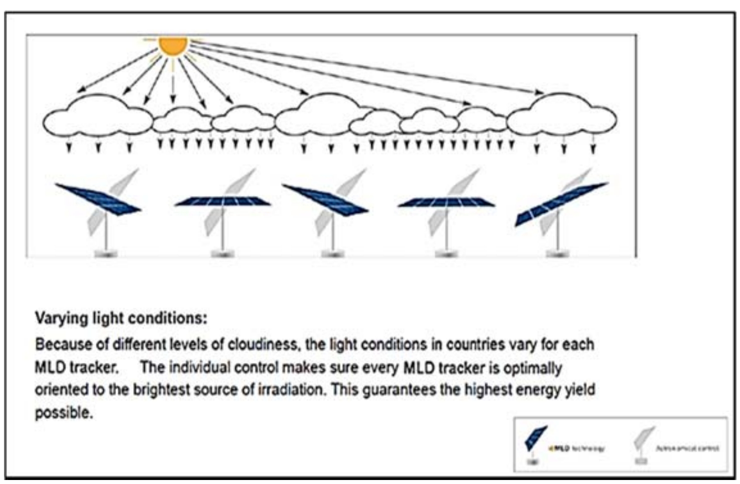

Figure 6. Dual-axis mld solar tracker with the optimized position for high energy yield [23]

3. RESULTS AND DISCUSSION

The collected data that obtained from the wireless data logger, all data related to PV systems and batteries, ambient site temperature, site global solar irradiation, along with the amount of solar radiation captured by Dual-Axis MLD solar tracking system. The PV system performance was appraised using the following important indices, the states of charge and discharge of batteries (SOC%) and the actual energy yield of Dual-Axis MLD solar tracking system. In our case, to accurately assess the system, the findings were collected during the selected four months under different weather conditions. January and February are rainfall northern monsoon season, and June and July are southern monsoon season characterized by clear sky or and sometimes cloudy with minimal rainfall (less rainfall than the north monsoon).

3.1. The advantages gained of solar tracking with MLD technology

The Adopting the dual-axis solar tracking technology with MLD sensor enables the tracking of sun altitude angle in real time and hence increasing the amount of solar radiation falling on PV arrays consequently increasing the amount of energy production. Figures 7 and 8 show the measurement data recorded of global solar radiation on the site, solar radiation captured by Dual-Axis MLD Solar Tracking System, the average ambient temperature for January, February, and June, July. This real experimental investigation has offered the positive results obtained from the use of the Dual-Axis MLD Solar Tracking System Since the efficiency of PV arrays are directly proportional to the amount of solar irradiation falling on the PV arrays. Thus the efficiency of the PV system has increased significantly.

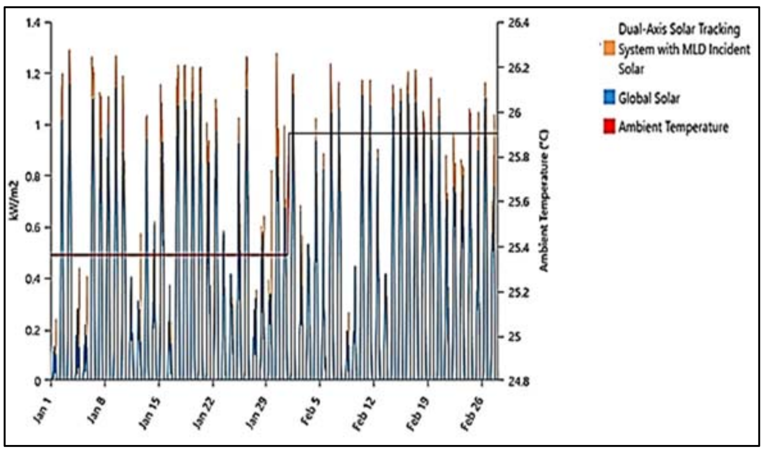

Figure 7. The measurement data recorded of global solar radiation on the site, solar radiation captured by dual-axis MLD solar tracking system, and ambient temperature for january and february

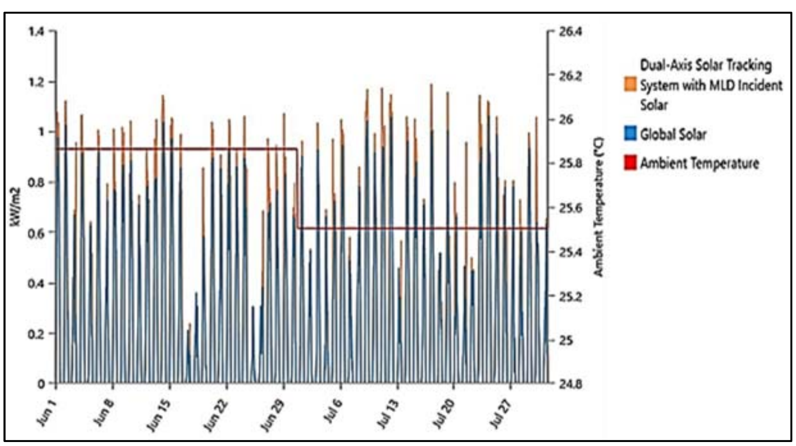

Figure 8. The measurement data recorded of global solar radiation on the site, solar radiation captured by dual-axis mld solar tracking system, and ambient temperature for june and july

3.2. PV array energy production

Different weather conditions such as high temperature, the purity of the sky, and the foggy weather significantly the PV array energy yield. In our case, the performances of PV array yield values are analyzed regarding the KWh/KWp produced. The calculation for daily and monthly array yields values are based on the following (1):

$$Y_a = \frac{E_{p.d} \times h}{P_o} \quad (1)$$

Where; the ***Ya*** is daily array yield in kWh/kWp.d, $E_{p.\,d}$ is daily average net output power of PV array in kW/d, ***h*** is average hours of sunshine, ***Po*** is peak power at STC (12 KWp). The daily average for the power output values for (January, February, June, and July) 2015 was measured and analyzed. The analysis results are plotted in Figure 9. The graph shows the average power output in KW of the selected months over day hours. From the chart can see that the average power output is gradually increased and when reached to 8:00 am, or later is steadily rising until arrived nearly 17 KW, 16 KW, 13.5 KW, and 13 KW in July, June, January, and February 2015 respectively. And then the curve is progressively decreased until the sunsets. If we look the four figures over time, we can see that July 2015 has the highest average power output accounting of 9.29 KW per day among others, this is due most of the days have proper solar irradiation. Followed by June 2015 accounting of 8.62 KW per day, then January 2015 and February 2015 which accounting for 7.1 KW per day and 6.88 KW per day respectively. Hence based on (1), the PV array yield of July, June, February, and January were as follows: 6.19 KWh/KWp, 5.74 KWh/KWp, 4.73 KWh/KWp, and 4.5 KWh/KWp respectively .This result reflects the effect of various weather conditions of the typical climate of Malaysia (sunny, cloudy, and rainy). The results of the study showed up that until in rainy months such as January and February, the PV array yield was recorded at 4.5 KWh/KWp and 4.73 KWh/KWp. These results are relatively high compared to a previous study [24]. In sum, in term of array yield and under different Malaysian weather conditions, The MLD solar tracker system design had a very positive effect on the performance of the PV system yield production.

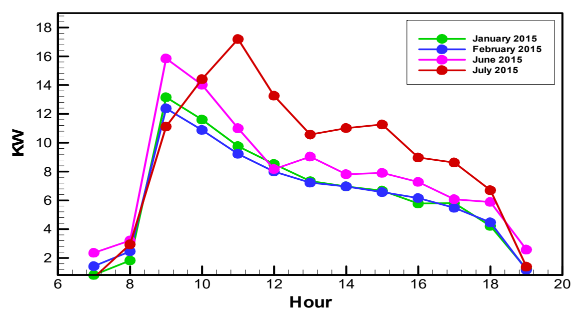

Figure 9. Graph showing the monthly power output average in KW per day of the 12kwp MLD dual axis solar tracking system for January 2015, February 2015, June 2015, and d July 2015

3.3. SOC%

The SOC% has a direct effect on the life of the battery and also reflects the level of PV system performance in general. Total of four months' data on the state of charge (SOC) of the batteries was collected and analyzed. The results of the analysis are plotted in Figure 10. The charts showed that, during all months, the MLD solar tracking system only took approximately about 4 hours to fully charged the batteries. And the batteries were remained charged for two to three hours in January and February and stayed from 4 to 5 hours in June and July. The results of the analysis also showed that the monthly average of SOC% for all analyzed months did not drop below 90%. This result was a very positive indicator of the level of performance of the PV system.

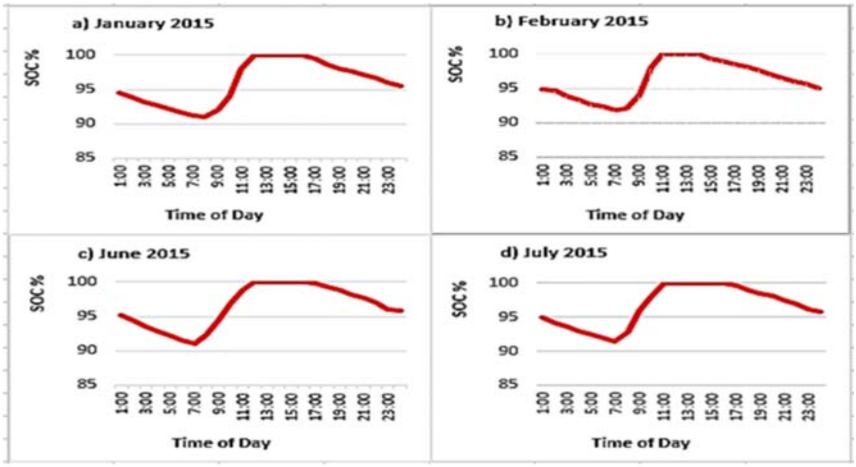

Figure 10. Graph showing the monthly average of soc% for january 2015, february 2015, june 2015, and july 2015

4. CONCLUSION

This study presented the performance of the standalone 12 KWp high-efficiency HIT PV module double-axis solar tracking system with MLD intelligent controller technique under different weather conditions in Malaysia during long-term investigation study. Based on the obtained results the dual-axis solar tracking system with MLD significantly improve the efficiency of PV systems and allow to achieve the best energy production performance. The real-time experimental investigation results indicated that the system has high performance and suitable for Malaysian weather, which was influenced by clouds. The increasing mobile application in the market requires more the construction of telecommunication towers. Therefore, the standalone high-efficiency HIT PV modules on MLD double-axis solar tracking system can be replicated to all telecommunication towers that are located in off the utility grid. In sum, under different Malaysian weather conditions, The MLD solar tracker system design had a very positive effect on the performance of the PV system production.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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