# The Effect of Haze on The Performance of a Double Axis Photovoltaic Solar Tracking System with Maximum Light Detection (MLD) in Malaysia

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*Abstract* - **The haze pollution, which occurred in September 2015 because of burning forests in Sumatra (Indonesia), reached many places in Malaysia. The results of this haze blocked the sunlight and hence decreased the energy generation of solar photovoltaic systems. In this study, the effects of haze conditions on the performance of dual-axis photovoltaic solar tracking system with the maximum light detection controller have been investigated. The investigation was based on the analysis of daily average photovoltaic system's power output and state-of-charge of the batteries bank during September 2015 haze event. It was then compared with data from non-haze months which are one month before and after the haze event. A detailed analysis showed that the haze had directly affected the system, where its performance was significantly declined with the levels of increased haze. If this level of haze is repeated in the coming years, it should be considered as a factor that reduces the amount of solar energy, when developing solar photovoltaic systems, especially in Southeast Asia.**

***Index Terms - Solar Energy, Dual Axis Solar Tracking System, Maximum Light Detection, Photovoltaic System efficiency, Air Pollution.***

## I. INTRODUCTION

The "haze season" that occurs annually in Southeast Asia caused many environmental problems, as a result of burning weeds and forests to expand farmland in some places of Indonesia [1]. Depending on the speed and direction of the wind beside proximity to "hot spots", many neighbouring countries of Indonesia are affected [2]. This type of air pollution is an airborne mixture of pollutants, which include carbon dioxide, soot particles, and other toxic gasses [3].

In 2015, Malaysia was affected by haze condition and had an air pollution crisis. The haze event occurred in the middle of August, got worsened in September, and lasted till the mid-October. Due to haze density, it has reached many countries in Southeast Asia; such as Singapore, Brunei Darussalam, Indonesia; and to a lesser degree, Thailand and Philippines. Many schools were closed in the southern and central part of Malaysia due to the increased haze density [4].

It's known the performance of solar photovoltaic (PV) system is affected by several factors, of which are two most essential factors weather and shadow. The shadow factor has most critical factors affecting solar yield losses. The results of this haze pollution blocked the sunlight and hence the amount of solar irradiance significantly reduced. This matter adversely affects the performance of PV system causing decreased in both energy production and efficiency.

The direct effect of haze pollution that occurs annually in Southeast Asia on both fixed and tracking of photovoltaic PV systems is limited without real field measurements. For this reason, research papers related to this topic are limited. Mohammadreza Maghami et al. [5] have evaluated the effect of Southeast Asian haze pollution 2013 on the energy yield of two types of photovoltaic PV systems, "fixed flat system" and "tracking flat plate system". The results showed that the effect was observed in both two systems where the fixed flat system was more affected by the haze condition then tracking systems. Andre M. Nobre et al. [6] have investigated "the effect of haze condition on the power output of fixed solar photovoltaic (PV) systems in Singapore during the June 2013 haze event". The investigation was conducted on wafer crystalline and the thin-film silicon PV technologies. The results indicated that the photovoltaic PV systems have lost between 15 to 25 % of yield. It is clear that the haze pollution can enormously affect the power output of PV systems and cause substantial negative power during the event.

Malaysia because of its location in the equatorial zone and of its exposure to monsoon rains, the solar irradiation intensity is influenced by primarily the clouds cover. That is the reason that it is crucial that a smart control system must be deployed to react to the conditions accordingly in the real-time situation. The Maximum Light Detection (MLD) solar tracking system technology is an intelligent solar tracking system that tracks the actual conditions of the sky [7]. It is developed by DEGER tracker company and becomes the best solution to deal with the Malaysia weather that primarily influenced by the clouds. The light, intelligent control module MLD is continuously sensing the intensity and angle of the incoming light and moves the solar PV modules installed to the best position to increase the amount of solar irradiation. Moreover, this

Figure 1. Photograph of Standalone Double Axis Solar Tracking System with Maximum Light Detection (MLD)

technology enables the PV system to increase its efficiency and energy yield. As shown in Figure 1, Full Autonomy Heterojunction with Intrinsic Thin Layer (HIT) Solar PV mounted on MLD Dual Axis Solar Tracking system has been designed and installed at a Celcom telecommunication base station. The system was located at the Universiti Kebangsaan Malaysia (UKM) Green Technology Park in Bangi, Selangor (latitude: 2°55.8'N, Longitude: 101°46.6'E). The site is located at about 30 km to Kuala Lumpur, the capital of Malaysia (Figure 2). This system is new in Malaysia, which was built with the cooperation between Solar Energy Research Institute (SERI), UKM, and Celcom Company. The purpose of this system is to solve the yearly increase in operational cost, faced by Celcom telecommunication base station, which relied mainly on diesel generators to supply the necessary electricity.

The present study aims to evaluate the effect of haze pollution in the year 2015 on the performance of double-axis photovoltaic solar tracking system with Maximum Light Detection (MLD) in Malaysia. This study was conducted during September 2015, where the haze pollution was at a high level and compared with non-haze conditions during July 2015, and November 2015.


Figure 2. Location of the MLD dual axis PV solar tracking system installed (image from Google Map)


Figure 3. Block diagram of Double Axis HIT modules with MLD

The measurements for the analysis has been logged using computer data acquisition system. A comparative study was performed based on calculation and analysis of the daily average power output of the PV system in kWh and a monthly average of 'state of charge' (SOC %) of the batteries. The movement of the tracking system during the haze condition was also observed.

## II. THE SESTEM CONFIGURATION

Figure 3 shows the block diagram of the installed system. The configurations of the PV system with MLD dual axis tracking consist of the following:

- Fifty units of 240 KWp Heterojunction with Intrinsic Thin Layer (HIT) PV cells with the efficiency of 19.4%. The total capacity and area of the PV cells are 12 KWp and 63.042 m2 respectively. The using of this high-efficient HIT PV cells able to reduce the cell area compared to the conventional ones. It also has a very low low-temperature coefficient of only -0.29%/$^{0}$ C. Hence it can maintain high efficiency even at high temperatures;
- A solar tracker system that has a dual axis (two degrees of freedom that act as axes of rotation), for more ability to accurately track the sun's path, to keep the PV panels directly incident to solar irradiation at all times. Increased efficiency represents a significant advantage because it maximises the power produced by the PV system;
- Two Maximum Light Detection (MLD) sensors are mounted on the photovoltaic modules (one MLD sensor controls the azimuth and the other controls the elevation tilt of the solar tracker) as a smart light sensing controller to sense the brightest point of the sun's radiation and automatically move the solar tracker towards it. In the case, cloudy conditions or similar to dense haze, the sunlight obscures and generates diffuse light. A solar tracker system with a smart light sensing controller moves the panel into a

horizontal position because the brightest angle cannot be determined. This position allows the system to capture the diffused light that penetrates clouds or haze;

- Twenty-four units of Valve Regulated Lead Acid (VRLA) batteries storage system with a capacity of 2000 Ah/2 volts for each battery;
- Three units of Maximum Power Point Tracking (MPPT) solar charge controller that have 48V/64A.

## III. RESULTS & OBSERVATIONS

The hourly data measurements were logged using a computer data acquisition system, see Figure 4. The one-hour data from the system was averaged to eliminate the daily variations and provide a more accurate estimation of the system performance. The methodology was based on the performance evaluation of the system within one month before the occurrence of haze event. Moreover, a month later, as the baseline reference for the system performance, it was compared with haze days.

### A. System performance yield

The site was covered by haze during September 2015 while the non-haze conditions for comparison were in July 2015 (before the haze event) and November 2015 (after the haze event). The energy produced by the system was analysed, and compared using variance analysis. Figure 4 shows the measurement results of average daily energy output of PV arrays in haze and non-haze conditions. The comparison graph shows the average daily output energy for July, November, and September was 9.59 kWh, 7.85 kWh, and 3.78 kWh respectively. July 2015 has the highest output compared to the other studied months because it is one of the southwest monsoon months, that is characterized by bright sky and less rainfall. On the other hand, November 2015 produced lower output due to the northeast monsoon that has more rain. However, these values seem somewhat close. A significant difference can be observed during the haze event of September 2015 with a remarkable reduction of energy output compared to the non-haze months. The result indicates the negative effect of the haze where the solar irradiation was comparatively low during the haze, and hence the energy output kWh of the PV arrays decreased significantly.

### B. State of Charge of the Batteries (SOC)

A total of three month's data on the monthly averages concerning the 'state of charge' of the battery (SOC) were collected and analysed. The months of September 2015 (during the haze conditions), July 2015 (a month before the haze event), and November 2015 (a month after the haze ends) were considered. The results of the analysis are plotted in Figure 5. It was observed the batteries demonstrated their best charging performance in July 2015. This is due to the excellent solar radiation experienced by the days of the month where the MLD solar tracking system took only approximately 4 hours to charge the batteries to 100%, and the SOC remained above 91%. In November, which had more rain, the MLD solar tracking system took 5 hours to fully charge the batteries to 100% and the lowest SOC for the month was 88%. In contrast, in September 2015 (during the haze), the charging of batteries did not reach 100% ever. The batteries were also at the lowest SOC, i.e. 85%. However, the process of the charging continued, and the SOC is still in the safe range for the batteries.

### C. The System Observation

When the level of haze increased, the MLD solar tracking system often moves into a horizontal position as in Figure 6. The reason for this is because the haze blocks the sunlight and causes a reduction in the sun's energy yield. In this case, the MLD controller could not sense the brightest point of sunlight.

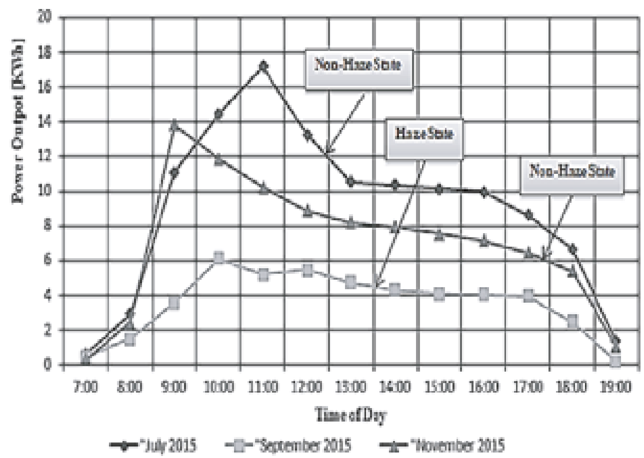


Figure 4. Power output from MLD dual axis PV module.

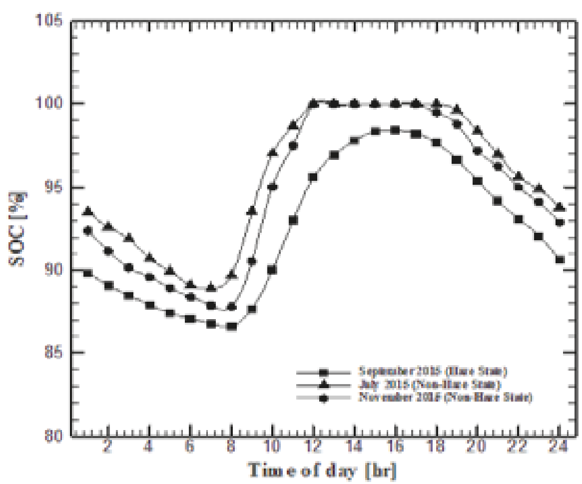


Figure 5. The Monthly Average of State of Charge (SOC %) for the batteries in the months; July 2015 (Non-Haze State), November 2015 (Non-Haze State) September 2015(Haze State)

Figure 6. Photograph of the positioning of the solar tracker with MLD during the height of the haze level.

The advantage of this position, it can maximise the capture of low diffuse solar radiation, which is dominant during haze conditions.

## IV. CONCLUSION

The study investigated the effects of haze pollution that occurred in Southeast Asia (2015) on the performance of a dual axis PV solar tracking system with MLD controller. The system is very suitable for Malaysian weather that is very much influenced by clouds. The function of MLD solar tracker system is to track the brightest point of sunlight during the day. This capability can significantly improve the efficiency of PV systems and hence increase the system energy productions. During the haze events the sunlight was blocked and hence directly affects the performance of the system where the power output of the PV cells declined. As a result, also the rate of charging and discharging decreased. These results are evidence of the negative impact of the haze pollution to the solar PV energy generation system. The haze also causes the diffuse solar radiation throughout the day. If the haze event is repeated continuously in coming years, it has to be taken into consideration as a factor that reduces the amount of solar energy, when designing and developing solar PV systems, especially in Southeast Asia. To conclude, the use of MLD controller in the solar tracking system is helpful where PV modules were actively moved to find the brightest point. Low diffuse solar radiation makes the MLD controlled the system into horizontal position to allow the PV cells to maximise the capture of diffuse solar radiation.

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## CONFLIT OF INTEREST

The authors declare no conflict of interest.

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