Mohd Ruddin Ab Ghani
Professor of Electrical Engineering, Universiti Teknikal Malaysia Melaka
System Engineering and Control- Energy and Distribution Automation System-Optimization - Operational Research
Verified email at utem.edu.my

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Performance Comparison for Parabolic Dish Concentrating Solar Power in High DNI Locations with George Town, Malaysia
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Rosnani Affandi, C.K. Gan, Mohd Ruddin Ab Ghani
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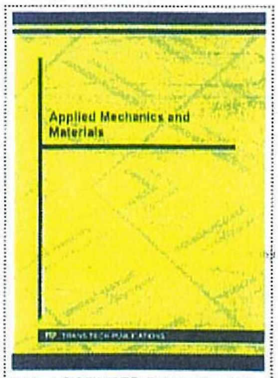

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C3: RENEWABLE ENERGY

Chair: Dr Suyitno

Room: ICE-SEAM 2

3:45 C3-1	***Performance Assessment of Slip Mode Frequeuncy Islanding Detection Methods*** Ahmad Farid Sapar (Universiti Teknikal Malaysia Melaka, Malaysia); Meysam Shamshiri (Universiti Teknikal Malaysia Melaka, Malaysia); Chin Kim Gan (Universiti Teknikal Malaysia Melaka, Malaysia); Anis Niza Ramani (Universiti Teknikal Malaysia Melaka, Malaysia)
4:00 C3-2	***Landfill Gas Detection in Leachate Pipe: A Consideration for Design Improvement of Leachate Piping and Gas Venting Systems*** Emmanuel Olisa (Universiti Teknologi Petronas (UTP), Malaysia); Hisyam Jusoh (PETRONAS Technology of Institute, Malaysia); Nasiman Sapari (Universiti Teknologi PETRONAS Malaysia, Malaysia)
4:15 C3-3	***Production of Biodiesel from Waste Cooking Oil via Ultrasonic-Assisted Catalytic System*** Norzita Ngadi (UTM, Malaysia); Lai Nyuk Ma (Faculty of Chemical Engineering, Malaysia); Hajar Alias (UTM, Malaysia); Anwar Johari (Institute of Hydrogen Economy (IHE) Universiti Teknologi Malaysia, Malaysia); Roshanida Abd Rahman (UTM, Malaysia); Mardhiah Mohamad (UTM, Malaysia)
4:30 C3-4	***Mathematical modeling of thermoelectric generator with solar parabolic dish*** Gunalan Muthu (National Institute of Technology, India); Subramaniam Shanmugam (National Institute of Technology, India); Arunachalam Veerappan (National Institute of Technology, India)
4:45 C3-5	***Estimating Daily Solar Radiation and Air Temperature using Hargreaves Model in Eastern Malaysia*** Mohd Irwan Yusoff (Universiti Malaysia Perlis, Malaysia)
5:00 C3-6	***Performance Comparison for Parabolic Dish CSP between Countries with Various Level of DNI and George Town, Malaysia*** Rosnani Affandi (Universiti Teknikal Malaysia Melaka, Malaysia); Chin Kim Gan (Universiti Teknikal Malaysia Melaka, Malaysia); Datuk Prof. Dr. Mohd Ruddin Ab Ghani (UTeM, Malaysia)
5:15 C3-7	***The Structural Analysis of a Mini Hydroelectric System*** Mohammad Azzeim Mat Jusoh (UiTM, Malaysia)

Performance Comparison for Parabolic Dish Concentrating Solar Power in High Level DNI Locations with George Town, Malaysia

Rosnani Affandi[1,a], Chin Kim Gan[1,b] and Mohd Ruddin Ab Ghani[1,c]
[1]Faculty of Electrical Engineering, Universiti Teknikal Malaysia Melaka
[a]rosnani@pmm.edu.my, [b]ckgan@utem.edu.my, [c]dpdruddin@utem.edu.my

Keywords: Parabolic Dish (PD), Concentrating Solar Power (CSP), Renewable Energy (RE), Direct Normal Irradiance (DNI), System Advisor Model (SAM).

Abstract. Parabolic Dish (PD) Concentrating Solar Power (CSP) generation has appeared as one of Renewable Energy (RE) that is efficient and trustworthy. As technology moves into commercialization, it is necessary to study the performance of PD system at various locations. Current literature on PD especially for tropical environment such as Malaysia and locations with Direct Normal Irradiance (DNI) lower than 1500 kWh/m2/year is still scarce and scattered. Most of the studies are focusing on the performance at location with DNI higher than 2100 kWh/m^2/year. Therefore, this paper presents the performance of PD in tropical environment of Malaysia and four other locations such as; Thailand, Korea, Australia and United States of America (USA). System Advisor Model (SAM) was used to analyze the performance of PD for the selection countries. The simulation result shows that the annual energy production for George Town in Malaysia is 21,845 kWh, and shows areas of high DNI have high power output such as Pheonix, USA 184,189kWh; Canberra, Australia 121,536kWh; Bangkok, Thailand is 48,736 kWh and Inch'on, Korea 45,450 kWh.

Introduction

Renewable Energy (RE) such as biomass, biogas, and small hydro as well as solar energy is gaining increasing interest. As stated by Exxon Mobil report in 2013, the role of RE will be increase to meet the needs of world's energy need in future thus contributing to the reduction of world carbon dioxide emissions [1].

Among RE, Solar energy is clean, abundant and the development is growing significantly [2, 3]. A various of solar technologies such as Photovoltaic (PV) and Concentrating Solar Power (CSP) systems has been developed to harness the solar energy [4]. Many studies have been done to examine the potential use of PV and CSP systems in various parts of the world [4–6]. As usual, a PV and CSP systems has their advantage and disadvantages. Nevertheless, CSP is one of the solar energy technologies that have huge potential to fulfill a part of world energy demand in the future [7–9].

However, the potential of CSP plants is largely dictated by the Direct Normal Irradiance (DNI) level. Hence, the knowledge on the quality of solar radiation is important to obtain accurate analysis on the performance of the CSP system. Meanwhile, until 2007 the commercial CSP plants have only built in sunbelt area where the DNI is higher than 2100 kWh/m^2/year, such as Mojave Desert in United States and Aldiere in Spain (refer : Table 1).

In 2008, the circumstances starting to change when Germany developed their CSP plant and becomes the earliest country that has CSP plant whereas the DNI are lower than 1000 kWh/m^2/year. Then it is followed by Italy (1,936 kWh/m^2/year) in 2010, France (1,800 - 1,930 kWh/m^2/year) and Thailand (1,400 kWh/m^2/year) in 2012 as well as United Arab Emirates (1,934 kWh/m^2/year) in 2013.

However, based on the study of European Solar Thermal Electricity Association (ESTELA, 2010) and as stated by International Renewable Energy Agency (IRENA, 2012), CSP plants in areas of high DNI will have lower Levelised Cost of Electricity (LCOE) than CSP plants that located in lower DNI areas [10,11]. Overall, it can be said that there is a strong relationship between the DNI, power output and LCOE. More importantly, different type of CSP will have different performance under different DNI level.

Table 1: List of country with CSP plant.

Country	Start Year	DNI value [kWh/m²/yr]	Installed Capacity [MW]
United States	1984	2,636 - 2,725	650
Spain	2007	1,950 - 2,291	2057
Germany	2008	902	1.5
Morocco	2010	2,400 - 2,600	20
Italy	2010	1,936	5
Algeria	2011	2,700	25
Australia	2011	2,600	12
Egypt	2011	2,431	20
India	2011	2,200	2.5
China	2012	2,000 - 2,100	1.5
France	2012	1,800 - 1,930	250
Thailand	2012	1,400	5
Mexico	2013*	2,050 - 2,305	Nil
United Arab Emirates	2013	1,934	100
South Africa	2014*	2,700	Nil
Chile	2015*	2,900	Nil
Malaysia	Nil	1500	Nil

*Under Development

Based on the observations from previous literature, most of the performance studies on the CSP focused on dry arid areas with high DNI value. Furthermore, there are still a gaps and a lack of research on the performance analysis of the CSP, especially for the Parabolic Dish (PD) in area with DNI lower than 1500 kWh/m^2/year. Therefore, this study is to presents the performance of PD in Malaysia tropical environment and four other countries such as Thailand, Korea, Australia and United States of America (USA).

The software tool, System Advisor Model (SAM) that has been developed by National Renewable Energy Laboratory (NREL), USA will be used to analyze the performance of PD for the selected countries. Generally, the study is composed of two main parts which are; analysis on the performance of PD system in Malaysia tropical environment and comparison on the performance for PD system in Malaysia with four other locations.

Methodology

Simulation Tools. Evaluation of technical performance PD system using experimental approach is costly and time consuming [12,13]. In this study, PD system's especially the technical performance is evaluated using a simulation approach. SAM simulation tool was chosen because the program has been proven and successfully used to simulate the CSP such as PD system [14]. Generally, SAM is a performance and financial model to facilitate decision making for those engaged in the RE industry (such as PV, CSP, Biomass, wind power and Geothermal). Furthermore, SAM can be used to predict the performance and energy cost estimates for grid-connected power projects. The estimation is based on installation and operating costs as well as the system design parameters to be input to the model [15,16].

Operational Framework. Referring to Fig. 1, simulation for PD performance requires a few external inputs such as; location data, weather data, field layout, mirror parameters, receiver input and stirling engine input.

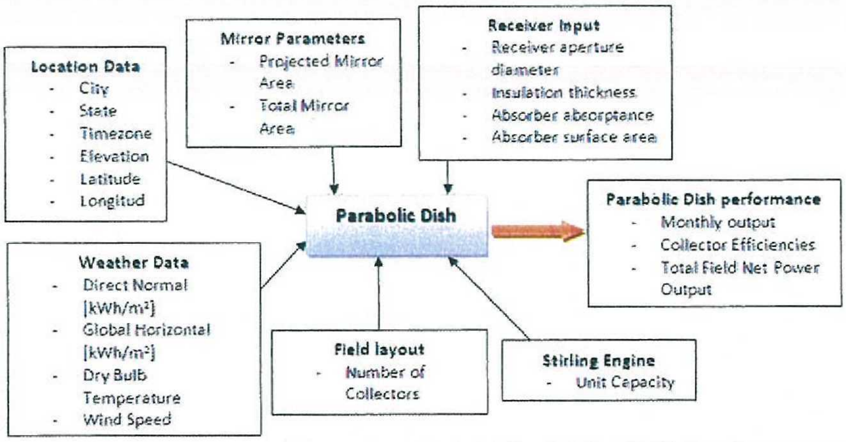

Figure 1: Process of simulation for Parabolic Dish (PD) Performance

System Description

Parabolic Dish (PD). There are four types of CSP technologies that SAM can model which are; Parabolic Trough, Power Tower and Linear Fresnel as well as Parabolic Dish. However, PD has been chosen in this study because PD is modular, suitable for small scale plant and most sophisticated for small CSP plant [17]. The plant area for PD system is small compared to the other solar technologies plant. Moreover, PD is one of solar energy technologies that has higher efficiencies which is nearly 31.25% [8][18][19].

From Dish Stirling Library, Wilkinson, Goldberg, and Associates, Inc or (WGA) type of PD has been chosen. WGA type has capacity of 10kW and smallest diameter for concentrator compared to the other type of dish that provided in the library system. For the Field layout, number of PD that has been chosen for the field is 10. Therefore, total capacity for the Parabolic Dish in the field is 100kW. While, the separation between each dish is 15m and it takes 2250m^2 for solar field area.

For the Mirror parameter (refer: fig. 2), the projected mirror area is 41.2m^2, total mirror area 42.9m^2 and the reflectance is 0.94. Generally, the typical values for solar mirrors reflectance are 0.923 (4-mm glass), 0.945 (1-mm or laminated glass), 0.906 (silvered polymer), 0.836 (enhanced anodized aluminum), and 0.937 (silvered front surface). In this case, WGA dish using collector are from mirrors with laminated glass type and the reflectance is highest among the others dish in the library. While, the receiver input can be referred from figure 3.

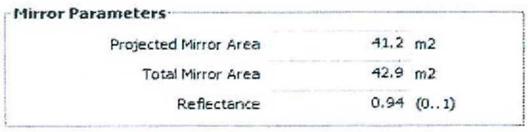

Figure 2: Mirror parameters for PD WGA Type.

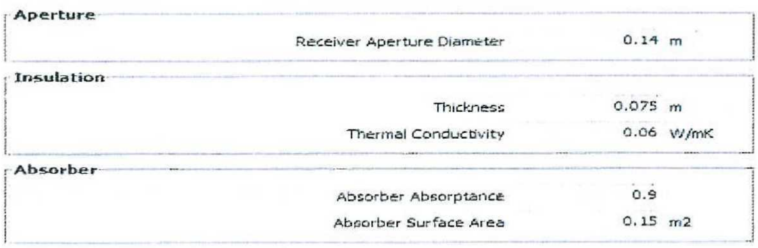

Figure 3: Receiver input for PD WGA Type.

Location Information. Simulations have been carried out for five locations. Malaysia, Thailand and Korea are selected because the level of DNI is from 1500 kWh/m2/year and below (refer: Fig. 4). While, George Town are selected for Malaysia location because of this area receive high solar radiation throughout the year in Malaysia. Northern states such as Bayan Lepas and George Town receive highest solar radiation rather than other area in Malaysia [20]. Whereas, other locations such as Thailand has been selected because of Thailand experiencing same tropical climate as Malaysia; furthermore, Thailand has developed their CSP plant. While, Korea is selected regarding to the experiences of this country in conducting a few research on the PD performance [13]. Meanwhile, Australia and USA are country that has experience and successfully developing PD plant in their countries [21][22]. The complete data for the selected location can be referred from Table 2.

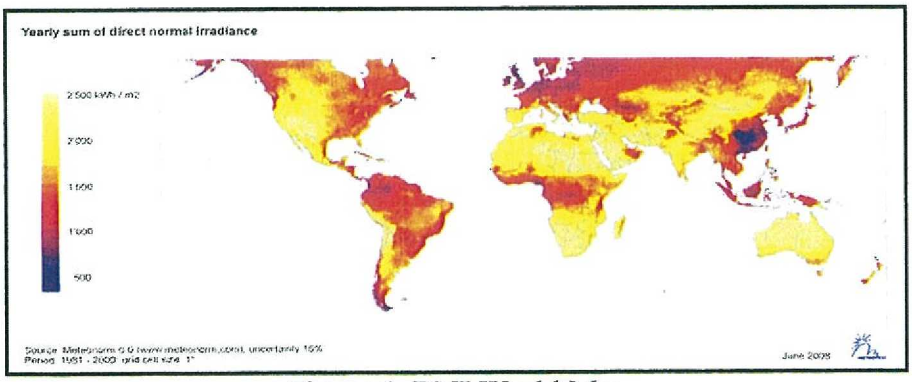

Figure 4: DNI World Map

Table 2: Location Data Information.

City, Country	George Town, Malaysia	Bangkok, Thailand	Inch'on, Korea	Canberra, Australia	Pheonix, USA
Time zone	GMT 8	GMT 7	GMT 9	GMT 10	GMT -7
Elevation	4 m	12 m	70 m	577 m	339 m
Latitude	5.3 deg	13.92 m	37.48 deg	-35.3 deg	33.433 deg
Longitude	100.27 deg	100.6 deg	126.55 deg	149.18 deg	-112.02 deg

Weather Data Information. Five locations that have been selected for this study covering a annual direct Normal range from 708kWh/m^2 for George Town in Malaysia up to 2518kWh/m^2 for Pheonix in the United States of America. The location and weather data for Malaysia, Thailand, Korea and Australia are downloaded from the U.S Department of Energy website, while the data for location and weather data for USA is from National Solar Radiation Data Base website.

Result and Discussion

Performance of Parabolic Dish in George Town, Malaysia Environment. Referring to Figure 5, the highest monthly output produce is on February which is 4446.57 kWh, while there is no output produce from the plant in August and October. This is due to the DNI value for August and October as a whole is below 200 W/m^2. However, the maximum DNI value reached over 900 W/m^2 in March. While it is found that the DNI value drop below 200 W/m^2 in December and January (refer: Fig. 6). Moreover, the results from simulation are also revealed that minimum DNI value for power production by the PD system was around 200 W/m2.

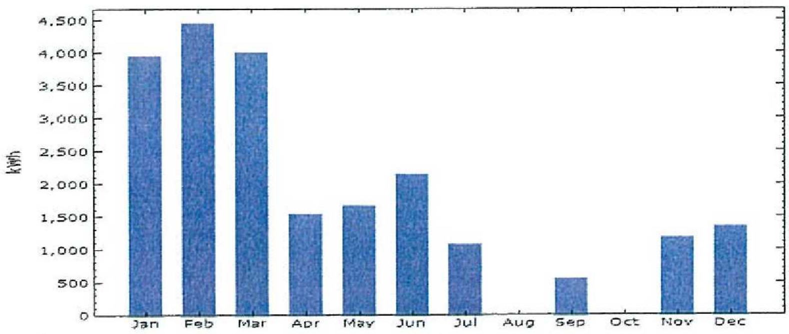

Figure 5: Monthly Output for PD in Malaysia environment

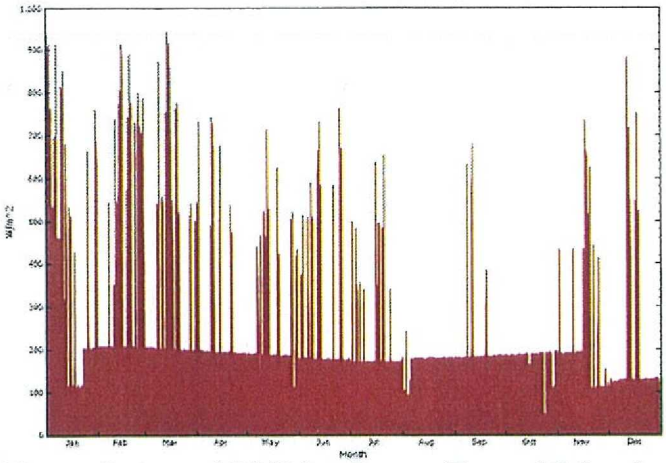

Figure 6: Annual DNI for George Town, Malaysia

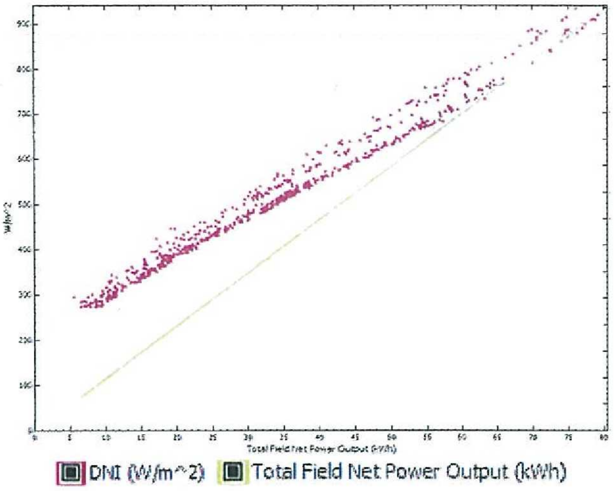

Figure 7: Total Field Net Power Output Vs DNI

Figure 7 shows the total Field Net Power Output for PD versus the DNI. It can be observed from the figure that the generated power output increase linearly with the increase of DNI. The collector efficiencies achieve 94% only if the DNI is higher than 200 W/m^2, whereas if the DNI is lower than 200 W/m^2, the collector efficiencies will be equal to zero. While, the power output of PD achieves 80 kWh at maximum value DNI of 938 W/m^2. Overall, the annual energy generated from PD in George Town, is 21,845 kWh.

Performance Comparison of Parabolic Dish. Figure 8 shows the monthly output for PD in five locations. It shows that Pheonix have the highest monthly output compared to the other locations. The annual energy for Pheonix is 184,189kWh and the DNI is 2518.6kWh/m^2. While, George Town have the lowest monthly output with annual energy 21,845kWh for DNI value of 702.8kWh/m^2. Bangkok, which experience the tropical environment as Malaysia have annual energy 48,736 kWh for DNI 1005.4kWh/m^2. Surprisingly, from the simulation result, it shows that Inch'on, have the annual energy higher than Malaysia which is 45,450 kWh for DNI value of 759.2kWh/m^2. Whereas, Canberra become the second location have high annual energy, which is 121,536kWh for DNI value of 1772.9kWh/m^2.

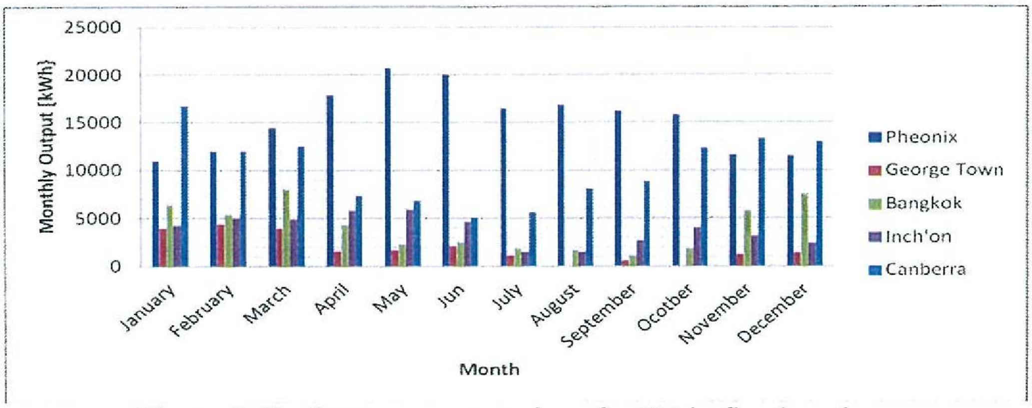

Figure 8: Performance comparison for PD in five locations

Summary

From the simulation result, it shows that PD can produce the electricity production or power output when the DNI is higher than 200 W/m2. However the performance of PD in Malaysia environment is still low when compare to the PD performance in other locations. Moreover, tropical settings in Malaysia such as heavy rainfall, high value of cloud cover, wind blow as well as high value of humidity will fluctuating and decrease the concentration process. Therefore, this will affect the temperature, efficiencies of solar to electric and power generation for the PD system in Malaysia environment. Overall, the simulation result proves that areas of high DNI will have high power output.

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