Determining The Reliability of Forecasting of Solar Power Plant in The Philippines

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Abstract: - Solar energy has been one of the leading renewable energy resources in the country and it has been promoted since as it brings great advantages especially for the environment. Forecasting the Solar Power is the way that the Power Plants used in determining the marginal possibility of their energy harvest within a given period of time. In this study the ways and processes of power plants are determined in order to define which ways brings a more accurate and reliable result. A comparison between the actual energy harvest and their forecast are presented in order to see the actual difference. In the end the, some techniques that are common within the two power plant are determined to be the most reliable techniques in order to bring the accurate forecasting methods for the Power Plants.

Key Words— *Solar Technology, Forecasting Techniques and Models.*

I. Introduction

Renewable energy sources such as solar, geothermal, hydro, wind, and biomass energy currently account for 33% of the country's energy supply. As foreign investors continue to show interest in the Philippine economy, it is expected that the country's renewable energy-based installed capacity target will increase to 15,304 MW by 2030, up from 5,439 MW in 2010.

Solar energy is becoming a more affordable alternative to fossil fuels. Solar energy is a renewable source of energy that has a low environmental impact and promotes energy independence. While solar energy has been widely criticized for being expensive or inefficient, it has now proven to be extremely beneficial - not only for the environment but also for the private economy, transforming solar into a significantly more efficient source of clean energy.

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Currently, solar power plants are prioritized dispatched, which means that their energy output is prioritized to be consumed first by customers when compared to oil and coal-based power plants. To ensure that the Grid Connection between the Solar Power Plants is balanced, the Energy Output of the Solar Power Plants is determined in advance using Solar Forecasting Methods. Solar forecasting plays a critical role in scheduling energy demand for other power plants to compensate.

Solar forecasting is the process of predicting the future energy output of solar power plants in hours, days, or weeks. Its procedure entails determining the factors that may affect future solar generation, such as irradiance, temperature, and weather patterns. Solar power forecasts are used for efficient grid management and power trading.

The purpose of this research is to examine the various techniques used by Solar Power Plants in the Philippines in their Solar Forecasting Methods and determine which methods provide the most reliable results

1.1 Statement of the Problem

The goal of the study is to determine the following questions:

- What kinds of methods does Solar Power Plant use to predict their Energy Output?
- How did they incorporate these method techniques?

- Ground-based sky observations
- Satellite-Based Methods
- Numerical Weather Prediction

The goal of the study is to determine the following questions:

- How do they include the following factors in their analysis and prediction?
    - Temperature
    - Humidity
    - Irradiation
    - Weather Forecast
    - Current Climate
- What is the Accuracy of the different techniques that the Solar Power Plant uses?

1.2 Significance of the Study

This study will identify the various techniques used by Solar Power Plants in the Philippines in their Solar Forecasting Methods, as well as which methods produce the most reliable results. Using this will assist us in determining which is the most efficient to use. Knowing the most efficient method to use can help provide more renewable energy supply as demand rises.

II. REVIEW OF RELATED LITERATURE

Renewable energy has been around for a long time. However, it has received increased attention in recent times due to the impending threat of climate change to the entire planet's existence. More countries and utilities are now attempting to support it. Because of the abundance of sunlight, solar energy is the most sought-after option among all renewable energy options. (Mansoor, Sabeeha, 2022).

"At Philippine pesos (PHP) 2.50-5.30 (USD0.05-0.10) per kilowatt-hour (kWh), excluding financing costs, rooftop solar can deliver lower-cost energy than conventional coal-fired power plants and unlock up to PhP1.5 trillion (US$2.8 billion) in new investment by 2030, according to a 2019 study from the Institute for Energy Economics and Financial Analysis," Solar Magazine stated (IEEFA). Larger scale commercial-industrial and utility-scale solar power plants can produce electricity even more cheaply." This statement implies that using renewable resources such as solar energy can significantly reduce electricity costs.

2.1 Solar Energy Harvesting Technologies

The following are five innovative solar energy harvesting technologies:

2.1.1 Photovoltaic Solar Panels

Photovoltaic (PV) solar panels generate electricity by harnessing the power of the sun. Today, this is the most widely used method of harvesting solar energy. These panels, which range in size from a few square centimeters to a few square meters, are made up of a complex matrix of PV cells. In theory, the greater the surface area available for sunlight to penetrate the PV cells, the greater the amount of solar energy harvested. (Zach Wendt, 2020)

2.1.2 Thermal Energy Harvesting: Energy of Electromagnetic Radiation

The sun emits a wide range of radiation at various wavelengths, including infrared. This spectrum efficiently transfers thermal energy to absorbable bodies. Elements that can effectively absorb this thermal electromagnetic energy are known as 'black bodies,' because the color black absorbs all visible wavelengths of radiation. All wavelengths of the electromagnetic radiation spectrum can be correctly absorbed and emitted by an ideal black body. (Zach Wendt, 2020)

2.1.3 Molten Salt Solar Power

Recent advances in molten salt systems are pushing the boundaries of solar energy power generation. Molten salt power plants, like the previously discussed solar-powered water heating systems, use electromagnetic radiation to melt salt.

This molten salt is then transferred to a heat exchanger, which converts water into steam, which is then used to generate electricity via a steam turbine. Molten salt power plants, such as the Ivanpah Solar Plant, rely on a vast network of heliostat mirrors to direct sunlight to a single point, known as a power tower or central tower. This tower collects enough energy from the surrounding heliostats to melt the salt at nearly 1500°F.

This molten salt is then stored in insulated tanks, where it can be used even when the sun is not shining. (Zach Wendt, 2020)

2.1.4 Solar Forecasting

Forecasting solar power is fundamentally a weather forecasting problem. It begins by simulating the Sun's position relative to a given location on the Earth's surface, and then simulates the transmission of solar radiation through the Earth's atmosphere. Finally, power modeling software is used to generate predictions of energy generation from a given solar facility based on accurate estimates of solar radiation availability. 2019 (Dr. Nick Engerer).

2.2 How are solar power forecasts created?

The most difficult aspect of modeling solar radiation transmission through the Earth's atmosphere is accurately capturing the scattering, absorption, and reflection processes of sunlight as it passes through cloud cover.

Solar forecasts are produced in three main categories, which are loosely organized by the forecasting time horizons they enable. These are:

- Statistical techniques
- Satellite imagery approaches
- Numerical Weather Prediction (weather models) (Dr. Nick Engerer, 2019).

2.3 Factors Affecting Solar Panel Efficiency

There are several factors that influence the efficiency of solar panels.

2.3.1 Temperature

The intrinsic property of the semiconductor material influences the efficiency of the photovoltaic cell. The efficiency of solar panels increases as the temperature drops and decreases as the voltage between the cells drops.

2.3.2 Energy Conversion Efficiency

The spectral response of the solar module varies depending on the type of module. As a result, changes in spectral irradiance have an impact on solar power generation. By reducing incident light reflection, the energy conversion efficiency is increased.

2.3.3 Solar Shading

Solar PV panels are extremely vulnerable to solar shading. Total or partial shading has a significant impact on energy delivery capability and may result in lower output and power losses. Cells in a solar panel are typically connected in series to produce a higher voltage and thus an adequate amount of electricity.

III. METHODOLOGY

3.1 Research Design

A Quantitative and Comparative Research Design will be used in this study. This design aims to compare which different methods of Solar Forecasting Technique are the most relevant compared to the actual energy generation.

3.1.1 Respondents/ Participants

The respondents of the study will be Solar Power Plants located in the Philippines mainly their personnel that generate their energy forecast data.

- Plant Engineers
- Electrical Engineers
- Data Analyst
- Statistician

3.1.2 Data gathering tools and techniques

In this study, questionnaires and survey forms will be collected using an online platform. Data on their energy forecast and actual energy generation will also be collected; these data are required for the computation of the reliability and accuracy of their technique. The tool will be descriptive statistics, and the statistical test will be Root Mean Square Error. According to H.D. According to Kambezidis, the RMSE statistic provides information about a model's short-term performance by allowing a term-by-term comparison of the actual difference between the estimated and measured value; the smaller the value, the better the model's performance.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N}(Predicted_i - Actual_i)^2}{N}}$$

Fig.1. Formula for Gathering Root Mean Square Error

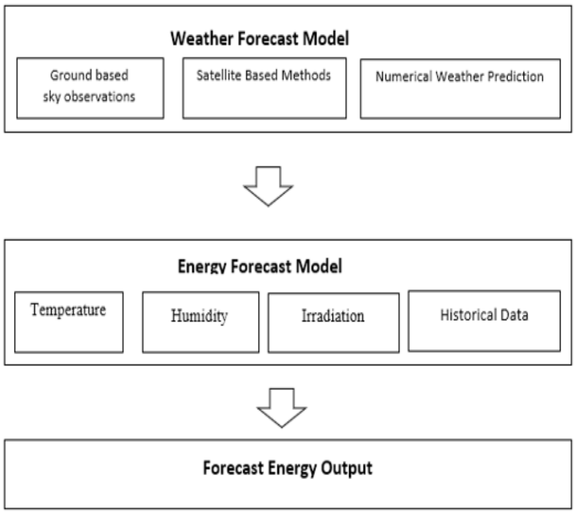
The information gathered will also include the location of the Solar Power Plant, the Rated Capacity Method used in Solar Energy Forecasting with the following options: Satellite-Based Methods, Numerical Weather Prediction, Ground Based Sky Observations, Statistical Methods, Computer Programs, and Other Methods. Temperature, humidity, irradiation, historical data of energy generation, and current climate will all be gathered as determining factors.

3.2 Scope and Limitations of the Study

The purpose of this research was to determine the Solar Energy Generation Forecasting Techniques used by Solar Power Plants. The research was carried out from February 2022 to June 2022. The subjects were chosen based on their availability to take part.

Two Solar Power Plants were studied which are all located in the Philippines. The research focused on the forecasted energy generation and actual energy generation of the Solar Power Plants from the period of March 7 to 13,2022 which are to be analyzed by the researchers using Root Mean Square Error.

3.3 Theoretical Framework



The Weather Forecast is first determined in the process of forecasting the Energy Output of Solar Power Plants, which is the key factor in creating the energy forecast model. The weather forecast model is made up of techniques that rely on ground-based sky observations, satellite-based methods, and numerical weather prediction. In short-term forecasting, these methods determine the amount of sunlight that will be present in an area, as well as the number of cloud volumes that will block sunlight from reaching the solar panels. Temperature, humidity, historical data, and irradiation are all factors in Energy Forecast Models.

IV. Results and Discussion

A Scatter Plot Chart is presented in Fig.2 to visualize the comparison of the Actual and Forecasted Energy Generation of the Cabanatuan Solar Power Plant and the Bulacan Solar Power Plant. The black line depicts actual energy generation, while the gray line depicts forecast energy generation. The line would overlap if the forecasts and actuals were identical, whereas distant lines would indicate a significant difference between the two. For example, on March 11, the actual and forecasted generation of the Cabanatuan Solar Power Plant overlapped, indicating that the two values are nearly equal.

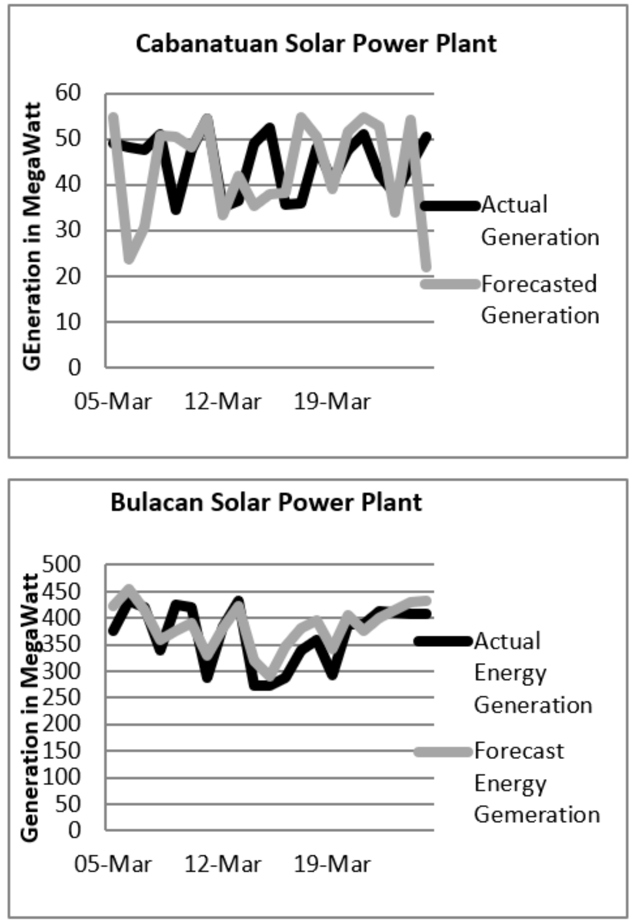


Fig. 2.1 & 2.2. Comparison between the Actual and Forecast of the Two Solar Power Plants

For a detailed calculation of the data, a table is presented in Table 1 which contains the Mean, Variance, Standard Deviation number of samples, and most importantly the Root Mean Square Error which is the determining value for the accuracy of the forecasting methods that are used.

Table.1. Cabanatuan Solar Power Plant

Cabanatuan Solar Power Plant		
	Actual	**Forecast**
Mean	44.737	43.511
Variance	40.362	109.25
Stand. Dev.	6.3531	10.452
n	21	21
SSQ	3046.2921	
Root Mean Square Error	**12.04414914**	

Table.2. Bulacan Solar Power Plant

Bulacan Solar Power Plant		
	Group 1	**Group 2**
Mean	369.559	385.1252
Variance	3028.5277	1689.5433
Stand. Dev.	55.0321	41.1041
n	21	21
Sum of Errors Squared	3357.0154	
Root Mean Square Error	**12.64349146**	

The forecasting methods of the Cabanatuan Solar Power Plant use Numerical Weather Prediction while taking Temperature, Irradiation, and Historical Data of Energy Generation into account. The forecasting methods used by the Bulacan Solar Power Plant include satellite-based methods, numerical weather prediction, ground-based sky observations, statistical methods, and computer programs for their Energy Forecast Model. Both Power Plants use Numerical Weather Prediction Methods and incorporate the factors of Temperature, Humidity, Irradiation, and Historical Data of Energy Generation.

V. Discussions

By calculating the Root Mean Square Error, we can determine the efficiency of Solar Power Plant forecasting techniques by comparing Forecast Energy Generation to Actual Energy Yield. Take note that the Root Mean Square Error is inversely proportional to the accuracy of their techniques; the lower the Root Mean Square Error, the closer the value forecasted Energy Generation is to the Actual Energy Generation. According to the findings, the Root Mean Square Error of the Cabanatuan Solar Power Plant, Bulacan Solar Power Plant, and Physical Models are all closely related. The RSME of the Statistical Model is slightly lower than those three, implying that the efficiency is not far off when comparing the Statistical Model used by other Solar Power Plants to the Physical Model used by Power Plants in the Philippines.

Table.3. Table Comparison of the Root mean Square Error.

	Root Mean Square Error
Cabanatuan Solar Power Plant	12.04 %
Bulacan Solar Power Plant	12.64 %
Average Physical Model from Other Power Plants	12.45 %
Average Statistical Model from Other Power Plants	10.50 %

The Root Mean Square Error for the Cabanatuan Solar Power Plant that uses Numerical Weather Prediction is 12.04%, which is slightly lower than the Average Value of the RSME for the Physical Models from other Power Plants. The Root Mean Square Error for the Bulacan Solar Power Plant's Energy Forecast Model, which uses Satellite-Based Methods, Numerical Weather Prediction, Ground Based Sky Observations, Statistical Methods, and Computer Programs, is 12.64%, which is higher than the Average Value of the RSME for the Physical Models from other Power Plants. Its value should, supposedly, be closer to the Average Value of the Statistical Model, which is part of their forecasting techniques; one major reason could be the capacity of their Solar Power Plant. Because of its higher capacity, the results have a larger margin of error.

VI. Conclusion

It can be concluded that in order to obtain Accurate and Efficient Forecasting Techniques, Numerical Weather Prediction can be used as a physical model because it is a technique used by both solar power plants. Irradiation and historical data on energy generation are also important forecasting factors. For Solar Power Plants with a small rated capacity, it is best to use a Physical Model for forecasting because the error is not that significant. It is recommended that larger capacity Solar Power Plants include a statistical model for their Forecasting Technique to compensate for the error introduced by the Power Plant's large capacity.

Recommendation

- Temperature and humidity can be added to the factors that affect the Generation for a more accurate forecasting technique. Additional factors that reduce errors can improve accuracy.
- Existing Solar Power Plants that use Physical Models such as Numerical Weather Prediction will see an improvement in their Weather Forecasting capability, which will affect and increase the accuracy of their Model.
- It is recommended that for research related to this study, the Solar Power Plants be grouped based on their rated capacity to obtain a more accurate comparison between them.

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