A STUDY ON SOLAR PV POWER GENERATION INFLUENCING PARAMETERS USING CAPTURED DATA FROM FACULTY OF ENGINEERING, UNIVERSITY OF JAFFNA SOLAR MEASURING STATION

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ABSTRACT

A number of parameters such as solar irradiance, temperature, wind speed, wind direction and soiling are influencing the solar energy harvesting. It is essential to develop deeper understanding of the factors influencing the solar energy production in a particular region and have reliable models to forecast energy production. For this research study, Killinochi district was chosen as it has a lot of potential for solar PV, and solar thermal compared to other districts. In this paper, initially it was analysed how the weather data and solar irradiance vary on a daily and yearly basis. Subsequently, the correlation between individual weather parameters, solar irradiance and silicon voltage are studied. Pearson correlation estimation was used for correlation studies. Based on correlation studies, it was found that the solar parameters are influencing the solar power generation. After that, temperature variations were modelled using ARIMA modelling and the model were used to forecast the next hour data. Similarly, the diffused horizontal irradiance (DHI) and global horizontal irradiance (GHI) data can be forecasted using ARIMA modelling, and the next hour data can be predicted. Future study will include modelling of correlation between solar irradiance and temperature or humidity using support vector regression methods; and DHI and GHI will be forecasted based on weather data. These prediction models are useful for power generation entities and households. The effects of soiling on PV modules which vary with soil type, location and weather patterns will also be considered.

1. Introduction

Nowadays home owners and medium and large size investors are trying to have their own solar power plant. This trend has come as the capital investment for building solar power plant has significantly reduced and the utility is charging more when the electricity consumption is higher than 120 units. In order to build profitable power plant, a number of factors needs to be investigated: (1) how the weather parameters vary, (2) how the solar irradiance vary, (3) what's the correlation between weather parameters, and (4) forecasting solar irradiance by analysing weather parameters. All these parameters differ from site to site. Thus it is essential to measure the weather parameters and local solar irradiation to design profitable solar power plants. For our research study, we have chosen Killinochi district as it has a lot of potential for solar PV, and solar thermal compared to other districts. Hence, it is essential to develop deeper understanding of the factors influencing the solar energy production in this particular region and have reliable models to forecast energy production.

Faculty of Engineering, University of Jaffna has its own solar measuring station which was donated by Sri Lanka Sustainable Energy Authority (SLSEA) with the support of Asian Development Bank (ADB). The solar measuring station data logger captures temperature, wind speed, wind direction, humidity, air pressure, diffused solar irradiance, global solar irradiance, silicon voltage. The measuring station will continue to give valuable data to improve the understanding on solar energy production capabilities of the region and improve forecasting models.

Previously, Ituen *et al* investigated the global solar radiation using relative humidity, maximum temperature and sunshine hours in Uyo [2]. Jakub *et al* investigated the relation of irradiation values to the power load on a yearly and daily basis and how should photovoltaics (PV) be integrated in the Polish power system [3]. Lave *et al* found that the Wavelet Variability Model (WVM) can be used to simulate a PV plant anywhere a single high-frequency irradiance sensor exists [4,5]. This can greatly assist in module siting, plant sizing, and storage decisions for prospective PV plants. Mejia *et al* found that soiling, the accumulation of dust on solar panels causes a decrease in the solar photovoltaic system's efficiency [6]. Kleissl et al studied the solar resource variability, solar forecasting methods, simulating solar plant variability using irradiance data [7]. Cadenas *et al* investigated wind speed prediction using a univariate ARIMA model and a multivariate NARX model [1]. Cyril *et al* present a review of state of the art machine learning approaches to predict solar radiation including support vector regression which will be used in further studies [9].

In this paper, it is initially analysed how the weather data such as temperature, humidity, wind speed, pressure and solar irradiance varies on a daily and yearly basis. As all the weather parameters are not influencing power generation, subsequently the correlation between individual solar parameters and generated power of reference cell is studied. For this study, Pearson correlation technique is used. After that temperature time series data is modelled using ARIMA modelling and the model is used to forecast the next hour data. Similarly, diffused horizontal and global horizontal irradiance data can be forecasted using ARIMA modelling. In future, the correlation between solar irradiance and temperature/ humidity will be modelled using support vector regression methods and diffused horizontal and global horizontal irradiance will be forecasted based on weather data. These prediction models are useful for power generation entities and households.

The remaining paper is divided in to subsections as follows: (1) Analysing the weather and solar irradiance data, (2) Analysing the correlation between weather parameters and solar irradiance, (3) Modelling the temperature variations using ARIMA model, and (4) Conclusions.

2. Analysing the weather data and solar irradiance data

Daily patterns

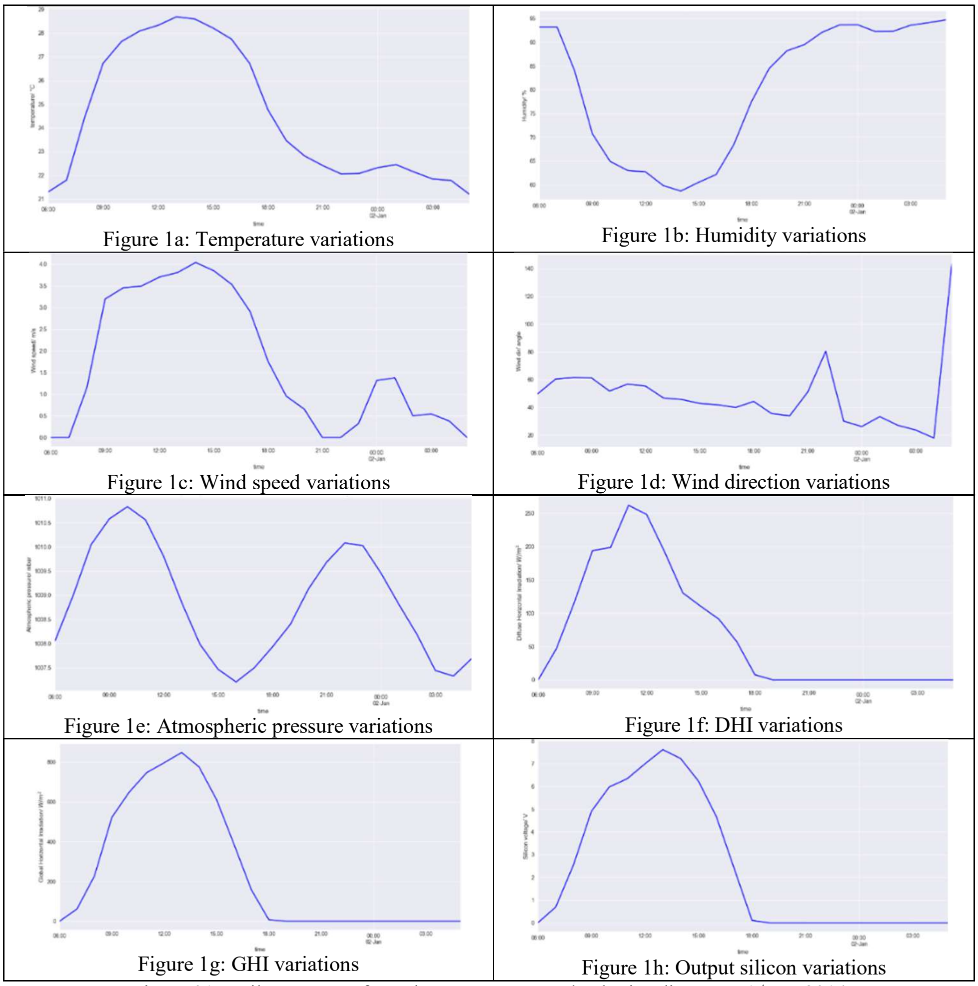

Figure 1a: Temperature variations

Figure 1b: Humidity variations

Figure 1c: Wind speed variations

Figure 1d: Wind direction variations

Figure 1e: Atmospheric pressure variations

Figure 1f: DHI variations

Figure 1g: GHI variations

Figure 1h: Output silicon variations

Figure 01. Daily patterns of weather parameters and solar irradiance on 1st Jan 2014

To analyse a typical daily pattern, data from 1st of January 2014 was chosen. It can be seen from figure 1a that the temperature gradually increases and peaks around noon. Figure 1b shows the humidity variations exhibits an opposite trend compared to temperature. The windspeed shown in figure 1c shows a trend similar to temperature, it sharply increases in the morning and peaks in the afternoon. There seem to be no visible trends related to other parameters observed during this day for the wind directions shown in figure 1d. The pressure variation shown in figure 1e shows that the pressure peaks twice during the selected day in the morning and then in the night. The DHI variations shown in figure 1f, the GHI variations shown in figure 1g and the Silicon output voltage shown in figure 1h exhibit a similar behaviour of peaking around noon like the temperature variations shown in figure 1a.

Yearly Patterns

To analyse yearly variations, data collected between January 2014 and January 2016 were used. The parameters shown in figure 02 exhibit a repeating pattern during year 2014 and year 2015.

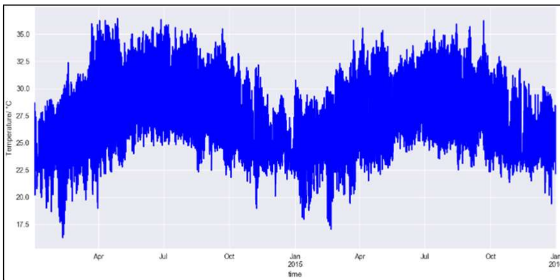

Figure 2a: Temperature variations

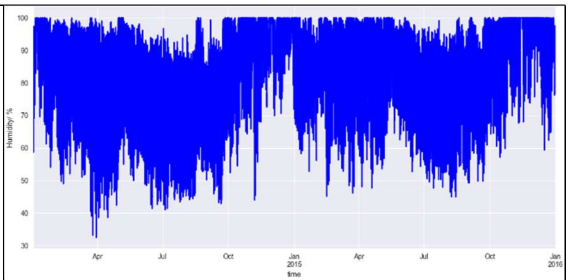

Figure 2b: Humidity variations

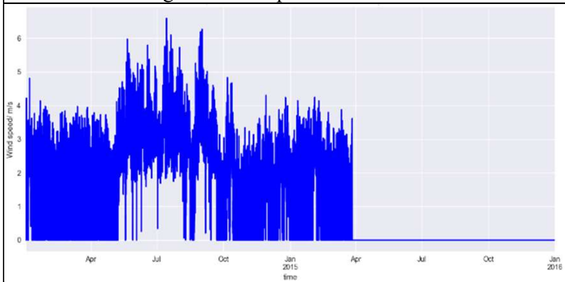

Figure 2c: Wind speed variations

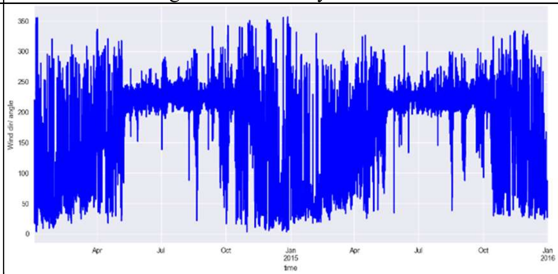

Figure 2d: Wind direction variations

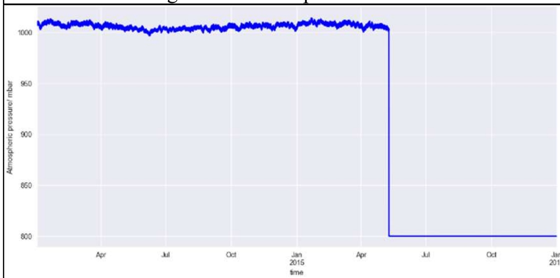

Figure 2e: Atmospheric pressure variations

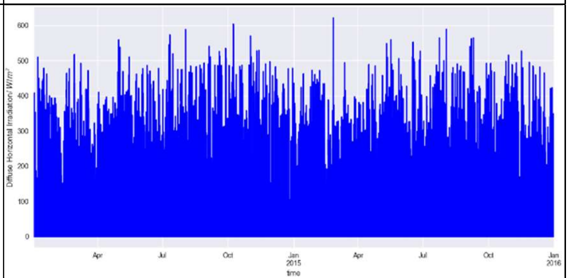

Figure 2f: DHI variations

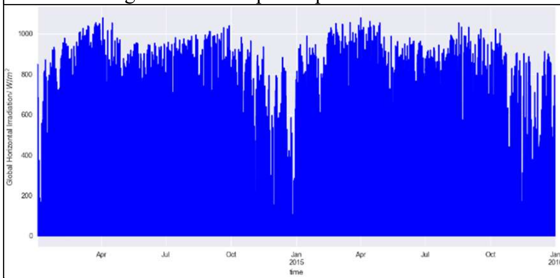

Figure 2g: GHI variations

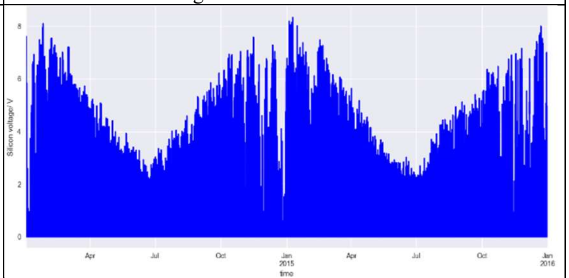

Figure 2h: Output silicon variations

Figure 2: Yearly patterns of weather parameters and solar irradiance between January 2014 and January 2016.

The temperature shown in figure 2a gradually rises from January to March and a sudden increase and elevated level could be seen during the April – May period, it seems to peak during July. The variation of humidity in figure 2b shows the opposite trend compared to temperature. Figure 2c shows that the wind speed during the period of May to September is relatively higher than rest of the year. The data for 2015 is not available for the wind speed and atmospheric pressure due to a technical issue at the time. Figure 2d shows that the wind direction during May to September is fairly stable compared the rest of the year. It can be seen that this stable period coincides with the elevated wind speed duration in figure 2c. In figure 2f, DHI shows lower values during the February to April period and it gradually increases and peaks during August-September period. Unlike DHI, GHI shown in figure 2g clearly shows that it peaks around April and then around August. It hits the minimum during the Dember-January period. Finally, the output silicon voltage level variations in figure 2h shows an interesting trend where it peaks during early part of the year around January and then gradually decreases and hits the minimum during July and then gradually increases to hit another peak in November and suddenly drops during December. This pattern shows an inverse relationship with the temperature; however, this trend seems to briefly depart during December which may be attributed to other solar and weather parameters.

3. Analysing the correlation between weather parameters and solar irradiance.

Pearson coefficient was used to measure the linear correlation between individual weather parameters and DHI, GHI and voltage for the period of 2015 (between 6am and 5pm).

Table 01: Analysing the correlation between weather parameters

Weather parameter	Temperature	Humidity	Pressure	Wind speed	Wind direction
Temperature	1.0	**-0.92**	-0.38	0.64	0.25
Humidity	**-0.92**	1.0	0.29	-0.63	-0.14
Pressure	-0.38	0.29	1.0	0.38	-0.23
Wind speed	0.64	-0.63	-0.38	1.0	0.18
Wind direction	0.25	-0.14	-0.23	0.18	1.0

Based on correlation coefficients shown in table 01, it can be observed that there is very strong correlation between humidity and temperature. Temperature (or Humidity) and wind speed exhibit a moderate correlation, whereas very weak correlation can be observed between wind direction and rest of the parameters.

Table 02: Analysing the correlation between weather parameters and solar irradiance, output voltage.

Weather parameter	DHI	GHI	Voltage
Temperature	0.59	0.76	0.49
Humidity	-0.51	-0.74	-0.55
Pressure	-0.03	0.006	0.08
Wind speed	0.24	0.28	0.26
Wind direction	0.05	0.03	-0.25

It can be observed from table 02 that solar irradiance and solar output voltage exhibit significant dependency on temperature and humidity. It can also be seen there is a weak dependence with wind speed while the dependence on pressure and wind direction are negligible. It was also found from table 01 that there is a very strong correlation between temperature and humidity, hence, we could use one of these features to forecast the solar irradiance and solar output voltage.

4. Modelling the temperature variations using ARIMA model

At the beginning of data collection, data was recorded every 10 mins and since recently, it is being recorded every minute. Having more data would help to accurately model the time series. Therefore time series modelling experiments used the data which was recorded from October 2016 to July 2017 at one minute interval. The temperature variations is shown in figure 03.

It was found form Dickey Fuller test that the temperature variation which is shown in figure 03 was not stationary. Therefore, by converting the original temperature variations into natural log, the stationary condition was satisfied. After that by using seasonal decompose stats model; trend, seasonal and residual variations were observed. The trend and seasonal variations were removed taking difference of temperature log data. It can be clearly seen from Figure 05 that observed data is almost similar to residual data and it can be said that trend and seasonal variation were removed from temperature log data. However, it can also be observed Figure 05 that there are still tiny amount of trend and seasonal variations. We believe that is not going to affect the performance.

ARIMA model is used to model the residual variations as our temperature log data is stationary data. The predictors depend on the parameters (p, d, q) of the ARIMA model. p is number of AR (Auto-Regressive) terms, q is number of MA (Moving Average) terms and d is number of differences. Based on our experiments, we found the best values of p, q, d as 4, 8, 1.

The observed fist log difference and model fitted values were respectively in blue and green colour in Figure 06. We’ve fund the root mean square error as 0.256. Finally, the log difference of temperature data and model fitted data were converted back to original scale. The Figure 07 shows the observed temperature variations in blue and ARIMA model fitted values in red. It can be observed that the model fitted values are almost matches observed temperature data.

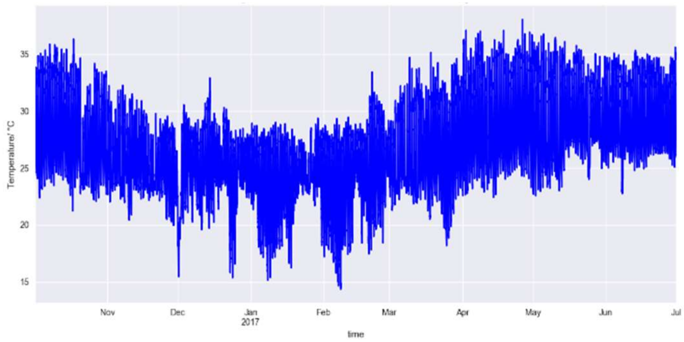

Figure 03: Temperature variations recorded from Oct 2016 to July 2017

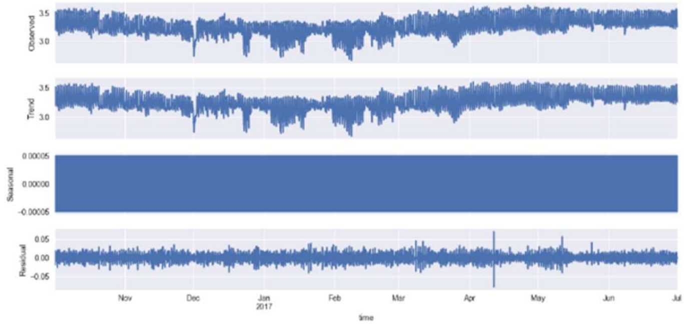

Figure 04: Observed natural log temperature data, trend, seasonal and residual variations are shown

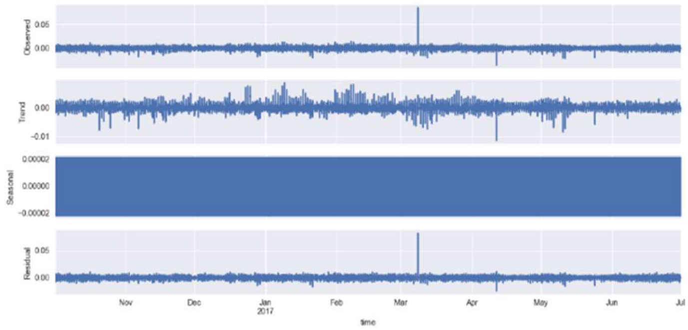

Figure 05: Observed natural log difference temperature data, trend, seasonal and residual variations are shown

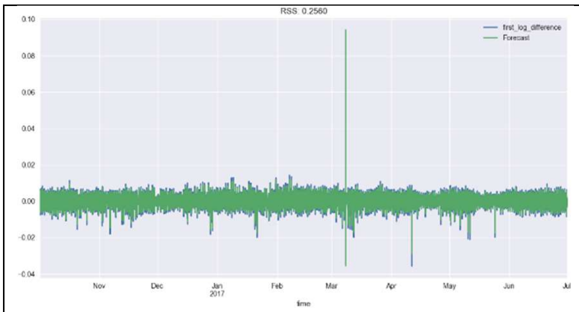

Figure 06: Observed natural log difference temperature data and ARIMA model fitted data as shown

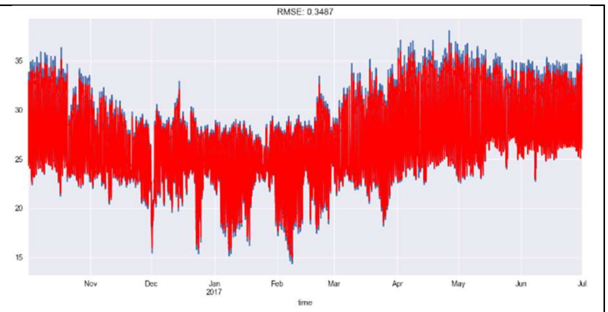

Figure 07: Observed temperature data and ARIMA model fitted data as shown

Finally the ARIMA model will be used for forecasting the temperature. In order to do this experiment, the last day temperature was removed from our data and it was defined as test data and the remaining data was defined as training data. The training data was used to model the ARIMA model, and the test data was to check the difference between observed temperature and predicted temperature. The next two predicted and observed values are given in table 03. One-step out-of-sample forecasts method was used for this prediction. Every time ARIMA model needs to be trained before the prediction and it takes significant amount of time.

Table 03: Next two predicted vs observed values

No	Predicted	Observed
1	25.134932	25.136100
2	25.132356	25.134300

Similarly, diffused horizontal irradiance (DHI) and global horizontal irradiance (GHI) and silicon output voltage can be modelled using ARIMA modelling.

5. Conclusion

Weather data and solar irradiance variation on a daily and yearly basis were analysed. Subsequently, the correlation between individual weather parameters and solar irradiance and silicon voltage were studied using Pearson correlation estimation. Based on correlation studies, it was found that the solar parameters are influencing the solar power generation. Further, temperature variations were modelled using ARIMA modelling and the model were used to forecast the next hour data. Similarly, the diffused horizontal irradiance (DHI) and global horizontal irradiance (GHI) data can be forecasted using ARIMA modelling, and the next hour data can be predicted.

In future, the correlation between solar irradiance and temperature or humidity will be modelled using support vector regression methods and DHI and GHI will be forecasted based on weather data. These prediction models are useful for power generation entities and households. The effects of soiling on PV modules vary with soil type, location and weather patterns. This will be considered in future study.

Reference

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