Solar Irradiation Forecasting for the City of Durban Using Time Series Analysis

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Abstract— As a result of the country's rich solar resources, local and international investors have grown interested in the solar energy industry. The country has sufficient renewable energy resources that can be exploited to generate electricity. Solar power has exposed achievement in the area of electric power generation. The fuel that powers solar energy is Light from the sun and solar radiation. As a substitute for fossil fuel-based energy, renewable energy plays a vital role in developing countries such as those in Africa, Asia, and Latin America. Published publications related to this topic often use mathematical models to model the solar resources instead of measurements. The most preferable data is measured since the effects of weather and pollution are included. The commissioning of regional networks for monitoring solar stations in southern Africa has established a unique source for sun strength measurements in Southern Africa. This study presents sun strength measurements from the solar station in southern Africa Universities Radiometric Network (SAURAN) is compared with NASA data.

Keywords— Solar assessment, radiometry data, renewable energy, Solar radiation

I. INTRODUCTION

The growing demand for Electricity, as well as public concern about the impact of power use on the environment. In a technologically driven world with diminishing energy supplies, since the global energy market is being liberalized rapidly, management and conservation of energy are becoming more relevant and important around the world. South Africa offers some of the world's best solar resources. [1] South Africa is currently producing a lot of solar power, and predictions suggest that production will continue to grow in the future. One of the world's best solar resources can be found in this country. [2] Climate change and rising energy demand are major factors driving the production of Solar radiation sideways with wind energy being measured as the vital resource of energy for the expansion and examination of energy for power plant development at specific geographical locations. reliable solar radiation data at specific places in the biosphere od of intense importance, as the biosphere shifts from fossil fuel to the renewable source. [3] The satisfactory information of solar radiation is the first opinion of all types of requests in the field of renewable energy overall and Photovoltaic (PV) solar energy in particular. [4] Providing common instruments for the study station in larger Durban in KwaZulu Natal. An analysis is made of data generated by SAURAN and compared to data from NASA. To identify any climate effects that may affect spatial variations, a comparison of station data is conducted.

II. RELATED WORKS OR LITERATURE REVIEW

In a world shifting from fossil fuels to renewable energy, solar radiation, and wind energy is measured as renewable energy. The analysis of solar power projects depends heavily on reliable solar data at a particular geographical location. Solar radiation sideways with wind energy is measured as the vital resource of energy for renewables projects as the biosphere shift from fossil fuels to maintainable power options, reliable solar radiation data at a specific geographical location is of vigorous importance for expansion and examination of energy for power plant developments.[5] The satisfactory information of solar radiation is the first opinion of all types of requests in the field of renewable energy overall and Photovoltaic (PV) solar energy in particular. With an estimated population of 3 176 254 (3 million) with a population growth of 0.57%. South Africa's largest city and third-largest by population is Durban, located in the KwaZulu Natal Province [6, 7] For a solar presentation in coming years, previous solar measurements energy at the location in the form of interrogation or measurement of the nearby site should be incorporated, but the estimate of solar radiation does not depend entirely on solar radiation irradiation models, commended by Beckman, Duffie Beckman, and Duffie. The majority of solar radiation models are based on instrument data collected by some form of measuring device for validation and development. The ground-based case irradiation solar measurement is crucial. [8] we face an increasing scarcity of power in our developing country, South Africa is a good place for exploiting its abundant resource of solar. The nation is devoted to surging the involvement of renewable energy in the national energy supply. A South Africa Solar Map

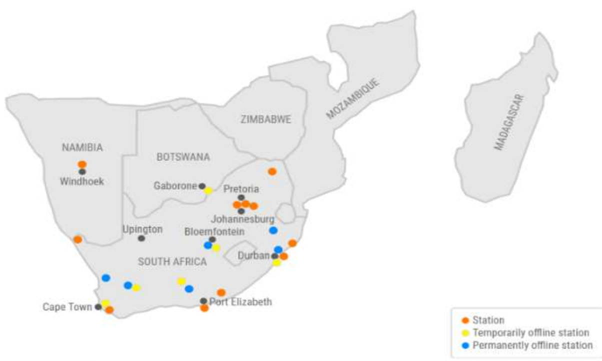

Fig 1 shows substantial solar potential resources for Solar Photovoltaic and solar warming applications.[9]

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In the Western Cape and Northern Cape Provinces, significant efforts have been made to characterize solar intensity, while urban areas have been overlooked. Substituting solar water heaters for electric water heaters in urban areas could reduce domestic electricity demand significantly, which is why it is vital to assess the solar resources for the biggest city in South Africa. Approximately 67% of the South African population survives in urban areas. [10]. There are numerous low-income families and rural residences in the area that would benefit from the installation of off-grid, technologies of sustainable energy such as water heating and solar cooker systems. A study has also presented that low-cost housing could contain smart energy types through the consumption of elements of solar passive construction design performs. This study results in fuel investments of as much as 65% that would impact low-income families. [11]

The climate of Durban is humid subtropical with hot seasonal and cold to mild winters with the perseverance of cloud-free skies and high-pressure systems. [1]

A. Development of the KZN station

A new radiometric station was established by the KZN School of Mechanical Engineering in December 2009. In February 2010, it became fully operational [6]. To measure the overall horizontal component, diffuse horizontal component, and direct horizontal component on a routine basis, in addition, to the Precision Spectral Pyrometers (PSP), normal incident Pyrheliometer (NIP) were acquired by the University On the rooftop of the Howard College Campus at the University of KwaZulu Natal, the site is located on the Desmond Clarence building. Platform Solar is located at -29.87097931 latitude South. at an elevation of 150m Longitude East. Several issues need to be taken into consideration when determining the site's location, including safety issues and ease of access for maintenance personnel. The location should be free of energy interference, which could make it difficult to detect and analyze the required signal, lowering its clarity. Also, it should be free of artificial impediments, which are towering buildings, as well as natural objections, long trees above the sensing element's plane, which could cast shadows on the sensors.

Fig. 2 Solar radiometric ground station at Howard College, UKZN.

The instrumentation bench at UKZN Howard College Campus is made up of a table that faces true north, shown in fig 2. Through the instruments, the sun can be tracked as it crosses the horizon on an east-west axis. On the Eppley ST-1, the solar track is mounted with three precision spectral pyrometers (PSP) and a normal incidence pyrheliometer (NIP), which are all Eppely devices. As the station does not currently have an interruptible power supply unit (UPS), it has been experiencing data loss because of energy surges and cuts from the National Grid. The GRADRAD solar calendar notifies users about lost data. Data reliability has improved since a UPS has been purchased. In the future, a weather station will be installed at Howard College to improve humidity and temperature observations. A spectral model can be developed using such weather data to GRADRAD in the future to provide more accurate estimates of direct normal irradiation. Details of the site

The University of Technology is located in the province of KwaZulu Natal and consists of five independent campuses, including the Westville campus, Durban campus, Edgewood campus, the Medical Scholl campus, and Pietermaritzburg sits in the heart of the scenic Natal Midlands, close to a variety of nature reserves and parks

TABLE I. GEOGRAPHICAL DETAILS OF SITE STUDY

	University of KwaZulu Natal (Howard College)
Latitude	-29.87097931
Longitude	30.97694969
Elevation	150m

The main emphasis of this paper is on the Compares of Solar irradiation received in UKZN Howard College using SAURAN and NASA which data is preparedly and effortlessly available. [11] Because the expense of measuring some climatic parameters is prohibitively expensive. We chose to utilize a method that calculated solar radiation and sunshine duration. [5] Records of solar radiation incidents in UKZN Howard College is conducted by Southern African universities radiometric network (SAURAN)

Fig. 3: an image of Existing UKZN Howard College Station.

III. Methodology

A. Recurrent Neural Network

RNN (Recurrent Neutral Network) is a powerful tool for modelling sequences. The current output acquires from the previous sequence, using the sequence passed on as an input to the input, and the recurrent neural network iteratively adds the previous output to the current input. Thereafter it would be prejudiced by the precious sequences. The previous carries on the past results which a combination. As a result, sequential information influences all outputs and continues throughout a series. [16].

B. Long Short Term Memory

The LSTM (Long Short Term Memory) is the state-of-the-art technique for sequence learning and it has the complex architecture associated with the RNN, the are three gates that are used to mesh and carry forward the past information [16]. The input is transmitted to the previous output and added to it. The gate determines whether or not the previous output is used to generate the current output. Unlike the RNN which carries on the previous output, the LSTM takes a decision on which data is carried forward through the cell state. Additionally, unlike RNN, the LSTM cell holds the input gate and the output gate to produce the final output carries the previous output to the next timestamp. However, unlike RNN the LSTM calculates the current output. LSTM hence has control over the past output and the current output rather than directly producing the output. LSTM cell is measured as a unit, which can be joined in any order. Before producing the final output, the LSTM has 100 LSTM units and the last layer has one dense layer. To get the most precise results, the Adam optimizer was employed.

C. Model Evaluation

The Root Mean Square Error (RMSE) and R2 are chosen as error metrics. The square of the correlation between the observed y values and the estimated y value is determined as R2

$$R^2 = \frac{\sum(\hat{y}_i - \bar{y})^2}{\sum(y_i - \bar{y})^2}$$

Or else it can be mentioned as the proportion of the difference in the forecast variable that is considered for by the relapse model. If the estimates are close to the actual values, R2 ought to be close to 1. Alternatively, if the predictions are dissimilar to the actual values, then R2 = 0. In all cases, R2 lies between 0 and 1. The usage of RMSE is a very common error metric for numerical estimates. Associated with the comparable Root Mean Square Error, RMSE amplifies and harshly punishes large errors [17]

$$RMSE = \sqrt{\frac{1}{n}\,(y_i - \hat{y}\mathrm{i})^2}$$

For model selection, RMSE was well-thought-out in the Random Grid Search and for test set estimation R^2 was used.

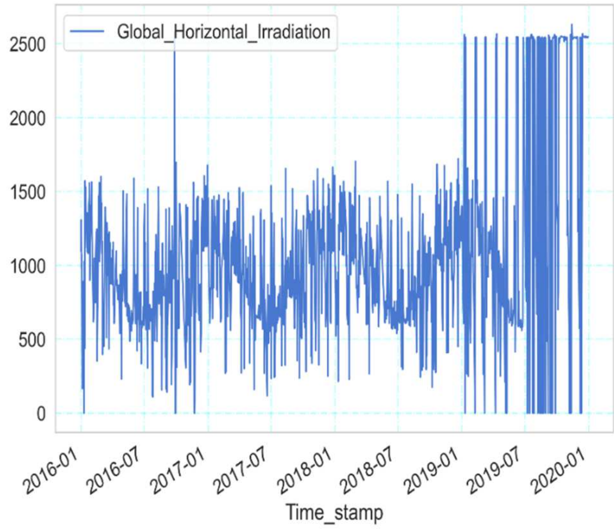


Fig 4: Global irradiation for Durban (2016-2019)., (W/m^2) form SAURAN

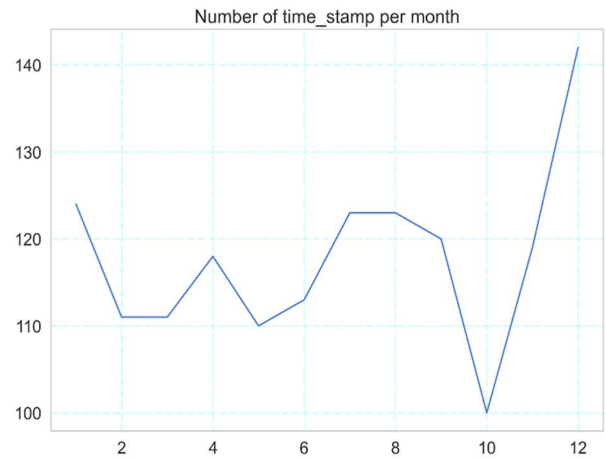


Fig 5: number of timestamps per month.

IV Simulations and Results

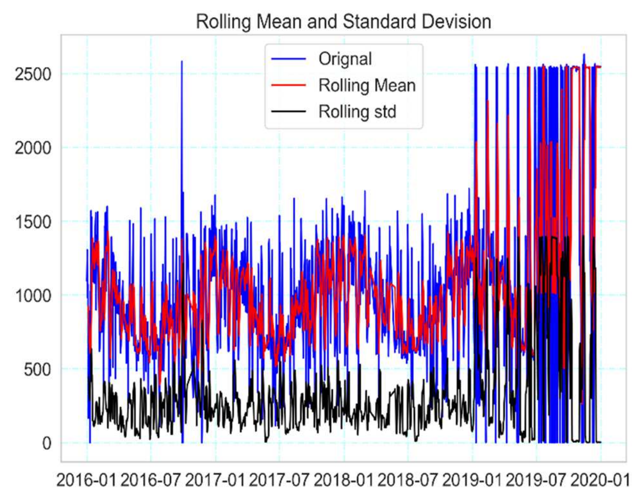


Fig 6: Rolling Mean and Standard division

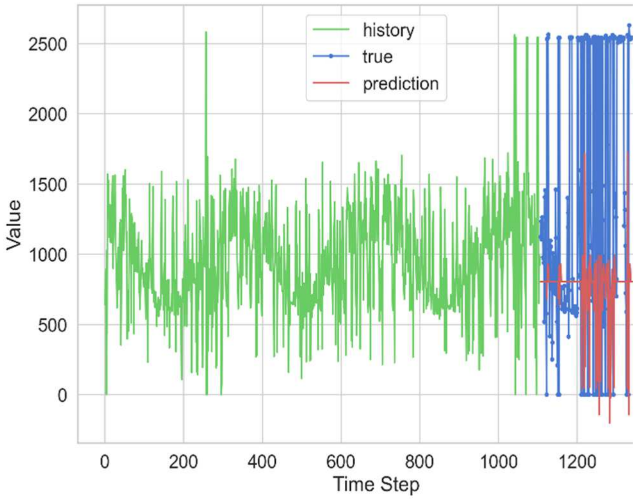


Fig 8: Forecasting of time series of history, true and prediction

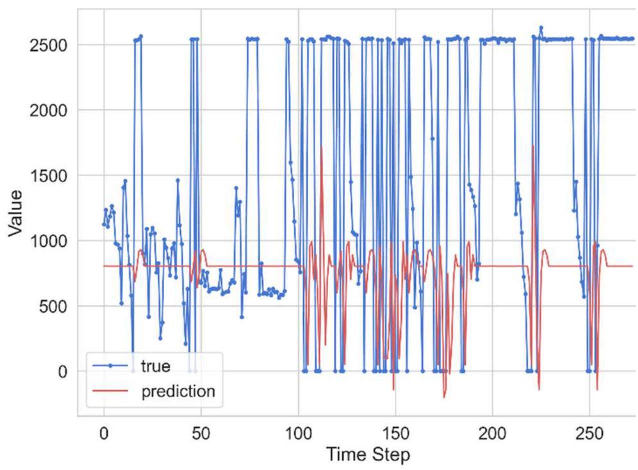


Fig 7: Forecasting of time series of true and prediction.

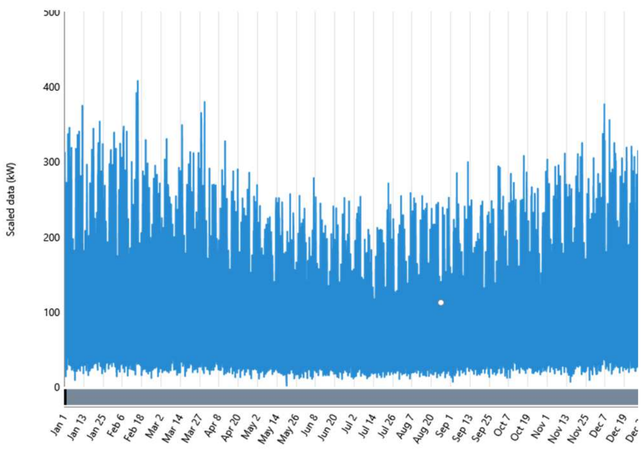
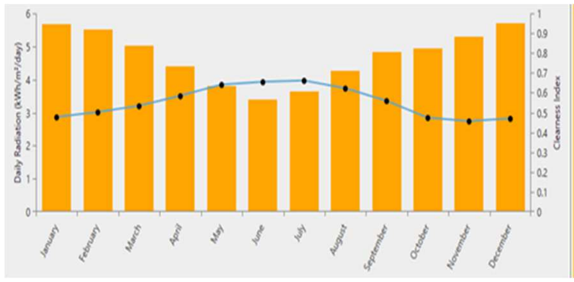


Fig 8. Global irradiation for Durban (kWh) from NASA

Monthly	Clearness index	Daily Radiation (kWh/m^2/day)
January	0.475	5.670
February	0.500	5.510
March	0.531	5.030
April	0.582	4.400
May	0.639	3.810
June	0.653	3.400
July	0.659	3.650
August	0.620	4.250
September	0.557	4.840
October	0.472	4930
November	0.455	5.300
December	0.468	5.690

Fig 9. Monthly Average Solar Global Irradiation (GHI) Data



Research Limitations

This study presented in this paper has the following main limitations.

- The solar resource was not measured in the complete Durban Area but only UKZN Howard College. Although the result was decent for the deployment of the solar plant technologies for power generation further evaluation will be required that will include more locations in dissimilar geographical areas.
- Nonexistence of earlier research on solar resource assessment in Durban and the nonappearance of solar irradiation data and assessment with the previous data was not possible. Assessments were completed with research in other countries (neighboring countries), which were measured to have climates closely to Durban.

IV. Conclusion

The objective of this section is to present an analysis of the UKZN station data collected from 2016 to 2020. The objective of this research was to determine whether there were any variances in spatial variations as a result of the Durban energy situation. The evaluation result shows that the solar assessment of Durban is adequate. UKZN receives efficient solar irradiation which is 4,71 kWh/m^2/day (Annual Average). This analysis shows that the assessment of solar power resources is acceptable for development of photovoltaic plants in this location. More research is required to assess solar resources in Durban using different methods to authenticate the data obtained in this paper.

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