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A Review on Solar Energy: Statistical and AI-based Solar Irradiance Forecasting

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Abstract

We must consider the excessive usage of fossil fuels and their disastrous effects on the environment in light of the current electricity crisis. This means that in order to promote sustainable development, renewable resources must be adopted. The integration of such sporadic renewable energy sources into the current grid increased its capacity but also created problems for the stability of the power system. This research offers a realistic solution to these issues using a novel technological idea known as "solar irradiance forecasting," which improves the stability of the system and offers better profile enhancement for the same. This paper reviewed the articles on statistical and AI-based solar irradiance forecasting in order to provide classifications for employees based on the situation.

Keywords: Solar Energy, Statistical and AI-based Solar Irradiance Forecasting.

1. Introduction

In the past, electric power systems produced energy in response to demand, and the voltage and frequency of the system were centrally managed by electric utilities. However, several countries are already decarburizing their power systems and integrating renewable energy generation facilities like wind and solar energy into their current systems, which is anticipated to account for even more than 20% of total energy production in the future [1].

Nowadays, energy production has a huge influence on the economies, cultures, and advancements of many different countries in modern civilizations [1]. Recent years have seen a significant increase in the use of fossil fuels, which have historically been the main source of energy production [2]. On the other hand, it is a major source of CO_2 emissions, which furthers the impacts of greenhouse gases and global warming [3].

Additionally, non-renewable energy sources are depleting more quickly than they can be produced. Cutting back on fossil fuel consumption is a vital component of the shift. Fossil fuels are costly and harmful to the planet. The majority of fossil fuels are used for industrial purpose and transportation worldwide. In most cities with a dense population that can support a mass transit system and industry , the majority of fossil fuels are used to power buildings.

According to [4], the energy required by only the transport industry is 5.6 10^{20} J/year (560 EJ/year); today, fossil fuels are burned to meet this demand, which makes up approximately 30% of the entire yearly energy demand worldwide. The US is a country that is always changing. As per a report, [5] transportation of persons and products accounted for about 28% of the total energy consumed in the United States in 2021.

Similarly, in India, transportation and industry has been a major user of energy, particularly oil. Roughly 4 EJ of energy, or 19% of India's total energy consumption, was

used by the transport industry in 2020 [6]. Figure 1.1 has shown the rise in fuel demand in India for transportation.

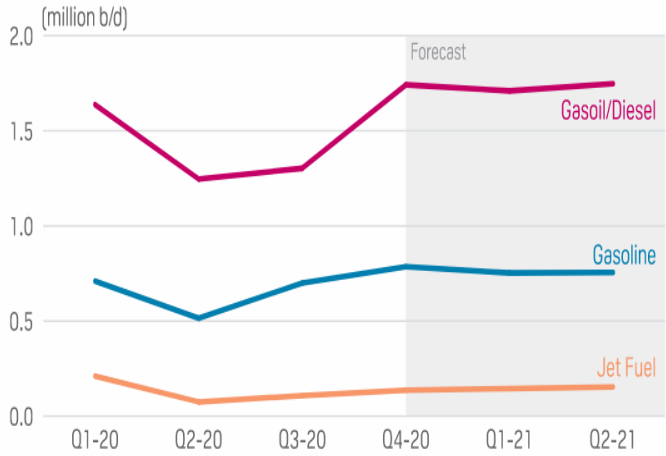

Figure 1.1: Rise of fuel demand for transportation in India [7]

Figure 7, has estimate that the amount of gasoil consumed in FY2021–2022 is raised to 83.677 million mt, up 16.36% from 2020 and 13.30% from the prior estimate for FY2020–2021 [8].

The world's population growth, rapidly expanding industries, and urbanization will surely demand the rise of electrical energy. Uncontrolled urbanization and industrialization are the main causes of this. But one of the key industries that contribute significantly to urbanization and population mobilization in cities is the industrial sector, which cannot be ignored. However, the use of fossil fuels resulted in air pollution and climate change through airborne particles, fumes, or odors that are released into the atmosphere in a way that was potentially harmful to plants, wildlife, or humans. Because poor air quality and climate change lead to an increased chance of exposure to various respiratory and cardiovascular diseases and a mortality rate, almost all states and localities are working hard to directly gauge and anticipate air quality and climate change in order to reduce these dangers and improve public health.

To deal with these circumstances, sustainable development goals (SDGs), commonly referred to as the global development agenda, were approved by the United Nations in 2015 as a global call to action to protect the environment by the year 2030. Of a total of 17 SDG's, Goal 7 (Affordable and Clean Energy), Goal 9 (Industry, Innovation, and Infrastructure), Goal 13 (Climate Action), and Goal 15 (Land Life) specifically refer to environmental and economic industrial growth with universal access to affordable energy through investing in clean energy sources such as solar and wind power, etc. In response to the same, numerous nations are decarburizing their energy systems and incorporating renewable energy generation plants such as wind and solar energy into their existing systems, which is expected to account for more than 20% of total energy generation in the future. This will definitely result in reduced environmental disturbance and surely be an effective approach to climate change mitigation.

There are also a non-renewable energy sources that is being used up faster than it can be created. Due to the rising cost of fossil fuels and their potentially dangerous environmental effects, there has been a noticeable increase in interest in utilizing this solar energy in recent years [9].

Hence, solar energy is considered a promising replacement for fossil fuels. But due to existence of various variables including precipitation, temperature, wind speed, and atmospheric pressure, it exhibits intermittent and volatile characteristics [10]. If all such unstable variable are ignored, voltage fluctuations may result that must be lead to instability in the power grid [11]. In contrast to this, if conventional power networks are integrated with renewable energy sources a precise balance between the supply and demand of electricity is necessary.

But in reality, maintaining this balance with conventional energy producing technologies can be difficult, especially in small or remote electrical networks. The electrical system's reliability is thus determined by its ability to withstand expected and unplanned variation and interruptions while maintaining a standard and progressive level of service for such consumers. The power system is unstable and has problems with voltage fluctuations, poor local power quality, and stability as a result of the irregular and unpredictable nature of solar energy [12].

As a result, accurate energy flow control into the solar energy supply system or optimal grid network functioning depend on the ability to estimate solar system energy output [13]. As a result, predicting solar radiation is becoming more crucial. Hence in this paper, various articles has been reviewed on statistical and AI-based solar irradiance forecasting in order to provide classifications for employees based on the situation.

2. Literature review

This section of the article has been designed to showcase the choice of power quality issues, methodology or technique, and results obtained in the reviewed article.

Table 1, present in this section, has demonstrated the complete analysis of the reviewed article in terms of author, year of publication, and outcome.

Table 1: Analysis of Reviewed articles

S.No	Year of Publication	Author/s	Summary	Ref
1	2020	Pilati et al.	By taking use of the short-term estimates of environmental and economic characteristics, a proper operation management can result in financial gains.	14
2	2020	Toopshekan et al.	An environmental analysis of a hybrid renewable system has been completed, and MATLAB Link has been used to create a unique dispatching strategy for a grid-connected PV/WT/DG/Battery system. controller in HOMER software.	15
3	2020	Murugaperumal et al.	Employing short-term load forecasting methodologies, the village's accessible load patterns were analyzed and their day-by-day and time-step variations were computed. This study also includes the AI based HRE sizing optimization for the best techno-economic configuration.	16
4	2020	Wu et al.	The findings show that, for air compressors employing variable speed drives, either artificial neural network perform well. However, only the short-term, long-term memory model performs well for air compressors employing on/off control and load and unload type air compressors do not produce satisfactory results.	17
5	2020	Raju et al.	As per author of the article, for smart grid functions like power dispatch and managing load, Short Term	18

			Load Forecasting (STLF) is crucial. IOT is a new technology that is permeating all fields of engineering and research.	
6	2020	Shadab et al.	The study determined that seasonal ARIMA simulations can be effectively used for predicting spatial time series solar radiation data. It also evaluated the ARIMA models as a feasible strategy to forecast the average monthly insolation data across an area of 18904 square kilometres around India's capital Delhi.	19
7	2020	Pazikadin et al.	The instrumentation used to detect solar irradiance and the use of ANN algorithms for forecasting solar power generation were both thoroughly reviewed in the current study. By emphasizing the various perspectives found in the literature on solar power forecasting, the review expands on earlier studies. The primary source of prior documentation for the review was four major databases, which made a substantial addition to the corpus of knowledge..	20
8	2020	Yagli et al.	An ensemble of 1-hour-ahead clear-sky score forecasts produced by 20 commercial machine-learning and combinational models that were trained using ground-based data gathered at 7 research-grade stations are post-processed in this work. The models that use data are selected from many model families with diverse prediction processes, including time series, rule- or tree-based, linear/nonlinear, and kernel-based models.	21
9	2019	Srivastava et al.	This case study analyses the solar radiation predicting achievements of the CART, MARS, M5, and random forest models. For the Gorakhpur, India , the model's abilities were analyzed hourly for solar radiation forecasts ranging from one day to six days in advance..	22
10	2019	Yagli et al.	Employing satellite-derived irradiance information collected from 7 locations across 5 distinct climate zones on the US mainland, a total of 68 machine learning (ML) models were evaluated in this study.	23

			During all-sky conditions, tree-based approaches were found to be better in long-term average nRMSE, while under clear-sky conditions, MLP and SVR versions were the most effective.	
11	2019	VanDeventer et al.	By contrasting the results with those of the original SVM and the suggested GASVM, the effectiveness of the suggested approach is confirmed. By contrasting the SVM without optimization with the suggested technique with optimization, a performance measure can be developed based on the assessment of performance findings.	24
12	2019	Qiu et al.	Utilizing data on solar radiation from Solargis as well as the EU solar power geographically data system, this research defines an improved computational framework that forecasts solar rays using a weighting technique that calculates the amount of sunlight along six the primary navigation routes, ensuring the accuracy of the forecast results.	25
13	2018	Mohan et al.	Electric load forecasting is critical to power system security, stability, and energy demand management. For the grid to operate reliably on a daily basis, a short-term load forecasting (STLF) model that is fast, resilient, and accurate enough is required.	26
14	2018	Ghritlahre et al.	In the current study, an Artificial Neural Network (ANN) model has been created and compared with real experimental data to forecast the transfer of heat from a textured absorber plate to air travelling via the solar air heater's ducts.	27
15	2018	Zendehboudi et al.	This study examined the use of SVM modelling in the solar and wind energy industries. Because of this model's consistency and precision in forecasting, it has drawn the interest of numerous academics globally and been extensively employed. Nonetheless, based on the related articles that were assessed in the wind and solar sectors.	28

According to the analysis of table 1, it has been shown that forecasting of solar irradiance have been performed by numerous researchers to make up long term and short term, but results has been found best with using of AI techniques.

3. Conclusion

Effective load demand can be fulfilled in the developing nations, thanks to solar photovoltaic power generation technologies. It takes practical methods that are directed by pertinent international engineering standards to suggest appropriate solar systems for various sites. The paper presents the off-grid solar PV design methodologies and the techno-economic and life cycle impact studies that have produced thorough outcomes of interest and academic significance. Both statistical and AI techniques has been reviewed in this paper. This could help with the planning and development of distributed photovoltaic power systems for off-grid uses in underdeveloped nations.

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