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Design Simulation and Review of Solar PV Power Forecasting Using Computing Techniques

Rajendra Kumar [1], Gulhasan Ahmad[2], Pawan Kumar Tiwari[3], Mukesh Kumar Yadav[4]
[1]*M.Tech. Scholar, Department of Electrical Engineering, SBCET, Jaipur, Rajasthan, India*
[2,3,4] *Assistant Professor, Department of Electrical Engineering, SBCET, Jaipur, Rajasthan, India*
rajkumarbundi12@gmail.com[1], ahmad.gulhasan@gmail.com[2], tiwaripawan746@gmail.com[3], mukeshece25@gmail.com[4]

Abstract— The field of renewable energies provides solutions to the sustainable energy challenges of developing countries. Various renewable energy options are used to solve the power shortage in India. In recent years, power generation has increased significantly, but the market is promising for domestic organisations, distribution networks and transmission networks, and the financial situation is sluggish and influential. India has 450,000 kilowatts of hydroelectric power, has an installed wind power capacity of 230,000 kilowatts, but has almost no great potential for renewable energy. However, India is currently very high in this region, 2022 (not including large hydropower), the target is to raise the current installed capacity from 37 GW of renewable energy to 1.75 million kilowatts. Solar energy is a key part of the government's extension policy. The demonstration of solar PV Systems is highly advantageous for geography and structure. For efficient structure, we need effective design and forecasting tools. PV system is a popular tool to optimise and schedule the design and construction of independent photovoltaic solar systems connected to the grid.

The objective of this research is to introduce the equivalent design model of the photo voltaic solar power plant and to analyses the impact of power forecasting on performance assessment of solar photo voltaic system. Mathematical model of solar photovoltaic system has been implemented using and performance is analysed using PV and IV characteristics of solar photovoltaic system. Modified prediction technique was implemented for optimum forecasting in the specified scenario of complex operating condition.

Keywords— Energy Forecasting, Renewable Energy, PV Power, IV Curve, PV Curve.

I. INTRODUCTION

Because According to analyses of standard arrangements, sustainable power source assets are available and reasonably priced in remote and abandoned areas, which has led to an exponential growth in the number of independent frameworks that use them. Given the rapid depletion of fossil energy sources, half-inexhaustible structures will have a significant offer for future energy gracefully. Elective energy sources are readily available, naturally uncontaminated, and consistently free. The limitations of customary appropriation frameworks' applications are brought on by their high initial costs and reliability problems.Exploiting photovoltaic (PV) technology to convert solar energy legally into electrical energy is an effective and simple technique of using solar energy. By the end of this century, it is anticipated that PV systems will become one of the key energy sources to provide all of the world's energy needs. Different approaches, such wind power plants, energy storage batteries, and solar-powered heating plants, are too effective and are frequently combined with photovoltaic (PV) units to increase structural stability. The approach utilized to organize and manage sustainable cross breed frameworks has become a significant and growing concern. Combining at least two limitless energy frameworks opens up a variety of tactics for presenting and managing force generating frameworks. These earth-benevolent structures' expense and unwavering quality are their most important and outstanding features. The employment of PV and wind generators is widespread today for a variety of purposes, including the provision of

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correspondence frameworks, light, and power in remote areas. Diesel generators could be used in equal measure to supplement force capacity. Given the importance of coordinated operation between diesel generators and a flexible, sustainable framework, the support expenses are apparent. This research paper conveys a workable philosophy for the design and demonstration of photovoltaic force age systems, taking into account their planning. In this work, voltage-based maximum power point tracking (MPPT) of PV frameworks are used to extract the highest amount of readily available energy under diverse ecological conditions. Each nation recognizes the natural and practical value of solar energy. As a result, solar energy plays a crucial role in the cost-effectiveness of any nation's economy; it directly employs labor and promotes the development of businesses on a small scale. The efficiency of the energy that the sun provides is the most important aspect influencing the solar energy age framework. Although there are other considerations, such as the absence of pollution, the absence of ozone-depleting substances, the security of the energy resource, and so on, that influence the decision of when to use solar energy, the structure decisions are only guided by the "level of energy cost." This same monetary threshold, which represents the average cost of the energy produced by the solar energy system throughout the course of the system's lifetime, is reached at the halfway. Therefore, a solar energy power system is the ideal energy source anytime the government and/or industrialists provide financial assistance to lower the cost of installing solar panels for contemporary, commercial, and individual purchasers. In a region with high levels of daylight, such as the Southwest, solar energy might provide all the power needed to run the nation's PV structures, which currently cover 0.4 percent of the country and a region of around 100 square miles. In reality, these boards will be spread across the country on rooftops and other buildings close to the areas where they are consumed. Innovations like PV rooftop shingles, windows, and changeable texturing that can be seamlessly and affordably integrated into both new and existing structures are on the rise. Solar energy is produced nearby, frequently at the location where it will be used, thus costs and supplies are resilient to blackouts, worldwide vulnerability, and do not rely on great distances gracefully. Air and water are not contaminated by solar energy. It removes risks to public health, such as carbon monoxide, particle, and dangerous compound emissions from workplaces powered by coal, petroleum gas, and other non-sustainable energizes by replacing the electricity produced by those offices. Additionally, when solar energy replaces power from a coal-fired power plant, it also eliminates a potential source of sulfur emissions, which make up a sizable portion of corrosive rain. Because solar energy doesn't produce CO2 or other ozone-depleting compounds, it helps to reduce the threat of climate change. Photovoltaic, or "PV," solar panels and other devices that capture light energy and convert it to power are used to produce solar power. Following that, this energy could be provided directly to customers, a power network, or a capacity device. Solar panels are frequently installed on the top of residential or commercial buildings, using the energy generated to provide the owner's energy needs and surplus power to the network. Other uses include providing power and heating water in places where power sources are not available, including on street signs, PDA pinnacles, and satellites. A photovoltaic cell cluster converts solar radiation into coordinated flow electricity through the use of a solar photovoltaic material. Monocrystalline silicon, polycrystalline silicon, microcrystalline silicon, cadmium telluride, as well as copper indium selenide/sulfide, are materials that are regularly used in solar systems. The world's fastest-growing energy innovation is photovoltaic generation, which has been growing steadily since 2002, averaging 48 percent yearly growth.

Solar energy is commonly discussed in relation to other developments in sustainable energy sources that also have the possibility for scattered energy ages. A photovoltaic system utilizes solar cells to convert solar energy into electrical power. Due to the individual solar cell's low voltage (typically 0.5V), several cells are combined to produce photovoltaic modules, which are then connected together to form an exhibit. The generated energy can be stored, used directly (independent plant), managed into a sizable power network powered by focal-age plants (lattice associated/matrix tied plant), or connected with one or more domestic power generators to manage into a small lattice (half and half plant).

Compared to conventional power, photovoltaic power has many advantages. It has input from sustainable power sources right away, such solar energy. It is not restricted by topography. Limits for PV frameworks might range from mW to GW. However, classic power age frameworks with only massive limits are more cautious. PV frameworks are economically friendly and have low maintenance and activity costs.

In recent years, the use of PV systems for lighting, heating, water siphoning, industry, commercial buildings, and other purposes has rapidly increased in emerging nations. Figure 1.1 shows a square normal graph of the solar photovoltaic power age framework.

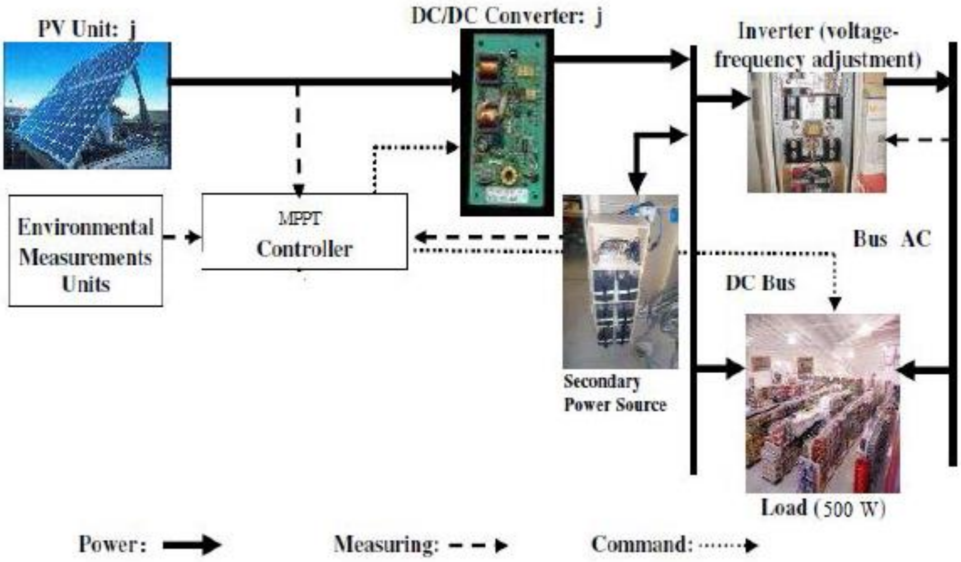

Fig 1.1 Block Diagram of Isolated Photovoltaic Power Generation System

PV installations on structures connected to the power matrix have been widely adopted in countries like Japan, Germany, Switzerland, the United States, and so forth. In matrix-related frameworks, PV frameworks kindly supply the structure with electricity, and any daytime surplus may be distributed to the framework. Because the network provides any further interest, batteries are not needed. However, the battery reserve may still be present to provide electricity outside of daylight hours. A pitched roof can have solar PV modules retrofitted over the existing roof tiles, or the roof tiles can be replaced with extremely structured PV roof tiles or roof tiling frameworks.Solar energy has traditionally been the power source of choice for contemporary applications where power is needed in remote locations. This suggests that in these cases solar power is just financial and endowed. The majority of frameworks in single applications need a few kW of power. The repeater stations for microwave, TV, radio, telemetry, and radiophones are powered by the models. Additionally, solar energy is occasionally used for transportation signaling, such as seaward route floats, beacons, airplane-cautioning lights on arches or structures, and increasingly, street traffic notice signals. \ It very well may be viable to set up a hybrid power system that combines the PV with a small diesel generator for larger electrical demands. Glass/glass PV modules, which can be installed semi-straightforwardly to provide concealed light, can be used to secure atria on a commercial building.

The main goal of finishing this exam is to create a detached power age structure using non-regular energy sources like solar energy. The benefits of this effort are numerous. Photovoltaic has become popular in developing countries as many cities are usually more than five kilometers from a network power source. A provincial lighting program in India has been providing solar-powered LED lighting to replace lamp oil lights in remote locations. The cost of the solar-powered lights is comparable to the cost of a few months' worth of flexible lamp fuel. These are areas where the societal costs and benefits make a compelling case for adopting solar, yet the lack of profitability could relegate such endeavors to charitable goals. As streets are typically unobstructed by the sun and speak to around the level of land zone expected to replace other energy sources with solar power, a 72 km stretch of street in Idaho is being used to explore the possibility of incorporating solar boards into the street surface. Large solar power array satellite structures have been the subject of extensive research for a long time.

II. RELATED WORKS

India is rich in solar energy. In addition, the solar photovoltaic technology is one of the most famous and comparatively much reliable in the renewable energy generation list. Lower cost, increased efficiency and better performance of PV panels over a wide range of temperatures are some of the recent developments in the PV technology. The field of Photovoltaic (PV) has experienced a remarkable growth for past two decades in its widespread use from standalone to utility interactive PV systems There are a number of advantages of solar system, some of those include distribution and transmission capacity relief, load peak shaving, deferral of high cost transmission and distribution (T&D)system upgrades. Despite these benefits as mentioned above, PV grid connection has many technical challenges, which must be tackled before considering it as a reliable source of supply. Marcelo Gradella Villalva, Jonas Rafael Gazoli, and Ernesto Ruppert Filho [1] proposed the strategy that finds the I– V condition for the single-diode photovoltaic (PV) display including the impact of the parallel and arrangement protections, and undertaking that the maximum power of the model matches with the maximum power of the genuine exhibit. With the parameters of the balanced I– V condition, it is then conceivable to manufacture a PV circuit display. Parameters are found by thinking about three essential points: open circuit, maximum power, hamper. The outcomes show accentuation on the estimation of the arrangement obstruction which can act significantly on the yield attributes. D. Sera, R. Teodorescu, and P. Rodriguez [2] Proposed photovoltaic board show, in view of on qualities given by the producer's information sheet, reasonable for on-line temperature and irradiance estimations and model-based MPPT, is introduced. It proposes to disregard the term "−1" in condition, as in silicon gadgets, the dull immersion current is extremely little contrasted with the exponential term.W. D. Soto, S. A. Klein, and W. A. Beckman [3] take information by recognizing that the derivative of the power at the maximum power point is zero. Although both the temperature coefficient of the open circuit voltage and the temperature coefficient of the short circuit current are known, only open circuit is used to find the five reference parameters. The operating condition dependence of the series resistance Rs, and the shunt resistance, Rsh is investigated.F. Caracciolo, E. Dallago, D. G. Finarelli, A. Liberale, and P. Merhej [4] proposes method based on the acquisition of experimental data related to the v–i characteristics of illuminated or dark SC/PVSM at fixed climatic conditions. The generalization of a method reduces the optimization process of the model's parameters to the single variable Rs which does not need any starting parameters estimation prior to the optimization process, has a high tolerance to measurement uncertainty, is stable, and yields results whenever the single-diode model and its extension to the solar module is an appropriate description of reality.S. S. Satapathyet al. [5] Presented a derated MPPT scheme for grid integrated solar pv energy conversion system and discusses the derated MPPT (Maximum Power Peak Tracking) system for the grid-connected solar PV systems. Due to reverse power flow to the grid, the voltage on PCC (Point of Common Coupling) rises. Permitting to the standards of the grid, simply up to 10% increase in PCC voltage is tolerable. The derated MPPT (Maximum Power Peak Tracking) scheme has been projected, for grid integrated solar PV system. The proposed method is derated perturb and observe (DPO) MPPT (Maximum Power Peak Tracking) algorithm. DPO MPPT algorithm has the ability to operate the PV array at MPP or at any lower operating point of MPP, which decides according to the PCC voltage condition.R. Subha et.al. [6] The performance evaluation of the algorithm of MPPT with natural shadows in solar photovoltaic systems with partial shadows is proposed. The author of this article discusses and analyzes the ability of five algorithms inspired by nature to track the maximum power point in partial shadows. Following the global MPP

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under partial shadow conditions is a difficult task because the P-V characteristic has numerous heights. Because of its success in solving difficult optimization problems, the use of algorithms inspired by nature is increasing. Therefore, this paper studies five general and best-performing intelligent natural heuristic algorithms to liken their competence in GMPP tracking.S. Moonjerin et.al. [7] Aiming at the photovoltaic system under partial shadow conditions, an MPPT algorithm based on beetle antenna search is proposed. The author discusses the unique MPPT algorithm for photovoltaic systems with PSC. This algorithm is based on Beetle Antenna Search method. We propose a novel MPPT algorithm for photovoltaic systems with PSC. The algorithm is developed based on the Beetle antenna search method. The presentation of this algorithm is realized in MATLAB environment. It can be seen from the numerical examination that the offered algorithm delivers earlier meeting and can track GMPP with less PV power oscillation.S Ahmad. et. al. [8] A technical comparison between different PV-MPPT algorithms is proposed to absorb rapidly changing illumination effects. The author discusses the comparative study of three MPPT methods P&O, incremental conductance and improved incremental conductance algorithm under fast charging solar radiation levels. DC-DC boost converter for compatibility with stand-alone and grid-connected. The power of the photovoltaic array is completely correlated with the radiation intensity. Under variable solar irradiance, the P-(V) curve shows many peaks. MPPT (Maximum Power Point Tracking) is one of the best necessary methods for discovering the entire MPP in these local power peaks, so as to maximize the power extracted from the PV system.K. Amara et. al. [9] The improved performance of photovoltaic solar panels based on MPPT of the adaptive neuro-fuzzy inference system ANFIS was demonstrated. The intelligent technology development of the adaptive neuro-fuzzy inference system (ANFIS) based on the maximum power point tracking (ANFIS MPPT) algorithm and the PI controller is aimed at improving the performance of the photovoltaic panel system in a changing atmospheric environment. It must be equipped with a suitable controller to maximize the use of photovoltaic generators to generate electricity and improve efficiency in all weather conditions. Various MPPT algorithms have been researched and developed in the literature. Among them, classic methods (for example: Perturbation and Observation (P&O) and Incremental Conductance (INC)) are very useful in practice because they can perform true tracking under constantly changing irradiation conditions and have simple implementation structures.Y. Ba-khuraisa et.al. [10] The experimental realization of MPPT for photovoltaic systems is introduced. The author discusses that solar panel efficiency is the basic parameter to determine the price of changing solar energy into electricity. This article introduces a technology that uses power electronic circuits to obtain maximum energy from photovoltaic (PV) solar systems to achieve maximum power point tracking. The design and application details are given, and the perturbation and observation algorithms based on DC-DC power converters are explained.

III. ANALYSIS OF FORECASTING MODELS

Solar photovoltaic displays (PV system), which is the array for many of photovoltaic modules that are interconnected. By means of a single photovoltaic module that is produced, the modules are arranged in such a way that a number of capacities can be realized. The associated cluster module is like the cells of the module.The solar cell collectively forms a photovoltaic panel. They are manufactured from a semiconductor, for example silicon, and a thin semiconductor wafer of gallium arsenide has not been typically recompensed to form a negative electric field on the opposite side. If a circuit from both sides of the conductor is connected with the semiconductor which has been thumped clear of semiconductor material molecules, electrons will continue to stream up. Forecasting methodologies can be described in the figure 1.2.

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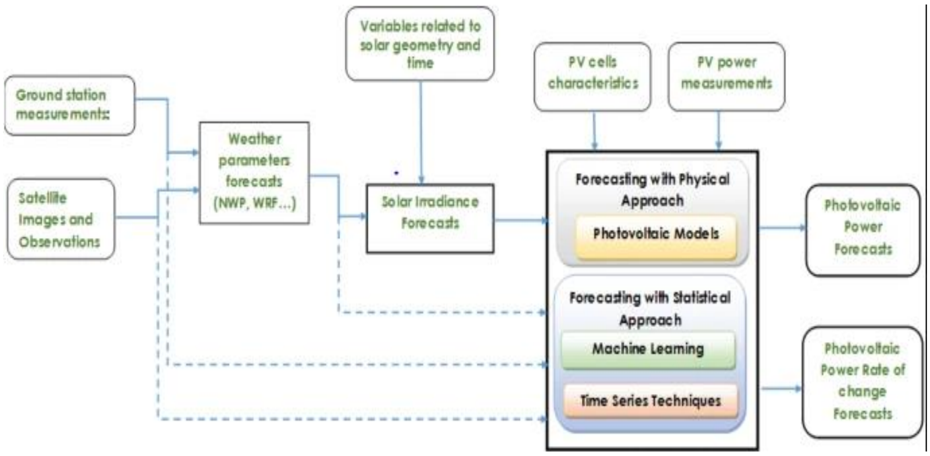

Figure. 1.2 Forecasting Methodologies

Solar energy has a lot of potential for producing power for domestic, commercial, and industrial needs alike [1–5]. The use of PV systems has increased in recent years as a result of photovoltaic solar energy's advantages of being plentiful, non-exhaustible, clean, and environmentally friendly [6-8]. [6–8]. Making accurate estimates is crucial when it comes to making decisions that would improve PV solar power plants. The biggest issue in the production of solar energy is the inconsistent generation of electricity from solar panels due to the weather. More than a quarter of the PV power produced can have its quality of energy output significantly reduced by changes in the weather and the sun's rays. utilizing actual solar power facilities. PV cannot be completely integrated into the electrical grid as a result. a precise short-term projection as a result. Forecasts for photovoltaic energy are very useful for controlling daily/hourly electricity generation and grid storage [13]. For the benefit of plants, PV requires precise solar energy forecasts in order to encourage their participation in the market for the production of renewable energy and for a more efficient use of resources [1-3]. In the literature [2–12] of PV energy, various methodological techniques to forecasting have been outlined. These approaches can be divided into four different types.Forecasting using time series, Statistical techniques ARIMA, Machine learning and Artificial Neural Networks (ANNs), other learning techniques, numerical weather prediction-based physical models, and hybrid tactics that integrate the first three techniques. The ARIMA model's biggest strengths are its elegance and simplicity. It is only possible to employ stationary time series [14, 18, 19]. In order to test the ARIMA model's applicability, we employ data from seasonal time series as well as non-stationary data that become fixed data. An illustration of a model This product was developed using state-of-the-art statistical techniques [20]. This method selects and evaluates the optimal approach. Another statistical model can be created using seasonal analysis of the ARIMA time series (SARIMA). improved by incorporating projections for short-term solar radiation from NWP (numerical weather prediction) models [19]. Accurate power forecasting from PV systems is necessary for the successful integration of solar power into the electrical grid.

Table 1: Details of Variables of Weather Data

Weather Features	**Unit**	**Weather Features**	**Unit**
Cloud Coverage	So range	Relative Humidity	%
Visibility	Miles	Wind Speed	Mph
Temperature	*C	Station Pressure	inchIg
Dew Point	*C	Altimeter	inch Hg

Improved forecasting models for solar and wind energy are constantly being developed.New solar and wind energy forecasting models are continually being developed. For instance, the physical relationships between different meteorological variables, terrain, and sun irradiation can be used to explain the plant's solar electricity output. The NWP model receives input from local meteorological measurements such as sky imagers and SCADA (the user) data for output power, in addition to other data about the nearby terrain and topography (NWP). Satellites and sky imagers track clouds and predict solar irradiance up to three hours in advance; after that, NWP is commonly used to project irradiance [7]. The projected solar irradiation from NWP and solar power generation are related, according to an analysis of historical data series using solely statistical approaches and disregarding system physics. The plant's future can be foreseen using this link. The association between predicted weather and electricity production is discovered using AI techniques using time series data from the past. Instead of performing an explicit statistical analysis, AI techniques can be used to intuitively depict nonlinear and complex relationships between input data (NWP forecasts and output power). Both the statistical and AI approaches depend heavily on temperature projections and historical data on power output. In today's realistic forecasting models for renewable energy, physical and statistical models are frequently applied. The statistical approach requires the physical relations of output power production while the physical approach requires statistics in order to create more precise projections. By modifying the weights of the combined models in the best possible way, it is possible to achieve the perfect weighting between physical approach-based forecasts and statistical forecasts [8, 9]. It is obvious from the scatter plots that the outliers do not change the data's overall trend. The significant majority of the data's extreme points happen during the sun's rising and setting phases, when the lifespan of solar panels is unknown.

According to Hannikainen, the model used for forecasting always determines the amount of data needed for prediction. 68 The benchmark Persistence model uses very little data, whereas the forecasting NWP model uses a vast quantity of data. According to Fischer et al., the statistical methods and ANN models in wind farms depend on historical meteorological data. The effectiveness of the applied prediction technique is assessed using the two main statistical indicators, MAPE and RMSE. For evaluating performance, other error measures like mean bias error (MBE) and skill score are also used. The following are some of the widely used statistical error parameters taken into account for performance evaluation: In Equation, the mean square error is reported.

$$\mathrm{MSE}=\frac{1}{N}\sum_{j=1}^{N}\left(P_{\text{lococusiod}}-P_{\text{actual, 1}}\right)^{2}$$

Here N is number of samples, whereas $P_{\text{actuml,}}$ and P_{Hrocstod} are actual and predicted values, respectively.

RMSE (as shown in Equation (12)) is the most suitable for WF applications because it gives extra weight for large changes between actual and predicted values in comparison with small changes as given by Staid et al. 7

$$\mathrm{RMSE}=\sqrt{\frac{1}{N}\sum_{1=1}^{N}\left(P_{\text{farocasiod 1}}-P_{\text{actual, 1}}\right)^{2}}$$

The MAE and MAPE (as shown in Equations (13) and (14), respectively) are regularly used statistical errors.

$$\mathrm{MAPE}=\frac{1}{N}\sum_{j=1}^{N}\left|\frac{P_{2ctayl,1}-P_{\text{forcastod, 1}}}{P_{\text{sctual, 1}}}\right|*100$$

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MBE as shown in Equation (15) indicates that the forecast value is under-estimated or ower-estimated. For statistical approaches and physical approaches with model output statistics, it gives low results.

$$\mathrm{MBE} = \frac{\sum_{i=1}^{N} \left(P_{\text{locsadod },t} - P_{\text{vetmal, }1}\right)}{N}$$

$$\text{Skill score } = 1 - \frac{\mathrm{RMSE}_m}{\mathrm{RMSE}_p}.$$

By taking into account the reported forecasts' variability and uncertainty, forecasting methods' efficacy is determined. The best prediction quality is indicated by the higher Skill Score values.

IV. CONCLUSION

Reviewing solar power generation forecast and evaluation strategies for solar and wind energy is the main objective of this work. In order to better utilize resources and offer consumers a range of high-quality services at affordable costs, almost all nations are introducing deregulated industry structures, which leads to transparent price discovery. One of the major study areas in electrical engineering involves the development of tools, models, and algorithms for renewable energy forecasting in today's power systems.Forecasting is an integral component of corporate strategy in today's competitive market. Participants in the electricity market have encountered a variety of problems as a result of the increased use of renewable energy sources and the deregulation of the power sector. Forecasting of renewable energy is now a major issue in power systems. According to market demands, a variety of approaches are employed to forecast renewable energy. As a result, we ran numerous tests in this work using deep learning models to precisely predict power generation based on the results of our trials. Through experiment prediction, the capability to create an accurate prediction model using only the monitoring system data deployed on-site at the solar power plant has been proven. The collection of additional potentially related feature data will still be needed for the practical applications, and numerous model tests may help to gradually improve the solar power forecast model until it is at its best. Since the model only makes use of the related feature values and data set of a single inverter that were gathered in the aforementioned experiment, the performance indicator predicted by the model can only be improved. The feature variables that are used in the best prediction findings will increase the forecast effect for power generation. The most likely reason is that solar thermal radiation and the greenhouse effect are related. It is advised to compile the key greenhouse or solar irradiance characteristic variables in order to increase prediction accuracy in the future. Numerous recently developed neural networks are currently applicable to the subject. Future research could use techniques based on a hybrid deep learning model to continuously enhance the performance of forecasts for solar power generation.

REFERENCES

[1] M. G. Villalva, J. R. Gazoli and E. R. Filho, "Comprehensive Approach to Modeling and Simulation of Photovoltaic Arrays," in *IEEE Transactions on Power Electronics*, vol. 24, no. 5, pp. 1198-1208, May 2009.

[2] Sera, Dezso & Teodorescu, Remus & Rodriguez, Pedro. (2007). "PV Panel Model Based on Datasheet Values". IEEE International Symposium on Industrial Electronics. 2392 - 2396. 10.1109/ISIE.2007.4374981.

[3] W. D. Soto, S. A. Klein, and W. A. Beckman, "Improvement and validation of a model for photovoltaic array performance", Solar Energy Laboratory, University of Wisconsin-Madison, 1500 Engineering Drive, Madison, WI 53706, USA.

[4] F. Caracciolo, E. Dallago, D. G. Finarelli, A. Liberale, and P. Merhej, "Theoretical and Experimental Analysis of an MPP Detection Algorithm Employing a Single-Voltage Sensor Only and a Noisy Signal", in *IEEE Transactions on Power Electronics*, 28(11):5088-5097,Nov 2013.

[5] Acakpovi, Amevi and Essel Ben Hagan, "Novel Photovoltaic Module Modeling using Matlab / Simulink." ,Internatnional Journal on computer application, vol.83, no.16, December 2013.
[6] Mboumboue, Edouard & Njomo, Donatien. (2013). "Mathematical Modeling and Digital Simulation of PV Solar Panel using MATLAB Software". International Journal of Emerging Technology and Advanced Engineering. Volume 3.
[7] Nema, Savita & Nema, Rajesh & Agnihotri, Gayatri." Matlab / simulink based study of photovoltaic cells / modules / array and their experimental verification". International Journal of Energy and Environment.,vol 1, Jan 2010.
[8] Gow, J.A. & Manning, C.D.. (1999). Manning, C.D." Development of a photovoltaic array model for use in power-electronics simulation studies".Electric Power Appl. IEE Proc. 146(2), 193-200. Electric Power Applications, IEE Proceedings -. 146. 193 - 200. 10.1049/ip-epa:19990116.
[9] N. Femia, G. Petrone, G. Spagnuolo and M. Vitelli, "Optimization of perturb and observe maximum power point tracking method," in *IEEE Transactions on Power Electronics*, vol. 20, no. 4, pp. 963-973, July 2005.
[10] W. Xiao, N. Ozog, W.G. Dunford, "Topology study of photovoltaic interface for maximum power point tracking", accepted for publication in IEEE transaction on Industrial Electronics in December, 2006. Hugo T. C. Pedro and Carlos F. M. Coimbra, "Assessment of forecasting techniques for solar power production with no exogenous inputs," Solar Energy, vol. 86, no. 7, pp. 2017–2028, 2012.
[11] Yanting Li, Yan Su, and Lianjie Shu, "An ARMAX model for forecasting the power output of a grid connected photovoltaic system," Renewable Energy, vol.66, pp. 78–89, 2014.
[12] Xwegnon G. Agoua, Robin Girard, and George Kariniotakis, "Short-term spatio-temporal forecasting of photovoltaic power production," IEEE Transactions on Sustainable Energy, vol. 9, no. 2, pp. 538–546, 2018.
[13] Kymakis, Emmanuel, Sofoklis Kalykakis, and Thales M. Papazoglou. "Performance analysis of a grid connected photovoltaic park on the island of Crete." Energy Conversion and Management 50.3 (2009): 433-438.
[14] Fisher, Brent, et al. "Field performance modeling of Semprius CPV systems." Photovoltaic Specialist Conference (PVSC), 2014 IEEE 40th. IEEE, 2014.
[15] Fatehi, Junaid H., and Kenneth J. Sauer. "Modeling the incidence angle dependence of photovoltaic modules in PVsyst." Photovoltaic Specialist Conference (PVSC), 2014 IEEE 40th. IEEE, 2014.
[16] Truong, Nguyen Xuan, et al. "Grid-connected PV system design option for nearly zero energy building in reference building in Hanoi." Sustainable Energy Technologies (ICSET), 2016 IEEE International Conference on. IEEE, 2016.
[17] Pillai, Gobind, et al. "The techno-economic feasibility of providing solar photovoltaic backup power." IEEE International Symposium on Technology and Society (ISTAS). Vol. 20. 2016.
[18] Sidney, Shaji. "Exergy analysis of a solar PV driven DC refrigerator for different ambient conditions." Energy Efficient Technologies for Sustainability (ICEETS), 2016 International Conference on. IEEE, 2016.
[19] Ahsan, Shahzad, et al. "Design and cost analysis of 1kW photovoltaic system based on actual performance in Indian scenario." Perspectives in Science 8 (2016): 642-644.
[20] Al Ali, Mona, and Mahieddine Emziane. "Performance analysis of rooftop PV systems in Abu Dhabi." Energy Procedia 42 (2013): 689-697.
[21] Axaopoulos, Petros J., Emmanouil D. Fylladitakis, and Konstantinos Gkarakis. "Accuracy analysis of software for the estimation and planning of photovoltaic installations." International Journal of Energy and Environmental Engineering 5.1 (2014): 1.
[22] Bhattacharyya, N. K., SR Bhadra Chaudhuri, and D. Mukherjee. "PV Embedded grid connected substation for enhancement of energy security." Photovoltaic Specialists Conference (PVSC), 2009 34th IEEE. IEEE, 2009.
[23] Carbone, R. "Grid-connected photovoltaic systems with energy storage." Clean Electrical Power, 2009 International Conference on. IEEE, 2009.
[24] Chaïb, Ahmed, Mohamed Kesraoui, and Elyes Kechadi. "PV panel positioning using a robot manipulator." Renewable and Sustainable Energy Conference (IRSEC), 2015 3rd International. IEEE, 2015.
[25] Choi, Young-Kwan. "A study on power generation analysis of floating PV system considering environmental impact." International Journal of Software Engineering and Its Applications 8.1 (2014): 75-84.
[26] Dong, Yinghua, et al. "Performance test and evaluation of photovoltaic system." (2015): 4-4.
[27] Do Sacramento, Elissandro Monteiro, et al. "Scenarios for use of floating photovoltaic plants in Brazilian reservoirs." IET Renewable Power Generation 9.8 (2015): 1019-1024.

[28] Fan, Lingling, Zhixin Miao, and Alexander Domijan. "Impact of unbalanced grid conditions on PV systems." Power and Energy Society General Meeting, 2010 IEEE. IEEE, 2010.