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The "Engineer" publishes the most significant results of scientific and applied research carried out in universities of transport profile, as well as other higher educational institutions, research institutes, and centers of the Republic of Uzbekistan and foreign countries.

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Improving control and management methods of electricity quality indicators produced by solar panels

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Abstract: In order to provide consumers with high-quality and uninterrupted electricity, great attention is paid to the use of renewable energy sources in the world, and the electricity generated by solar panels is already in sufficient quantities in this regard. This, in turn, requires monitoring and correct management of the quality indicators of the electricity generated by solar panels, increasing the service life of solar panel elements, and correct diagnosis during their service. In this regard, the demand for compact, economical and inexpensive remote control and management element devices increases, and the scientific article presents sufficient solutions and recommendations for these problems.

Keywords: solar panels, electricity, grid connection, power balance, control, time-dependent characteristic

1. Introduction

The global green energy development agenda has become one of the most pressing issues of our time, with significant investments in developing energy sources based on geothermal, hydroelectric, solar, wind, and other clean energy technologies.[1] In this regard, solar energy has become a leading candidate in the renewable energy sector due to its huge and clean energy potential. Solar energy is a sustainable and environmentally friendly alternative to traditional fossil fuel-based electricity generation by harnessing the power of sunlight.[2] A number of government policies and strategies, including tax incentives, subsidies, and other supportive measures, have played a significant role in increasing PV installations worldwide, along with the sharp decline in the cost of photovoltaic PV modules over the years.[3] At the same time, these factors have led to a sharp increase in the number of PV installations in the solar energy network, making solar energy the largest and fastest growing source of electricity in the world.

2. Research methodology

It is known that solar power grids are currently being used in industrial production and economic sectors of our country in two modes, namely On-grid and Off-grid, and the transition to grid-connected photovoltaic (PV) systems is economically cheap and convenient, so most consumers are using this method. These systems use semiconductor materials to convert sunlight into electricity, thereby reducing carbon dioxide emissions and helping to control global warming. Grid-connected PV systems provide many advantages, including: reducing power losses along the line, improving voltage drop, increasing energy efficiency, correcting power factor and improving harmonic current content[4]. They also provide ancillary services to local consumers, optimizing generation and distribution. Today contribute to energy security and environmental protection. The environmental friendliness of PV systems is also reflected in low emissions, minimal noise, and low water consumption compared to other power plants. The analysis suggests that renewable energy technologies will become the largest contributor to electricity generation in Saudi Arabia over the next two decades; this demonstrates the great potential of solar energy to radically change the energy landscape[5]. In addition, integrating solar energy into the grid can improve energy efficiency by reducing energy losses and increasing the overall efficiency of the grid [6]. Feasibility studies of off-grid, grid-connected solar photovoltaic systems combined with grid-connected battery energy storage have shown that such systems can provide a cheap and reliable source of energy for households and large consumers[7]. The results of the study show that the integration of PV power into the existing grid is difficult due to the natural variability and non-intermittency of solar energy, which leads to power supply fluctuations. Grid-connected solar systems pose serious challenges for grid operators, as the variability and non-intermittency of solar energy can disrupt the stability and efficiency of the grid. In order to improve the reliability of solar power consumers, a hybrid CNN-LSTM model was proposed to predict the PV power of a solar power grid, which was developed to solve these problems when operating from a hybrid system source. The model achieved good accuracy and can effectively reduce the fluctuations in power generation[8]. The lack of input solar radiation data may limit its application in areas with highly variable solar radiation. Also, in [9], a hybrid multi-stage CNN-stacked LSTM model was proposed to predict the solar radiation (GHI) and POA radiation. This model showed high accuracy, achieving RMSE = 0.36 (R^2 = 0.98) for GHI and RMSE = 61.24 (R^2 = 0.96) for POA. The model effectively combines the strengths of CNN and LSTM, improving the accuracy of solar radiation and POA forecasting and is a powerful tool for solar energy forecasting. Similarly, in [21], a two-stream CNN-LSTM network with a self-attention mechanism, called DSCLANet, was proposed for short-term solar energy forecasting. The model significantly reduced errors and performed better than state-of-the-art methods. However,

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combining CNN and LSTM to extract spatial and temporal features increases the complexity of the model, which may lead to high computational costs and training difficulties. The authors plan to address this issue by developing a single architecture that can efficiently extract the two features. In addition, the results of three popular models – ANN, Angstrom-Prescott and ARIMA – were compared with the proposed hybrid model. A hybrid model combining RF, principal component analysis (PCA), K-means and Harmony Search-based Gray Wolf Optimization (HGWO) was used to forecast the solar power plant capacity one hour in advance. This hybrid model achieved significantly lower mean absolute error (MAE) values than previous models, demonstrating the benefits of combining multiple techniques [10]. The data collection process for this study involved simulations of a grid-connected photovoltaic (PV) power plant using a-Si technology, resulting in a comprehensive database. The data were collected over a full year, from January 1 to December 31, for a 365-day period, capturing seasonal and operational variations in power generation. The annual database was divided into three parts: a 267-day training period. An algorithm developed for the solar power system management system.

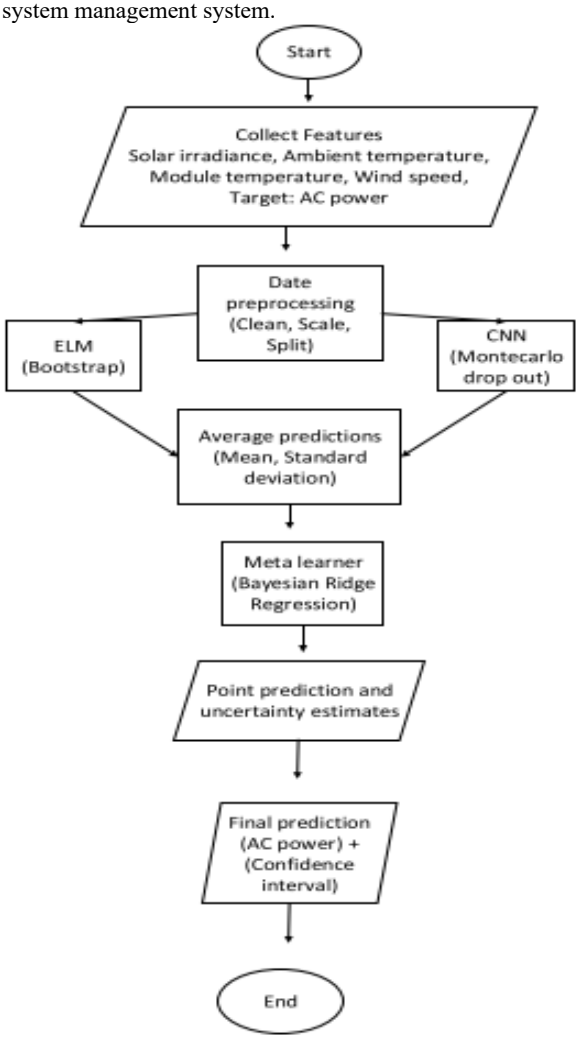

Fig. 1. Algorithm developed for the quality indicators of the solar power supply system

The power supply system under development of solar panels has a 67-day test period and a 31-day forecast period. Each time interval was recorded hourly, which ensured the availability of high-precision data for training, testing and forecasting the model. The time resolution of the input data was 1 hour, and the model was designed to predict 1 hour in advance, that is, it predicted the energy production for the next hour based on the current and previous hourly data. The geographical location of the power plant is in the city of Andijan, which is located at the coordinates of 26.42° north latitude and 50.08° east longitude, at an altitude of about 10 meters above sea level.

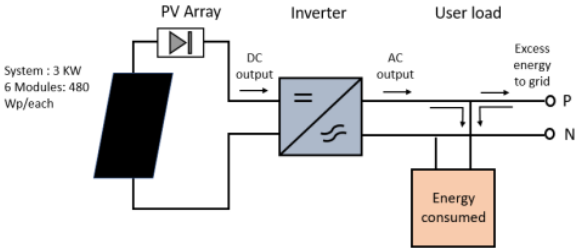

Fig. 2. Power distribution control scheme in a smart solar power system

The photovoltaic arrays are oriented to the south, resulting in an azimuth angle of 0° and a tilt angle of 30°. The PV plant configuration consists of six modules, each with a nominal power of 480 W p (Wp). They are arranged one after the other in six strings, for a total nominal power of 2880 W p (Wp). The schematic of the proposed grid-connected PV system is shown in Figure 2. The data were simulated using the PV syst program. While this approach provides stable and controlled input conditions for model development, it may not fully capture unexpected performance variations encountered in real-world conditions, such as inverter outages or unscheduled maintenance, dust accumulation, bird droppings, or equipment failure.

The following is a time-dependent diagram of the quality of electricity produced by a solar power system when operating according to the above algorithm.

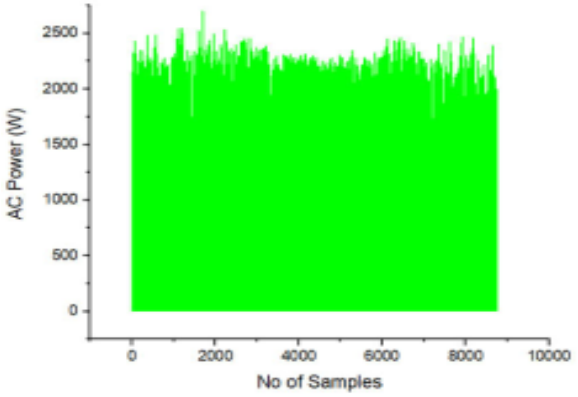

Fig. 3. The time-dependent change in the quality of electricity generated by a solar power system

The efficiency of the electricity generated by the solar power system is considered using a hybrid model that combines probability theory with an artificial solar grid to predict the power output of the electricity generated by the solar power system when it is converted into alternating current by an inverter. This model is designed to improve the forecasting accuracy under different weather conditions including rainy, cloudy, and sunny periods.

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3. Conclusion

In this study, we developed a deep learning-based stacking model for forecasting and uncertainty analysis of grid-connected PV systems. The objectives achieved in this study are: Improving forecasting accuracy: Extreme learning machine (ELM) and convolutional neural network, Uncertainty detection: Applying uncertainty analysis to the model — bootstrap method for ELM, Feature engineering using SHAP: Feature engineering using Shapley additive explanation (SHAP) analysis improved the model accuracy, Supporting compensatory energy integration: By providing reliable and robust energy forecasts, the model helps integrate solar energy into existing grids.

References

[1] Siddikov I. et al. STUDY OF POWER BALANCE OF SMALL POWER ASYNCHRONOUS MOTOR //Scientific and Technical Journal of Namangan Institute of Engineering and Technology. – 2025. – Т. 10. – №. 1. – С. 282-287.

[2] Mirzoev N., A'zamov S. Quyosh energiyasi ta'minoti tizimida faol va reaktiv quvvat balansini nazorat qilish va boshqarish //Mejdunarodnyy nauchnyy jurnal «Injener». – 2025. – Т. 3. – №. 1. – S. 39-44.

[3] Siddikov I., Azamov S. Research on the reactive power consumption of an asynchronous motor powered by energy generated by solar panels //Вестник транспорта-Transport xabarnomasi. – 2025. – Т. 2. – №. 1. – С. 205-208.

[4] A'zamov S. S. ELECTROMAGNETIC CURRENT TRANSDUCER FOR CONTROL OF REACTIVE POWER CONSUMPTION OF AN ASYNCHRONOUS MOTOR FROM A SINGLE-PHASE SUPPLY OF RENEWABLE ENERGY SOURCE.

[5] A'zamov S. The INVESTIGATION OF ELECTROMAGNETIC CURRENT TRANSFORMER PERFORMANCE CHARACTERISTICS FOR MEASURING AND CONTROLLING THE REACTIVE POWER DISSIPATION OF A SHORT-CIRCUITED ROTOR SYNCHRONOUS MOTOR: We know that we have been using asynchronous motors, which are widely used in the industry and production of the world and in our country, and despite a number of advantages of this type of motor, there are also enough disadvantages. In order to eliminate these shortcomings, the aim of the article is to reduce the ... //Scientific and Technical Journal of Namangan Institute of Engineering and Technology. – 2023. – Т. 8. – №. 1. – С. 136-141.

[6] Khakimovich S. I. The problems of power supply systems with renewable energy sources of the equipment's and objects of digital technologies and the ways of their decisions //Science and innovation. – 2024. – Т. 3. – №. Special Issue 17. – С. 18-22.

[7] Жегусов Ю. И., Остапенко Р. И. Современные научные исследования и инновации //инновации. – 2021. – Т. 117. – №. 1.

[8] Siddikov I. X., Denmuxammadiyev A. M., A'zamov S. S. MUQOBIL TURDAN OLINGAN ENERGIYADAN ISTEMOL QILUVCHI ASINXRON MOTOR QUVVAT BALANSINI NAZORAT VA MONITORING QILISH. – 2023.

[9] Аъзамов С. С. УЛУЧШЕНИЕ МЕХАНИЧЕСКОЙ ПРОЧНОСТИ ЭЛЕКТРИЧЕСКИХ ПРОВОДОВ ВЫСОКОГО НАПРЯЖЕНИЯ //Universum: технические науки. – 2021. – №. 5-5. – С. 47-49.

[10] Khakimovich S. I. The problems of power supply systems with renewable energy sources of the equipment's and objects of digital technologies and the ways of their decisions //Science and innovation. – 2024. – Т. 3. – №. Special Issue 17. – С. 18-22.

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