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Simulation and Analysis of Optimal Power Injection System Based on Intelligent Controller

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ABSTRACT- Many countries are seeing significant improvements in the fields of building, urban planning, technology, network management, and the need for diverse forms of energy and different generating techniques, as well as the necessity for low and middle distributing voltage in all areas. Depending on the needs of the user, starting needs, capacity, intended usage, waste output, and economic efficiency, many methods are used to generate this energy. To solve the problems brought on by the suggested excessive voltage of the provided system, energy collection devices can be used, and they can be used efficiently with smart grid intelligent control systems. A mathematical model was developed with four main components: simulation, correlation, and evaluation following the solar the program was set of photovoltaic panels solar panels, An Adaptive Neuro-Fuzzy Inference System (ANFIS) controller based on Maximum Power Point Tracking (MPPT), as well as 600-volt electric network, in order to examine and analyze the viability of the proposed network collaboration and storage of electricity in private photovoltaic networks based on solar energy. This phase next looks at the output power impact on the network, as well as the influence of network temperature and coincident radiation. An analysis was conducted to ascertain the impact of these basic limitations on actual use. This section covers the computer simulation of the proposed system. The final section contains the created system's block diagram. The system's input light is transformed into electricity that circulates in this system's power. The main electrical system with a 600-volt capacity can use this energy. The suggested system was evaluated using MATLAB simulation tapes and graphing for each system component, and the simulation outcomes of the entire system were considered.

Keywords: Power Injection, Electrical Distribution, ANFIS Controller, Neuro-Fuzzy, MPPT, On Grid.

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1. INTRODUCTION

The most widely used renewable energy source is solar energy, which provides alternate answers to the present energy dilemma [1]. With the use of solar cells and the photoelectric effect, it may be transformed into usable electricity [2]. Solar energy has many applications in industry, transportation, medicine, and daily life [3]. Solar energy, like other forms of renewable energy, is inherently unstable [4]. This is because the amount of energy that is instantly collected from the sun varies according on-air conditions [5], research is still being conducted to optimize solar energy utilization and output [6]. A technique known as maximum PowerPoint tracking is applied in these investigations. Numerous techniques have been put out to track PV systems' maximum power point [7]. The power outputs of solar and wind energy are erratic and nonlinear. MPPT algorithms have the ability to effectively overcome this anomaly [8]. Conventional MPPT algorithms that track the panel's voltage, current, power, and other characteristics can help make the most use of the electrical energy generated by PV panels [9]. In addition, hybrid MPPT techniques include traditional methods and can detect the maximum power point (MPP) even in cases such as partial shading [10]. Maximum power point tracking algorithms using traditional methods approach the MPP of the PV with a fixed or variable step [11]. Accurate measurement of the energy produced or various methods of estimation can also lead to efficient energy use [12]. Temperature and solar radiation variations in the atmosphere have a significant impact on the amount of electricity generated by photovoltaic panels. Consequently, in this situation, panel power estimation based on these two parameters is useful. Daily, weekly, and monthly energy output forecasts can be made using mathematical models, FL, and ANFIS [13].

Furthermore, estimating the instantaneous power output of a photovoltaic (PV) panel may be facilitated by considering factors such as geographical coordinates (latitude and longitude), temperature, and solar radiation. Research using estimated values derived from ANFIS training has shown superior outcomes compared to conventional methodologies. Capable of generating the required rated power values and control signals for use in basic power electronics circuits such as DC-DC converters [14].

For non-standard operating conditions, voltage source converters, or VSCs, are frequently recommended. On the other hand, adaptive neuro-fuzzy inference systems (ANFIS) may be directly in charge of solar panel-fed power modules that are capable of producing alternating current [15]. The management of today's increasingly common building-integrated photovoltaic modules may also fall under the purview of ANFIS [16]. With a feedback structure to be added, maximum power can be obtained from the PV system. Another study to make maximum use of PV panels is the system that follows the sun mechanically. These systems can be provided to increase power generation and efficiency by automatically adjusting the PV panels [17]. Another valuable use of energy estimates utilizing real-time, changeable atmospheric data is as a benchmark. Examples are power management studies that aim to keep the load in harmony with the source or hybrid power sources. Smart grid applications may also benefit from the use of artificial neural networks (ANNs) and artificial neural fuzzy inference systems (ANFISs) in the energy integration process [18].

2. RELATED WORK

A variety of ANFIS-based MPPT scheme configurations and design approaches have been given in the published literature. In Mlakic' et al [19] the ANFIS technique, when applied to a real-world solar plant system, produced superior performance versus more conventional approaches. Khosrojerdi et al [20] to simplify the control system, ANFIS was used to lessen the reliance on current and voltage sensors. Naik and Sujatha [21] the use of ANFIS has also been seen in the context of error reduction via high-performance tracking. However, in these approaches, the ANFIS controllers include inputs from radiation and temperature sensors. Kharb et al [22] Enhancing operational efficiency may be achieved by the use of several strategies, such as minimizing oscillations occurring at the highest power point, augmenting high-speed gain, and enhancing sensitivity to parameter fluctuations. In Bin-Halabi et al [23] the precision of ANFIS predictions for the maximum power point (MPP) was enhanced. In Murdianto et al [24] The use of the Adaptive Neuro-Fuzzy Inference System (ANFIS) in the optimization of output power for photovoltaic (PV) modules has been seen to provide significant enhancements in efficiency and stability, particularly in the face of changes in temperature and irradiance. In Abido et al [25] An effective and straightforward methodology is used to enhance the tracking effectiveness of the Maximum Power Point Tracking (MPPT) controller via data training. shows increased power output and consistency with the adjusted MPP over a wide range of climatic conditions [26]-[27]. Methods that combine ANFIS with a proportional-integral controller have proven to be more effective than those that use ANFIS alone in terms of performance, steadiness of operation, precision, and stability.

The ANFIS technique, however, still makes use of sensor inputs like irradiance and temperature readings. On the other hand, there is evidence in the literature for a hybrid MPPT method based on ANFIS. To start, the old-fashioned way in Desikan and Kalaichelvi [28] the use of the Adaptive Neuro-Fuzzy Inference System (ANFIS) in conjunction with the Perturb and Observe (P&O) algorithm demonstrated proficient and precise tracking of the Maximum Power Point (MPP). This approach exhibited prompt responsiveness and minimal oscillations. Amara et al [29] also include P&O while thinking about things like efficiency, cost, and how energy is being used. In Bataineh et al [30] ANFIS and HC work together to monitor the MPP more efficiently since they employ both the efficiency of offline approaches and the accuracy of online techniques at the same time. Due to the training's reliance on the information acquired from conventional approaches and for particular circumstances, these methods, however, demonstrated more complexity and slower performance, especially in quickly changing irradiance settings. Secondly, ANFIS is integrated with advanced techniques like FLC in Azizi and Izadfar [31] and Jha and Srivastava [32] Efforts were made to minimize the complexity of the sensor, although it remained intricate, necessitating the development of optimal rules for the fuzzy logic controller (FLC). Further methods for ANFIS-based MPPT with PSO were described. In Farzaneh et al [33] and Priyadarshi et al [34] Using a hybrid ANFIS-PSO method, we were able to determine the optimal MPPT setup, which lent credence to the widespread use of MPPT controller design; nevertheless, the PV tracking time required to reach MPP was very long. In Padmanaban et al [35] When applied to ANFIS, the ABC method allows for the optimum adjustment of ANFIS membership characteristics with a corresponding reduction in root-mean-squared error (MSE), albeit ANFIS-ABC also has a slow convergence time when used for PV power tracking. In Yadav et al [36] Combining ANFIS and GA made the tracking better, but the light sensor is still needed.

3. MATHEMATICAL MODELING

3.1 PV Cell Equivalent Circuit

There is a straightforward method for analyzing solar cells. The data used to get the result is crucial and is dependent on the electrical- outputs of PV cells [IPV cell - VPV cell - PPV cell]. A photovoltaic- cell's semiconductor functions similarly to a diode, and the following groups are involved in the process: ideal -model, simple- diode model and double- diode model.

The goal of using mathematical models to depict photovoltaic cells is to get reliable characteristic curves, such the ones shown in *figure 1*, and to determine the values of electrical parameters for a PV power system in various states.

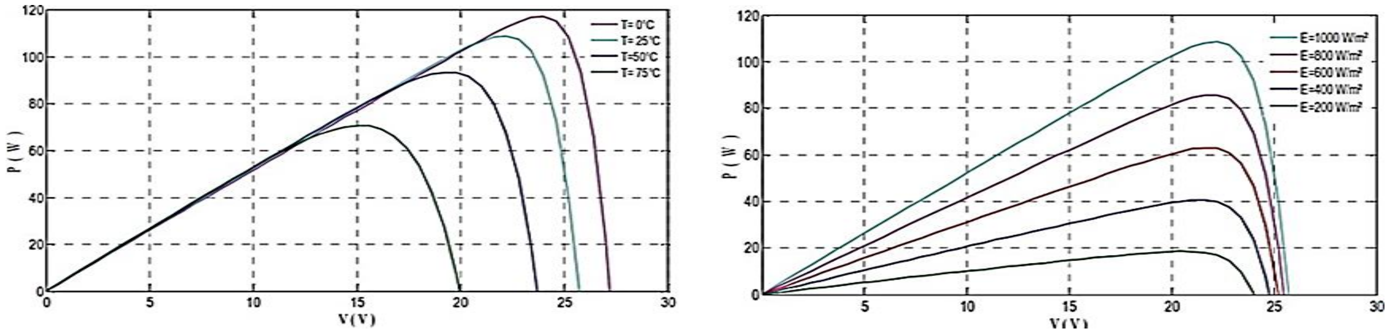


Figure 1: a – IV Graph, b – PV Graph [37].

The collective consisting of Rs and Rsh is a simulation model used to represent the behavior of solar panels. The model considers both the presence of a series -resistance (Rs) and the shunt resistance (Rsh) for the photovoltaic (PV) array. By using this methodology, we anticipate acquiring more accurate and authentic outcomes. The circuit that is equal in value is shown in *figure 2*.

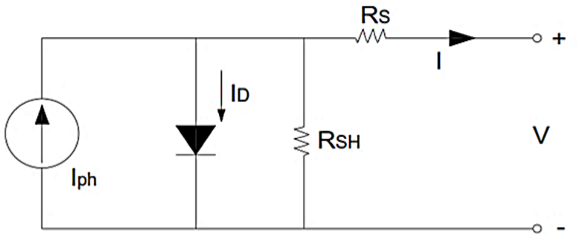


Figure 2: The equivalent circuit of PV with Rsh and Rs [38].

The following equation is used to calculate the output current value:

$$I = I_{ph} - I_d - I_{sh} \tag{1}$$

The following equations are formed by solving the formulae for Id and Ish as the solar cell generates a strong electric current:

$$I_d = I_0(\exp \frac{q(V+IR_s)}{nKT_{op}} - 1) \tag{2}$$

$$I_{sh} = \frac{(V+R_sI)}{R_{sh}} \tag{3}$$

$$I = I_{ph} - I_0(\exp \frac{q(V+IR_s)}{nK\text{the}T_{op}} - 1) - \frac{(V+R_sI)}{R_{sh}} \tag{4}$$

Here: K: Boltzmann constant, n: diode factor $(1 < n < 2)$, q: electron charge $(1.6021X10{-}9)$, $I0$: Diode saturation current, Iph : photocurrent, and T: operational temperature.

With 100kΩ resistance, we were able to produce a simplified instance with large Rsh values. It is appropriate to compare the short-circuit current Isc with the photovoltaic current Iph. Assumptions for the common test conditions are applied as follows:

$$I = I_{ph} - I_0(\exp \frac{q(V+IR_s)}{nK\,T_{op}} - 1) \tag{5}$$

3.2 DC-DC Booster

A non-isolated DC-DC boost converter, as shown in *figure 3*, consists of a switching controller, an inductor (L), a power switch (M), a capacitor (C), and a diode (D).

When the input voltage for a DC load is low, the topology cell may be used to link the interface to a higher battery bank. When the input -voltage is higher than the output- voltage, the DC-DC boost collective increases the output -voltage. In order to provide the desired output, the controller modifies the input voltage by turning the appropriate switches on and off. Turning on the switch causes a diode to go into the opposite state, and the inductor stores electrical energy. Concurrently, the load receives current from the capacitor. Turning off the switching process allows the inductor to send electrical energy to the capacitor and load. Both continuous conduction mode (CCM) and discontinuous conduction mode (DCM) are available to a DC-DC boost converter. Performing the DC-DC boost operation in the CCM causes the inductor current to be greater than zero. A zero-level indicator switching cycle is achieved during DCM. There is current in the DC-DC boost converter's research bearing, and it is used to eliminate harmonics. Load balancing, zero regulation voltage, and the correlation power factor are all rather important.

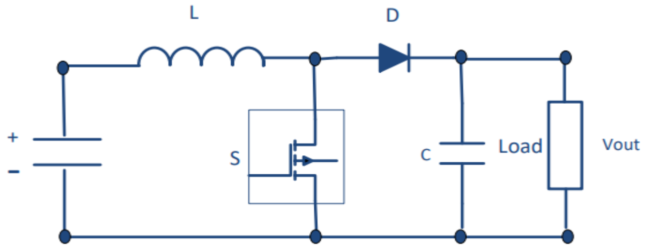


Figure 3: DC-DC boost converter [39].

Output voltage:

$$V_{out} = \frac{1}{1-D} \cdot V_{in} \tag{6}$$

4. PROPOSAL SYSTEM DESIGN

4.1 Adaptative Neural Fuzzy Inference System (ANFIS)

ANFIS as an architectural and learning technique that may build a mapping between a complicated system's inputs and outputs using membership functions to categorize the data. This procedure does not need any previous understanding of modeling. Parameters in these datasets are then trained using the rule to provide the desired results. With ANFIS, you have a mixed learning algorithm. In order to find and optimize the Sugeno system's parameters, it uses a combination of regression, back propagation, and the least squares technique. The training procedure is carried out until the specified stopping criteria are met, such as the amount of periods or the error tolerance. ANFIS is able to integrate the parallel storing and learning capacities of artificial neural networks with the analytical abilities of neural networks, similar to those seen in humans. By integrating the benefits of neural networks with fuzzy logic, ANFIS is capable of accurately modeling nonlinear and complicated functions, detecting nonlinear components in real-time, and forecasting chaotic time series [40]. All ANFIS setups are feeder setups. Hence, ANFIS is a complete collection of supervised learning feedforward neural networks. For these reasons, ANFIS finds widespread use in the fields of prediction, control and inference. When there are more input variables, more ground rules, more outputs, and more membership functions (MFs) for each input, ANFIS's structure evolves. Figure 4 shows that type 3 ANFIS structures are the most prevalent. The ANFIS design consists of five layers, with adaptable nodes—represented by a box—in the first, fourth) layers. Nodes that are fixed and represented by a circle are found in the second, third, and fifth layers [40].

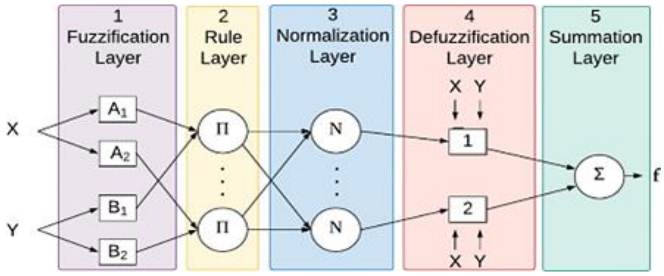


Figure 4: Adaptive neuro-fuzzy model structure [40].

Nodes that are adaptive have their own set of parameters that are modified with each cycle. There are no configuration options for static nodes' rules.

In the first layer, MF generation takes place. This is why it's called the noise layer. Fuzzy rules are located at each node in the second layer, which may have up to n nodes. Every node's output stands for the base firing force, and the second layer gets these outputs from the jamming layer.

After the second layer's rules are applied to all input values, the third layer determines the normalized level of operation for each rule. This layer is known as the normalization layer. The rule outputs are computed by means of the defuzzification layer, the fourth of these layers. The adaptive nodes in this layer combine the inputs by multiplying their normalized activation degrees, and the output is a linear combination of that. One node in the final layer is responsible for collecting all the signals received and retrieving the ANFIS aggregate output. The summation layer is the name given to this layer. One of the key benefits of ANFIS is that it may provide a systematic computation to handle inadequate sensory data. Further selling points of ANFIS are its speed, accuracy, and ease of implementation, as well as its outstanding generalization skills. Effective problem-solving aided by fuzzy grammar, seamless linguistic integration, and numerical expertise. Consequently, ANFIS has a notable impact on the solar PV industry [40].

4.2 Proposal Intelligent Controller Structure

Figure 5 displays the complete structure of the single-stage electrical network connected to the PV network under investigation. The system consists of a photovoltaic display, followed by a DC-DC boost converter and a single-phase full-bridge inverter for grid connection. The execution of the test set relies on the sophisticated signal processor, which integrates several computations such as phase-locked loop (PLL) and maximum power point tracking (MPPT), as well as regulators including the inverter DC transmission regulator, MPPT support converter, inverter, and current regulator.

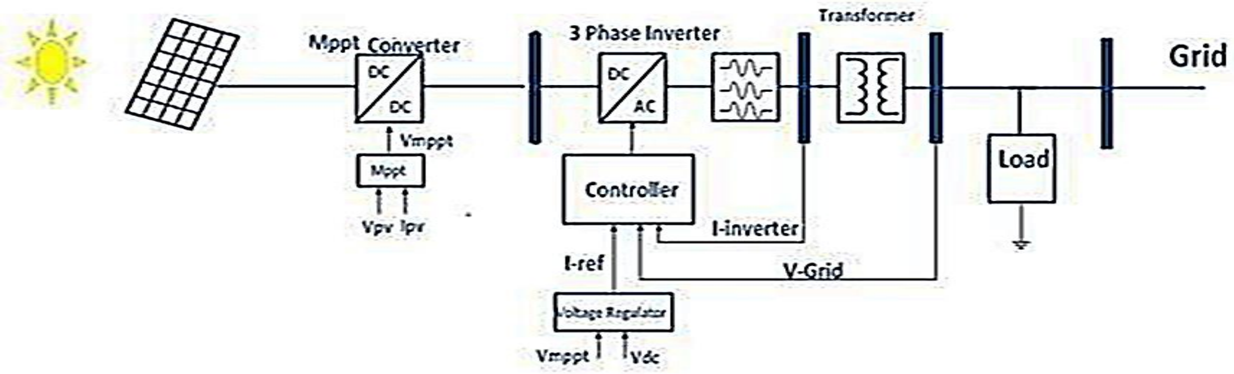


Figure 5: PV grid-connected system

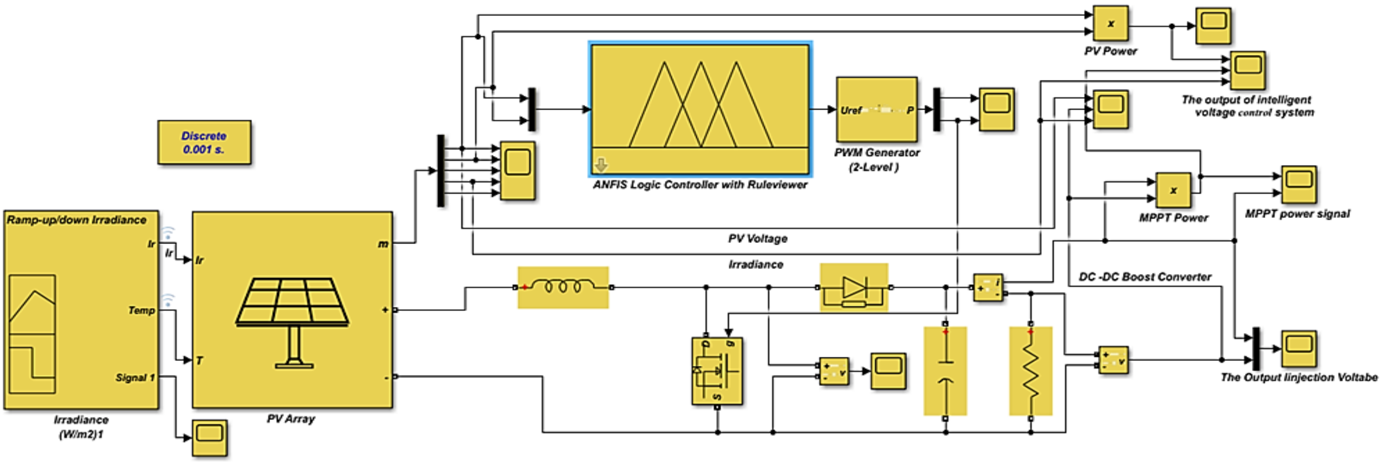


Figure 6: The overall simulation structure of prosed system design

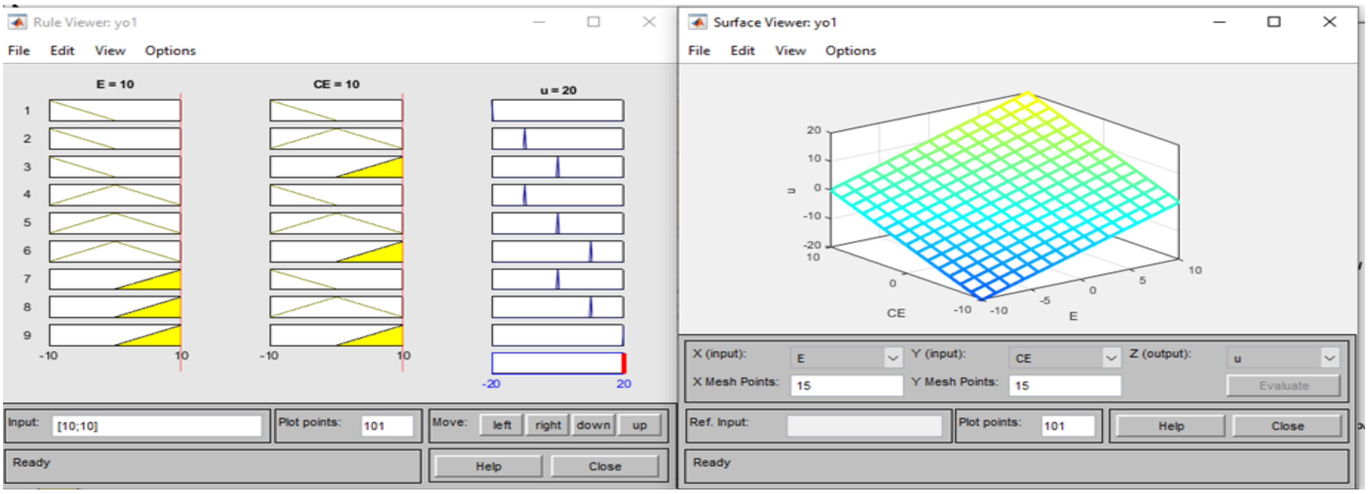
5. SIMULATION RESULTS AND DISCUSSION

The suggested method states that additional electricity can be added to the distribution network from the extra power generated by individual homes using solar-powered boards, and that intelligent systems management systems for the smart grid can profit from this excess electricity. Self-utilization is the process of using excess solar-powered photovoltaic power that is stored in batteries to force the night load. The simulation part of the recommended system, shown in *figure 6*, will be covered in this section. In this part, light from the input is converted to electrical energy. With this power, 600V of electrical power might be sent to the main electrical grid. Not only can the power be used instantly, but any load may be added to the system. The parameters and graphs of each system component's MATLAB simulation were used to evaluate the proposed system. The aggregate system's simulation findings were also taken into account.

Figure 7 displays the system's characteristics of fuzzy rules that used in intelligent controller and curves for 10 seconds. The output energy and irradiance curves displayed exceptional stability and flawless performance. The scopes also provided power statistics because the maximum MPPT power was 2.7*104 while the median was 7.6*103. The minimum power was 7.4*101, and it presents the rules for the ANFIS controller to implement the optimal controlled signal to the system.

Figure 8 displays the amount of active (P) and reactive energy (Q) added to the grid. In this figure, the results of the DC-AC simulation are displayed. The output reaction power near 1105W at action power is stable throughout the measured 10s in the figure. On the other hand, reaction power is still quite low.

The simulation of the whole structure is used to model the actual solar power distribution feed. Simulations demonstrate the efficacy of the suggested reactive power coordination technique in reducing tap counts, avoiding poor management, and maintaining feed voltage within desired ranges. Think about the photovoltaic inverters' provision for reactive power during the night. It has been shown that when solar generators are present and the PV system's active output power is zero, making use of the reactive power capabilities of the PV inverter can minimize bypass operations. It is believed that distribution system operators will gain from the recommended strategy. Different voltage regulator settings and solar generator controls can be designed into the overall injection power system using various strategies. This system's stability is accurate and proved by the output power shown in *figure 9*.



Input: [10;10]
Plot points: 101

X (input): E
Y (input): CE
Z (output): u
X Mesh Points: 15
Y Mesh Points: 15
Ref. Input:
Plot points: 101

Figure 7: The overall simulation of intelligent voltage control for injection power system

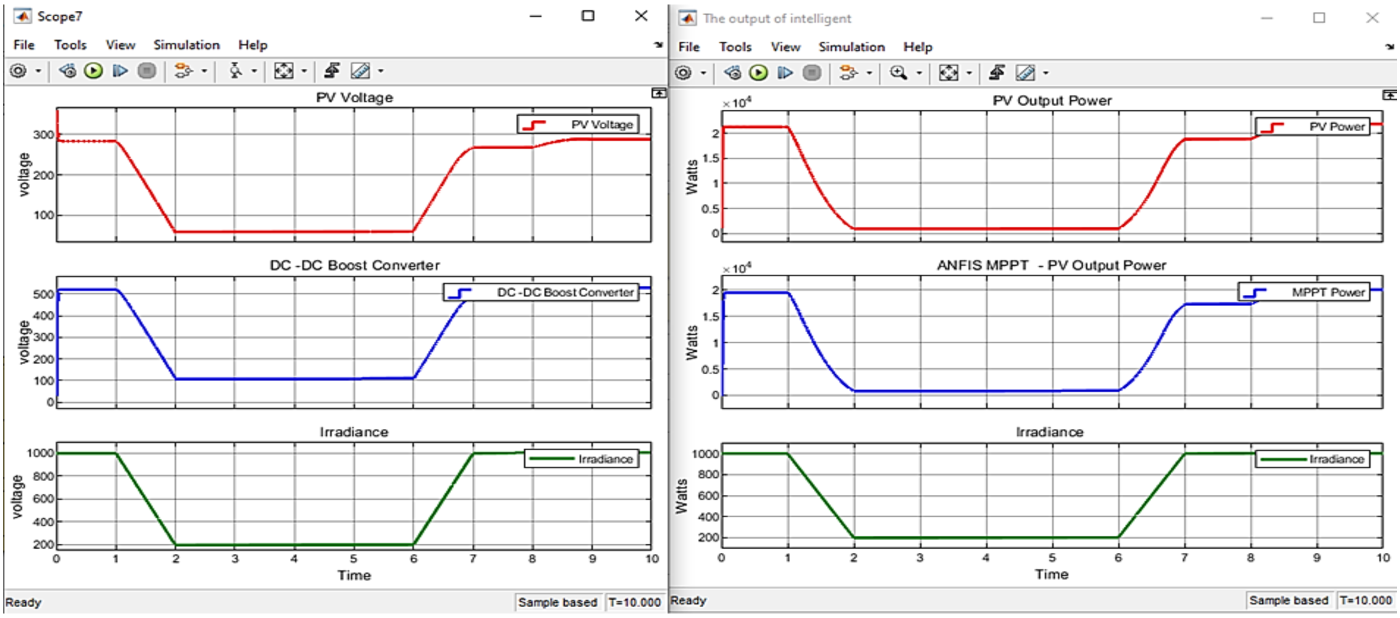
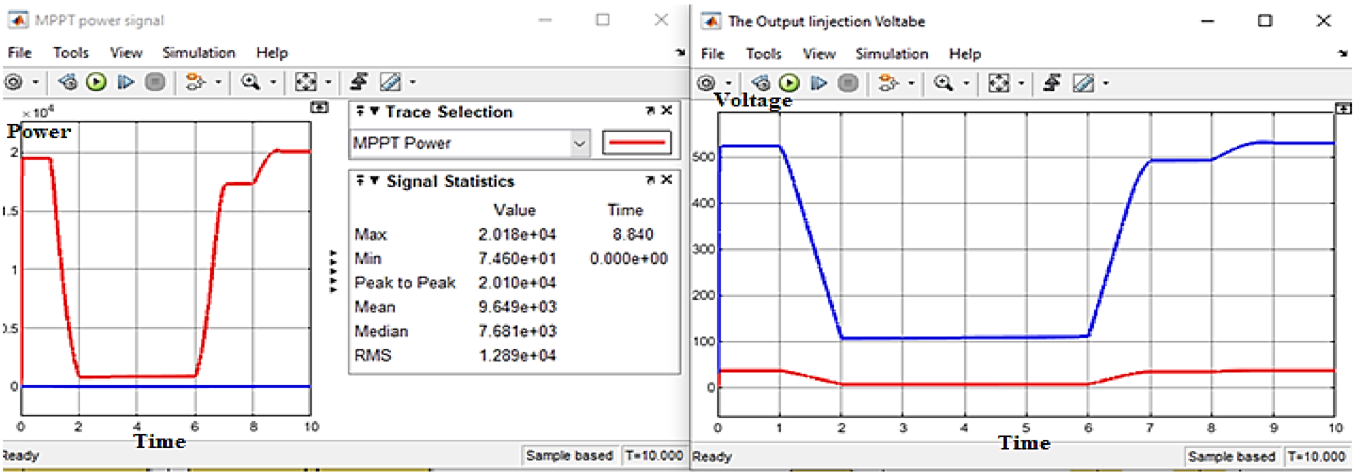


Figure 8: The overall simulation of applied intelligent controller with grid power system



	Value	Time
Max	2.018e+04	8.840
Min	7.460e+01	0.000e+00
Peak to Peak	2.010e+04	
Mean	9.649e+03	
Median	7.681e+03	
RMS	1.289e+04	

Figure 9: The overall simulation results prove the stability of injection power

Finally, the description of the overall process for simulation of the proposed system design (Power Injection system for Electrical Distribution Networks based on ANFIS Controller) with all results explained by the video in the following link: https://drive.google.com/file/d/1dsa6MbQhd66ml9Yu-ySqvGaoL4jz7ud3/view?usp=sharing

6. CONCLUSION

The primary objective of our proposed system is to harness renewable energy sources, using their natural temperature variations, to integrate smaller electric grids with larger electrical distribution networks effectively. A device for managing solar energy, a system to raise voltage levels, a device to convert direct current to alternating current, an intelligent control system, and a connection to a 600-volt utility grid are some of the essential components of the system. To evaluate the system's ability to maintain constant voltage and effectively manage energy, we have carefully detailed every part and run simulations in a computational environment.

By channeling surplus energy into larger distribution networks, our system aims to provide electricity to individual households and efficiently distribute power. This approach is economically advantageous as it maximizes generated energy, reducing waste and enhancing the nation's electricity supply. Our methodology involved developing mathematical models for each element of the power feeding system, conducting simulations of each component, analyzing the output signals, and identifying variations within the system's elements."

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