Power Quality Improvement of Solar Energy System with Deep Neural Network Controller

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Summary
High power quality ideally produces electrical power that is always available, completely pure and noise-free, has a sinusoidal waveform, and is always within voltage and frequency tolerances. In this paper, a new method is implemented on the solar energy system for improving the power quality based on the deep learning neural network. The model is implemented on Matlab 2021a version with Core i7, Intel. The different weather conditions are used and tested

Key words:
Power Quality, Solar Energy System, Deep learning Controller

1. Introduction

The issue of electricity quality, as an increasing problem, has caused industry owners to worry about the increase in losses. Problems caused by poor quality of electricity on the one hand cause damage to sensitive and expensive equipment and on the other hand can cause interruptions in production.
Proper quality of electricity indicates the proper state of changes in voltage, current and frequency quantities that will not lead to failure or improper operation of network equipment and subscribers.
There are many reasons for the decline in the quality of electricity, such as:
Interruptions or interruptions can disrupt the basic microprocessors of equipment such as computers, causing data loss. They may be directly affected and exposed to failure.
Overheating of the electric motor due to voltage imbalance which can reduce the life of the motor by half or less.
Malfunction of frequency converters used to control the speed of induction motors and dc motor speed control converters
Malfunction of protection systems such as relays and contactors
Damage to electronic equipment and bursting of capacitors
Overheating of the transformer and shortening its life due to harmonies
Capacitor heating corrects power factor and reduces its life or burst.

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2. Theoretical Consideration

A study [1] suggested an operating strategy, through which, the PV array operates at maximum power output with a flexible operational mode while PEMFC sustains high efficiency; therefore, it increases the operationality, supports system stability, and decreases the operating-mode changes.
A study [2] presented a solar photovoltaic (PV) system's mathematical analysis, which included a PEMFC, which was integrated with the RE sources and the PV system to generate power from a hybrid PV/FC system. The primary RE source forms the basis for the PV system while the PEMFC becomes a power backup source in a PV system's unfavorable conditions. A fuzzy logic-based MPPT was also proposed for maximizing power generation.
A research paper [3] included a battery, photovoltaic (PV), fuel cell (FC), and super-capacitor (SC) in a hybrid system for fulfilling the need for isolated DC loads. Thus, the PV acted as a primary energy source while SC and battery had different power densities for supplying steady and transient loads, respectively.
In this research work [4], a converter has been proposed, which interfaced a bi-directional port and a couple of uni-directional input power ports as a single and unified structure. For hybridizing RE sources like PV, FC, and battery, this converter is interesting. It was made possible for charging/discharging the battery to supply the output load for simultaneously operating PV and the FC power sources.
A research work [5] proposed MPPT for a hybrid PV-wind-FC system for providing electricity to the Egyptian El-Farafra Oasis community. The system included a PV system, PMSG wind turbine, energy storage system, and FC. The Cuckoo Search (CS) artificial intelligence technique was separately used for an MPPT, which is applied to hybrid PV, FC, and wind generation systems using three DC-DC boost converters.

According to the results, the Cuckoo Search Control Technique achieved the MPPT for every generation source.

A research paper [6] analyzed power control and management methods for hybrid systems, which have storage in the grid-connected mode. PV array, battery, supercapacitor, and fuel cell are all used in a hybrid form. PV array with MPPT technique makes it uncontrollable. Feeder flow control (FFC) and unit power flow control (UPC) are the two-power flow controlling methods presented in the paper.

A study [7] presented a hybrid PV-FC system to supply power charge by isolated integration. It can also perform autonomous integration through sustainable power enhancement. The hybrid power system's RE sources have a PV array and a PEM fuel cell. The common DC-AC inverter benefits the proposed topology by injecting the generated power for supplying the charge.

Another research paper [8] showed a control strategy for hybrid RE systems with different options, such as solar power, wind, battery, and FC in a grid-connected system. They performed the control strategy on random levels of solar temperature and insulation for obtaining maximum power through ANFIS. The purpose behind this paper was to maintain a constant DC bus voltage supply and analyzing power flow improvements in HPS.

A study [9] showed a hybrid form of PV-FC system that uses an MPPT-controlled DC-DC converter with variable load and it transfers energy to produce hydrogen through electrolysis that was stored for further use in a fuel cell. In case, load demands are not met through the PV system, the FC system provides the power backup.

Photovoltaic (PV) array is part of the energy system as a primary power source while FC is a secondary or auxiliary power source. In the proposed system, the control system guarantees regulation of motor speed and maximization of power generation through energy sources under different load conditions and environmental variations [10].

A new sizing method [11] has been presented on a two-pronged optimization criterion, which includes reliability in terms of power supply loss and system cost, which show no satisfaction about the load. When a load is given and loss of energy has a certain probability, it is possible to calculate the optimum number of photovoltaic panels and hydrogen storage tanks.

A study [12] discussed a specific load frequency control to operate an interconnected hybrid power system, which comprises solar PV, wind turbine, ultra-capacitor (UC), and fuel cells for the energy storage system. Using a PI and PID controller, the system frequency with variable loads has been studied.

In [13] the proposed a method with an objective to control a hybrid system, which assures continuous supply of power. When sudden load changes occur, the inverter is aptly controlled to provide bi-directional support. At the inverter side, a novel MPPT controller is also established.

A study [14] suggested a grid-connected hybrid three-wire three-phase PV-PEMFC. A unit template controls the system and I-cos (phi) technique has been applied for simulation. During odd weather conditions, the system fulfills a stable load. That PV system supplied electricity and used hydrogen taken from water during the daytime to make the FC ready for night-time performance. There are certain objectives of controlling techniques, such as load balancing, voltage regulation, and harmonic suppression.

A study [15] presented the DSP processor application to manage renewable and non-renewable energies in grid-connected mode. Clean energies from wind, solar, and FC have zero hazardous emissions, which are used for portable and stationary power generation. An ultra-capacitor or a battery stores the energy when linked in parallel for improving the transient response. This scheme explains the PWM generation using a TMS320F28335 DSP digital signal controller using Code Composer Studio (CCS) and MATLAB.

Another study [16] modeled a power management strategy, which was simulated in MATLAB for FC, super-capacitor and PV. They used a micro-grid, which had two distributed generation units, and each one of them has a PV unit, FC, and super-capacitor. The PV unit's shortage power, load demand, and FC stack are compensated by the super-capacitor energy storage.

A control strategy has been presented for an islanded medium-voltage microgrid [17] that has been presented for controlling interfaced multi-level inverters under non-linear and unbalanced loads, and also to assure coordination between hybrid power sources (HPS) units. A cascaded H-bridge (CHB) multi-level inverter connects the loads in the proposed HPS systems. The multi-level CHB inverters improve the level of output voltage and quality of power. In this case, the main sources include fuel cells and PVs while the complementary power sources are super-capacitors. The proposed system is effective because it has high performance, fast transient response, low FC fuel consumption, and high-power density.

3. Methodology

Since ANN has a feed-forward topology, it is also termed as a feed-forward artificial neural network, and it has just a single condition: The input-output information flow should have a single direction and no back-loops, as Figure 1 shows. The number of layers is not limited, and the same is true for the number of connections between individual artificial neurons and types of transfer function, which are used in individual artificial neurons [18]. A single perceptron is actually the simplest feed-forward ANN, which can learn separable linear problems. For analytical description, a simple multi-layered feed-forward ANN is given below:

$$n1 = F1(w1x1 + b1) \quad (1)$$

$$n2 = F2(w2x2 + b2) \quad (2)$$

$$n3 = F3(w3x3 + b3) \quad (3)$$

$$n4 = F4(w4x4 + b4) \quad (4)$$

$$m1 = F4(q1n1 + q2n2 + b4) \quad (5)$$

$$m2 = F5(q3n3 + q4n4 + b5) \quad (6)$$

$$Y = F6(r1m1 + r2m2 + b6) \quad (7)$$

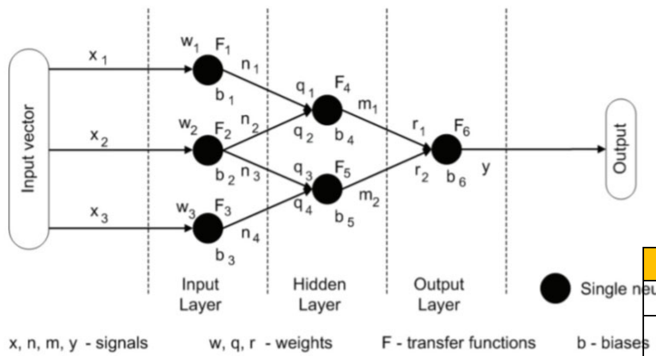

Figure 1: Feed-forward deep neural network (single neuron model)

4. Experimental results

In this section, the simulation results will discuss and investigate. For implementation of the model, we used the MATLAB 2021a with deep learning toolbox, Ram 8Ghz, Core i7, Intel. The block that used in this model are represent in following.
The irradiation values is shown in figure 2.

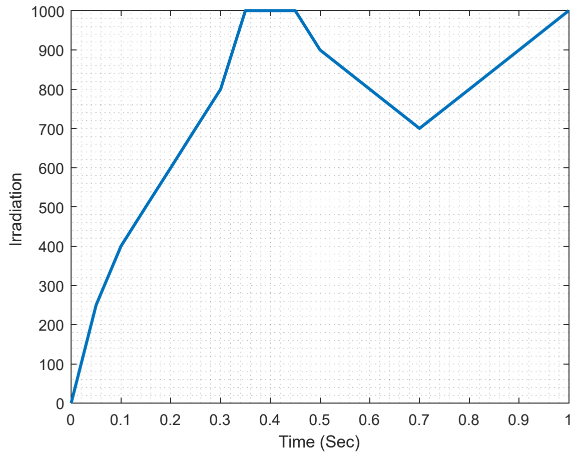

Figure 2. Irradiation vs. time
The photovoltaic specification is shown in figure 3.

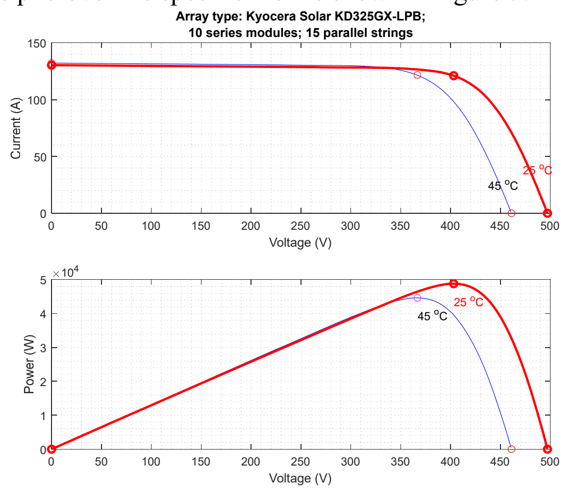

Figure 3. PV specification
The parameter values available in table 1.
Table 1. Solar system parameter

Parameter	Value	Parameter
Parallel strings	15	-
Series-connected modules per string	10	-
Module	Kyocera Solar KD325GX-LPB	-
Maximum Power	325.221	W
Cells per module	80	Ncell
Open circuit voltage Voc	49.7	V
Short-circuit current Isc	8.69	A
Voltage at maximum power point Vmp	40.3	V
Current at maximum power point Imp	8.07	A
Temperature coefficient of Voc	-0.3624	%/deg.C

Temperature coefficient of Isc	0.071001	%/deg.C

The load-real power result is shown in figure 4. As seen in this figure, the simulation time is selected 0.1 Second and the maximum load-real power reached to 110 KWatt. The minimum power is 0, that's mean there is no any power in the system and at this time the system doesn't produce any energy.

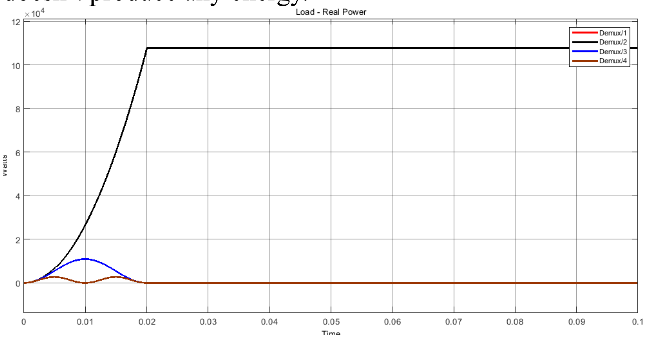

Figure 4. The load-real power result

The output PV voltage, irradiance, temperature results are shown in figure 5.

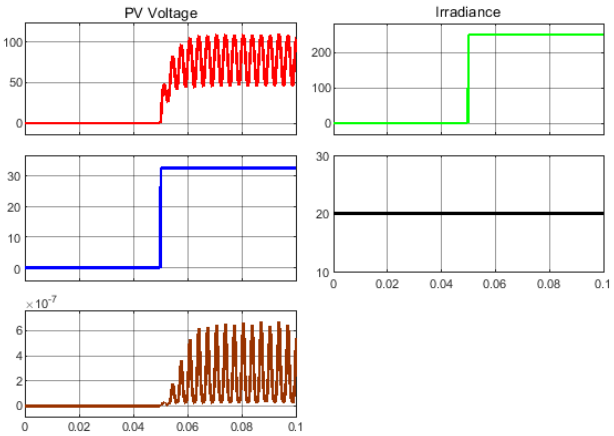

Figure 5. The output PV voltage, irradiance, temperature results

The power system distribution voltage and load current simulation results are shown in figure 6.

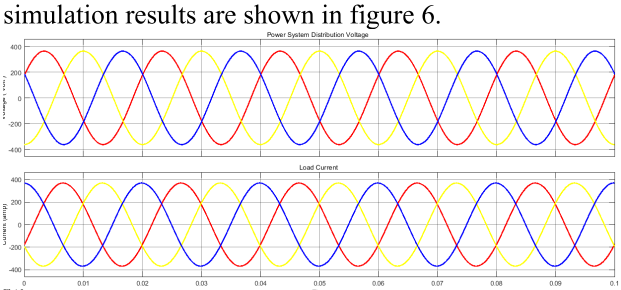

Figure 6. The power system distribution voltage and load current

The PV power without MPPT, PV power with MPPT and related irradiance results are shown in figure 7.

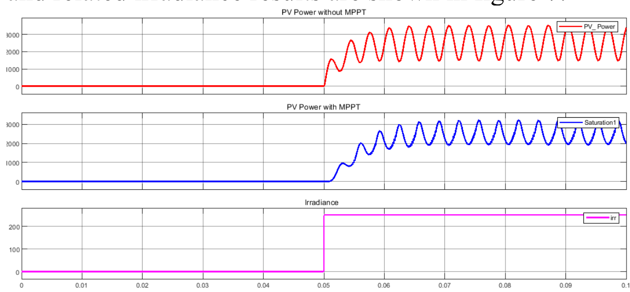

Figure 7. The PV power without MPPT, PV power with MPPT and related irradiance.

4. Conclusion

Improving energy efficiency offers huge benefits to businesses, lowering energy and operations costs and increasing sustainability. Lower power costs can be achieved by lowering the received voltage and increasing the quality of the power. In this paper a new method implemented and analyzed for the improving of the power quality. In proposed method the deep learning used to find the best parameter of the power quality. Simulation results shows that the proposed method has high efficiency in the output.

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