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Characteristics Performance Prediction of PV Panel Using Cuckoo Search Algorithm

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Abstract. This paper focuses on prediction and evaluation the correlation factors of PV panel characteristics in order to determine the implicit correlation forms for the efficiency and temperature of the system under Iraq climate conditions. Implicit correlation forms consisted on the ambient temperature, solar radiation, wind speed and humidity. Cuckoo search algorithm was employed as an intelligent optimization method to predict the correlation factors of each variable under different evaluation method which are, mean square error (MSE), integrate absolute error (IAE) and integrate square error (ISE). The results appeared that the proposed method was succeeded to predict both of the PV panel temperature and efficiency with MSE evaluation method compared with other methods. Where, the lowest MSE was recorded lower the 1 % for each characteristic.

Keywords: cuckoo search algorithm, MSE evaluation method, PV panel characteristics

1. Introduction

Performance and the rate of capacity utilization of photovoltaic panels are largely affected by climate conditions; solar radiation, ambient temperature, humidity, wind speed, shadows and dust density. Climatic conditions directly effect on the design parameters of solar panel (short-circuit current, open-circuit voltage, and maximum voltage and current) due to the effect of them on the operating temperature of PV panel. In addition to the prevailing weather, PV cell's temperature and then its performance characteristics depend on many physical variables such as photovoltaic cells material and module configuration conditions, [1,2,3]. The effect of geographical and meteorological conditions on location picking of the photovoltaic power plant was studied to determine the optimal sites of photovoltaic solar farms [4,5].

As a primary step to design a solar power plant, the designers need tools to determine the number of solar panels and the power produced for the nominated geographical location. Due to climate change during the year in most regions of the world and Iraq, so the need to have implicit formulas as primary tools for designers is necessary.

Many models have been formulated for predicting the PV module temperature and conversion efficiency by assessing input energy (solar radiation) and output energy (losses energy and power generated).

Several researches have been predicted the temperature of PV modules or other correlations such as solar radiation, power and efficiency using conventional and intelligent optimization methods [6-7]. Recently, employing the artificial neural network [8-9&10], artificial fish swarm algorithm [11] and firefly algorithm compared with Qusi-Newton method and Self Organizing Migration Algorithm to predict the temperature or electrical or characterizations of PV modules [12].Cuckoo search algorithm (CSA) is one of effective metaheuristic method that used previously for optimizing in many other



applications under different validation methods such as mean square error (MSE), Integrate square error (ISE) and integrate absolute error (IAE) [13-14]. Therefore, the main contribution of this work is to construct implicit correlations and optimize the correlation factors for temperature and efficiency of PV modules with several validation methods which are, MSE, IAE and ISE that not employed previously in this application. This paper divides into many parts which are, design and develop the experimental setup of PV panel after presenting the pervious works that relate with the solar PV panel and intelligent optimization method, presenting the CSA theory and validation methods, collecting the temperature characteristic and finally, presenting the results and discussion.

2. Cuckoo Search Algorithm (CSA)

CSA is one of the metaheuristic methods that depends on levy flight and inspired by the birds behavior. The first implementing was by Yang and Deb [15]. The notion of CSA relates with putting the fertilized eggs for original parent in other cuckoo nest with simulating their shape and color of eggs with the host eggs. In a few times, the host bird discovers that some of eggs doesn't belong to their eggs and working on leave their nests or get rid of it. Process of this method is to select the random nests and lay one egg with taking in consideration the eggs quality in each generation for each nest. Then, fixing the number of nests (n) with probability of discovering it of P_a between [0-1]. In the next generation, find a new nest based on the value of validation method [14]. The main equation that describes this method is:

$$x_i^{(t+1)} = x_i(t) + P_a \times S \times (x_i(t) - \text{nest}) \times \text{randn}(N) \quad (1)$$

Where, x_i^{t+1} and x_i are new and old generations respectively. S represents the steps and calculates by:

$$S = \frac{U}{|V|^{(1/\eta)}} \quad (2)$$

U and V is as statistical parameters and value of η ranged from 0-2. Where $U = \text{randn}(N) \times \omega$,

$$V = \text{randn}(N) \text{ and } \omega = \left(\frac{\Gamma(1+\eta) \times \sin(\pi \times \eta/2)}{\Gamma(1+\eta/2) \times \eta \times 2^{(\eta-1/2)}} \right)^{(1/\eta)}.$$

3. Experiments Setup

To obtain the proper correlations of operating temperature and efficiency of PV panel, an experimental data has been collected. The considerable data are; ambient temperature, radiation intensity, relative humidity and wind speed.

Figure. 1 shows the experimental setup. It was installed in Baghdad city (34 m elevation, 33.33° N latitude, and 44.39° E longitude) and consisted from two different types of panels. One of them is Mono-crystalline, type RNQ – 20D (20W maximum power, 17.5 V peak voltage and 0.59A peak current) and the other is Poly-crystalline type JP 0120D (10W maximum power, 17V peak voltage and 1.14A peak current).

Other Accessories were used in the rig setup like digital multimeter, battery and regulator. Different types of PV panels were utilized to diversify data sources, which will give the proposed formula more credibility for various kinds of panels. The panels were mounted toward the south with a tilt angle of 31.2° (the yearly optimum angle in Baghdad), [16]. Calibrated thermocouples (type k) were used to measure and then record panels' temperature by a digital data recorder. A digital thermo-hygrometer devise (type UNI-T UT332) was utilized for measuring ambient temperature and relative humidity while, wind speed was being measured by wind gage (Kaindl Wind master 2). Solar radiation was evaluated by solar meter pyranometer (TES 1333R). The required data have been measured through February to September in 2018, from 9:00 am to 4:00 pm and recorded every twenty minutes.



Figure 1. Experiments setup

4. Validation method

Three types of validation methods have been employed to evaluate the proposed method as well as to reach into the best factors value which are; mean square error (MSE), integral absolute error (IAE) and integral square error (ISE). All validation methods compare between actual (y) and predicted ($\hat{y}$) errors as shown in equations below [15].

$$MSE = \frac{1}{N} \sum_{t=1}^N y(t) - \hat{y}(t)^2 \quad (3)$$

$$ISE = \int_0^{\infty} e^2(t).dt \quad (4)$$

$$IAE = \int_0^{\infty} |e(t)|.dt \quad (5)$$

5. Results and discussions

5.1. Experimental set-up results

These sections are shown and discuss the temperature characteristic and solar efficiency results which consist of ambient temperature (T_a), wind speed (W_s), humidity (H_d) and solar radiation (I). Two forms below have been used for each of temperature and efficiency which are;

$$T_{mod} = K_p * T_a + K_i * I + K_d * W_s + K_m * H_d + K_s \quad (6)$$

$$Eff = K_p * T_a + K_i * I + K_d * W_s + K_m * H_d + K_s \quad (7)$$

Where, K_p , K_i , K_d and K_m refer to the correlation factors for ambient temperature, solar radiation, wind speed and humidity, respectively while, K_s refers to constant factor.

Figures 2-7 show the actual temperature characteristic and efficiency for PV panel which are consisted of 1650 data for each one that recorded from March to September. Around 16 data have recorded for one day during this period started from 8.00 Am and ended to 5.00 Pm. Different days have been selected during 7 months and it were intensive during June to September as average from 18 to 27 days based on Iraqi environmental.

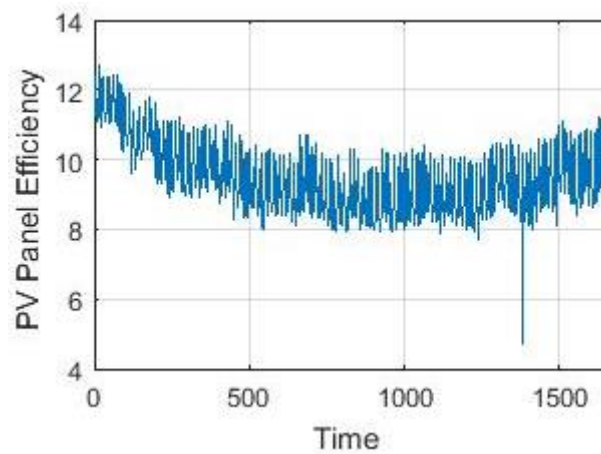


Figure 2. The measured efficiency of PV panel

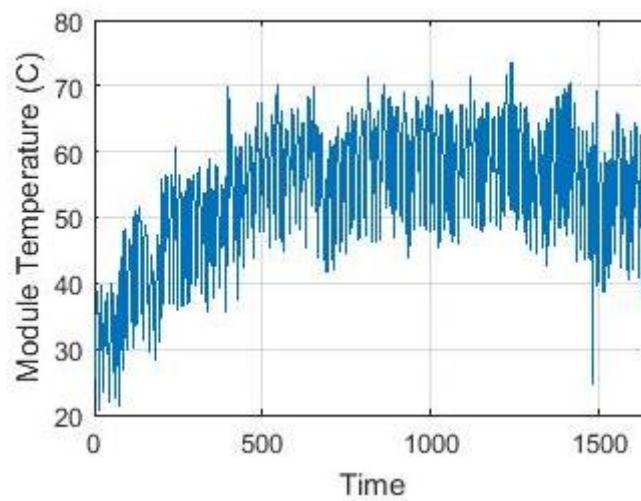


Figure 3. The measured temperature of PV panel

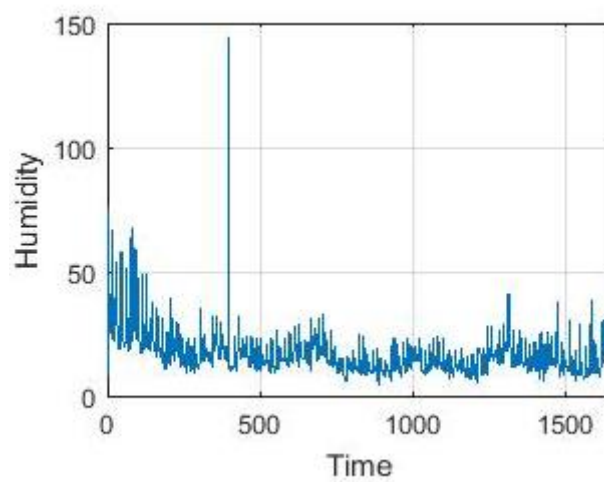


Figure 4. The relative Humidity of climate in Baghdad during the measurement period

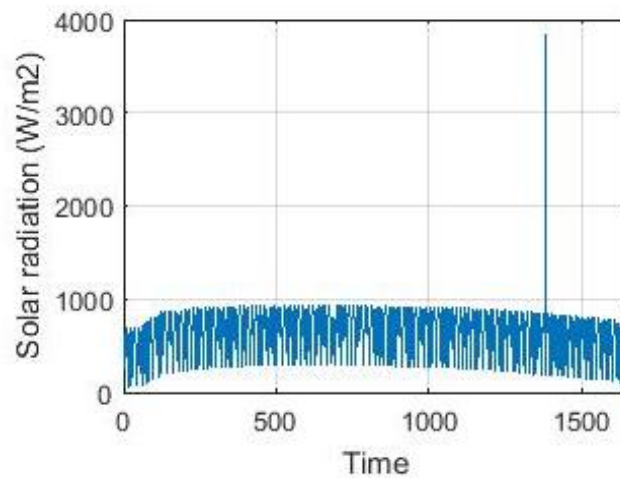


Figure 5. The solar radiation distribution

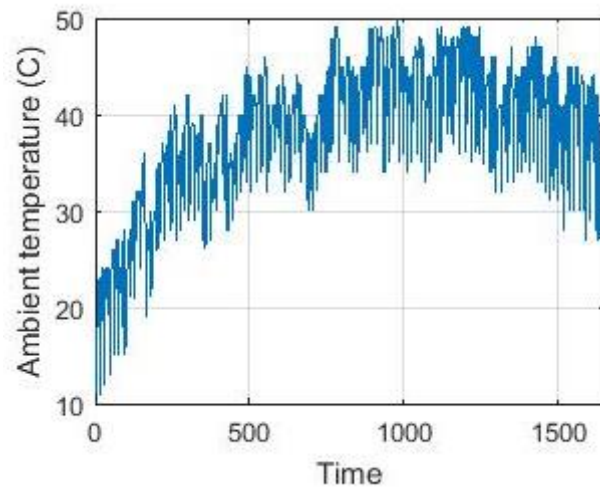


Figure 6. Ambient temperatures variation

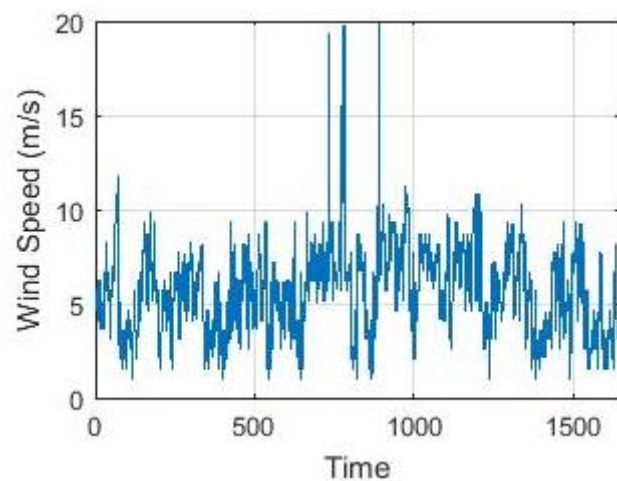


Figure 7. Wind speed variations

5.2. Optimization results

CSA was used to predict the module temperature and efficiency for PV panel. Several iterations have been applied to find the correlation factors. The range of correlation factor specified based on the previous work that ranged for -10 to 10 in order to predict the module temperature and efficiency for PV panel and specifying which factor is affected compared with the other factors. Figures 8 show the actual and predicted module temperature for each validation methods while, Figures 9 show the validation method behavior and Figures 10 show the correlation factors behavior to reach the optimal value.

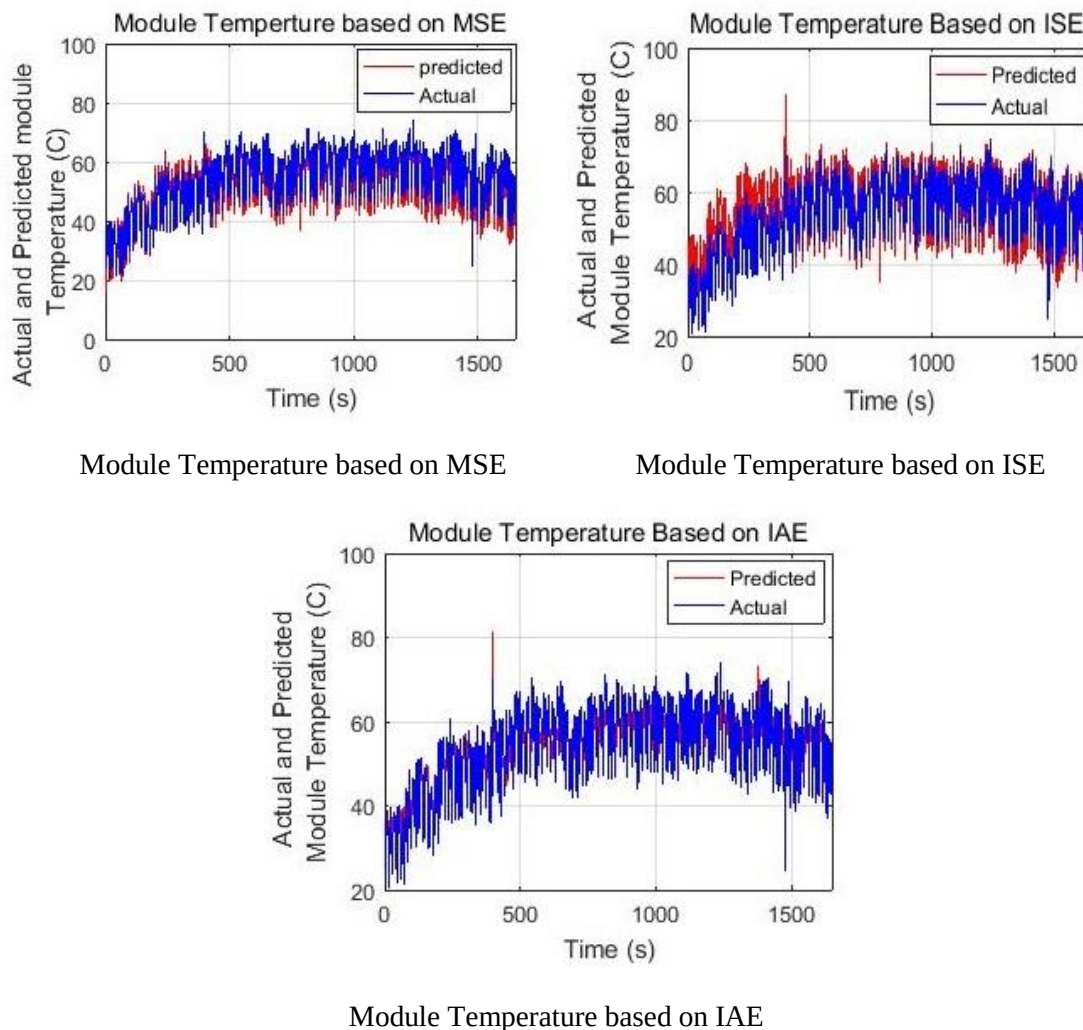


Figure 8. Actual and predicted Module Temperature based on validation methods

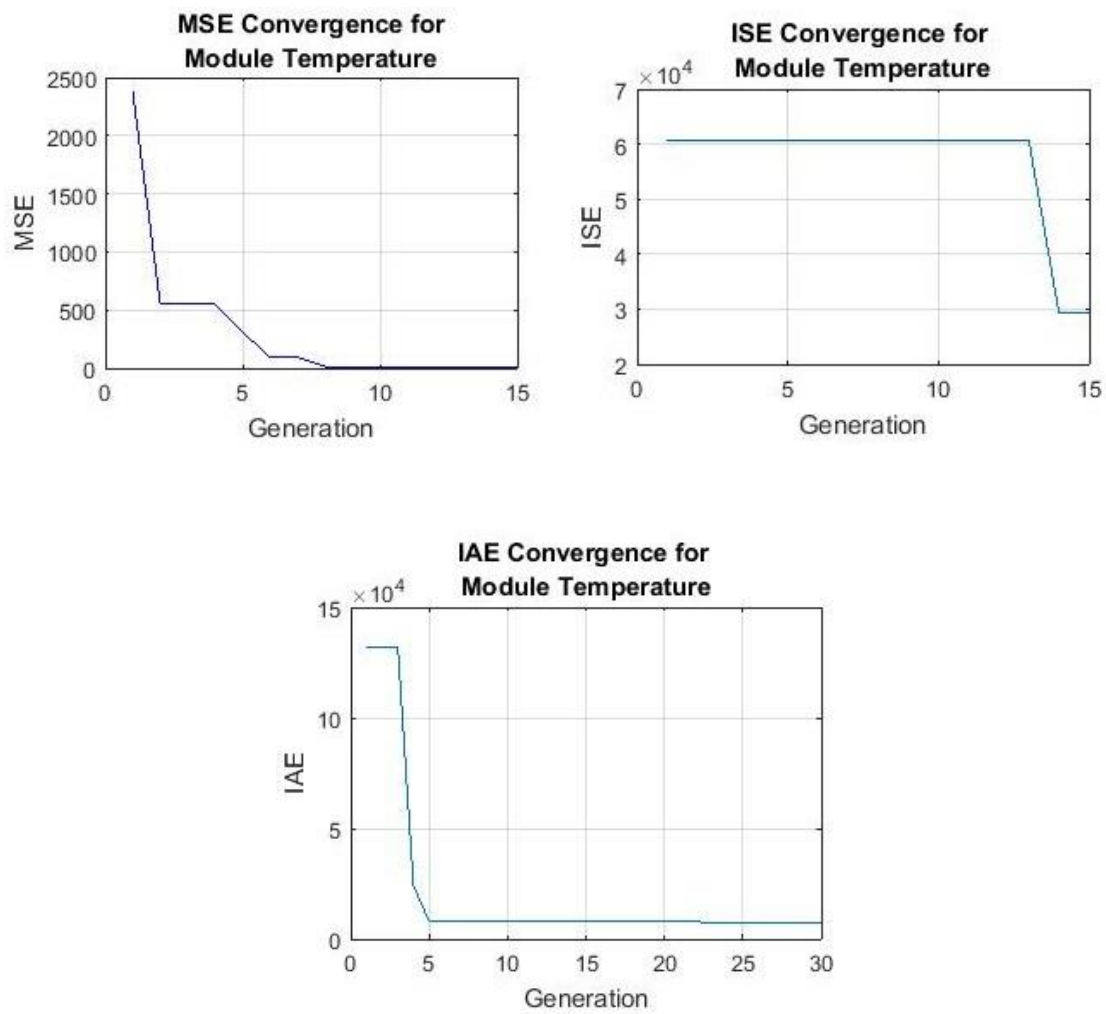


Figure 9. Validation method behavior

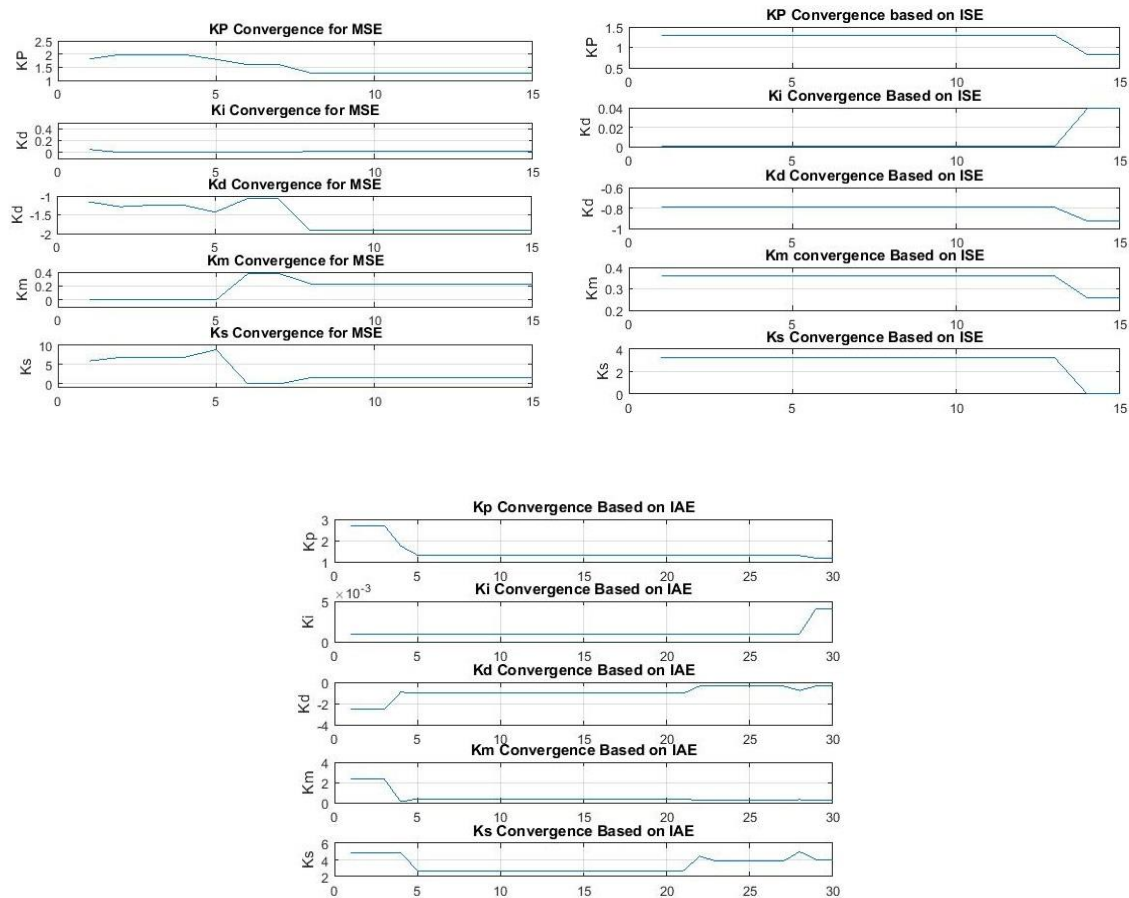


Figure 10. Actual and predicted Module Temperature based on validation methods

According to Table 1, it's noticed that the MSE was best validation method compared with the other methods and recorded lowest error of 0.51782 at $K_p = 1.0081$, $K_i = 0.0172$, $K_d = -0.9671$, $K_m = 0.0939$ and $K_s = 6.5531$. On the other hand, the results revealed that the wind speed factor doesn't affects much compared with the other correlation factors.

Table 1. Validation method performance for module temperature of PV panel

Validation methods	Lowest error	K_p	K_i	K_d	K_m	K_s
MSE	0.51782	1.0081	0.0172	-0.9671	0.0939	6.5531
ISE	2.9221×10^4	0.8250	0.0390	-0.9277	0.2574	0.0001
IAE	7.2659×10^3	1.17369	0.00411	-0.34389	0.23228	4.02741

Moreover, CSA is used to predict the PV panel efficiency based on same environment during specifying the appropriate correlation factors. Figure 11 shows the actual and predicted module temperature for each validation methods while, Figure 12 shows the validation method behavior and Figure 13 shows the correlation factors behavior to reach the optimal value.

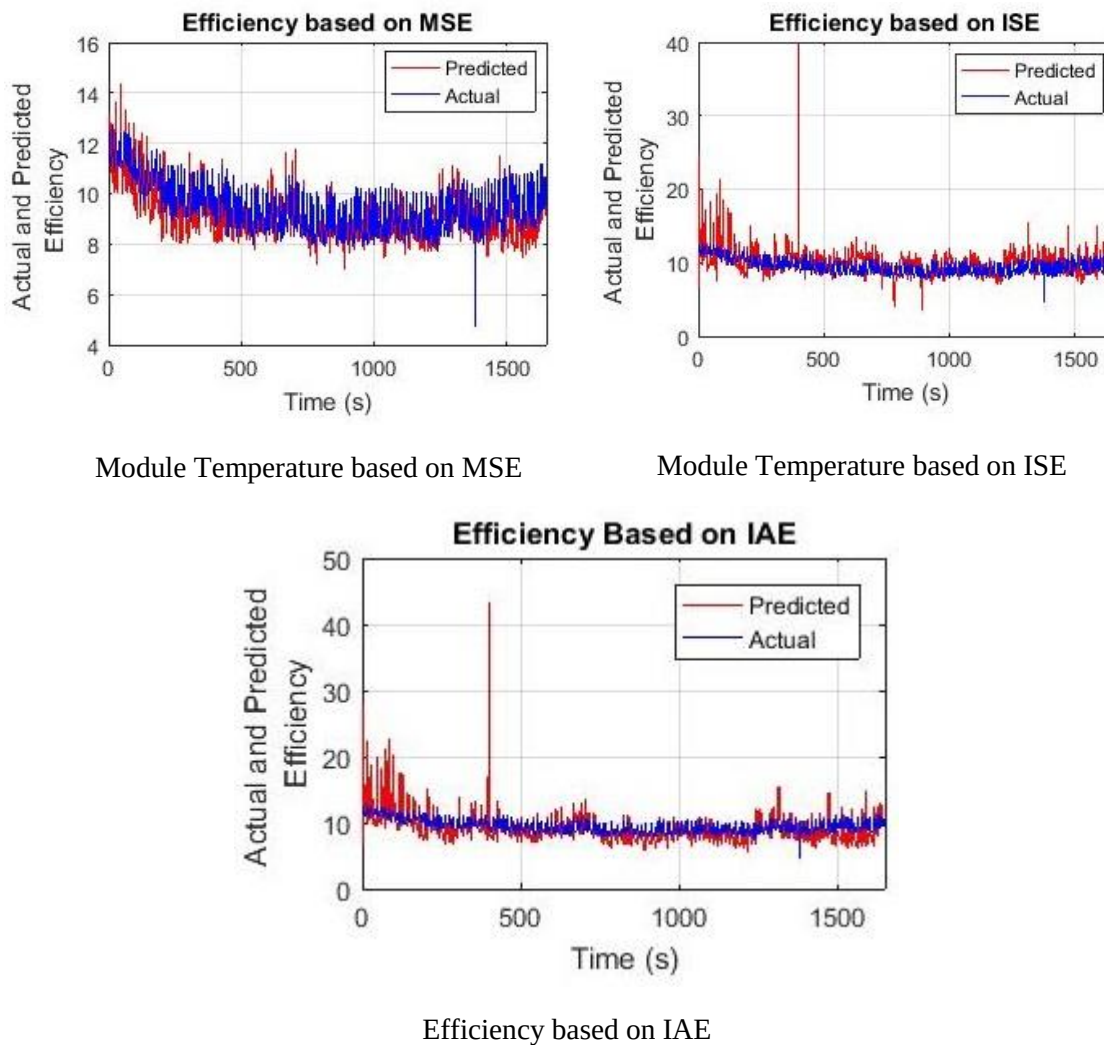


Figure 11. Actual and predicted efficiency based on validation methods

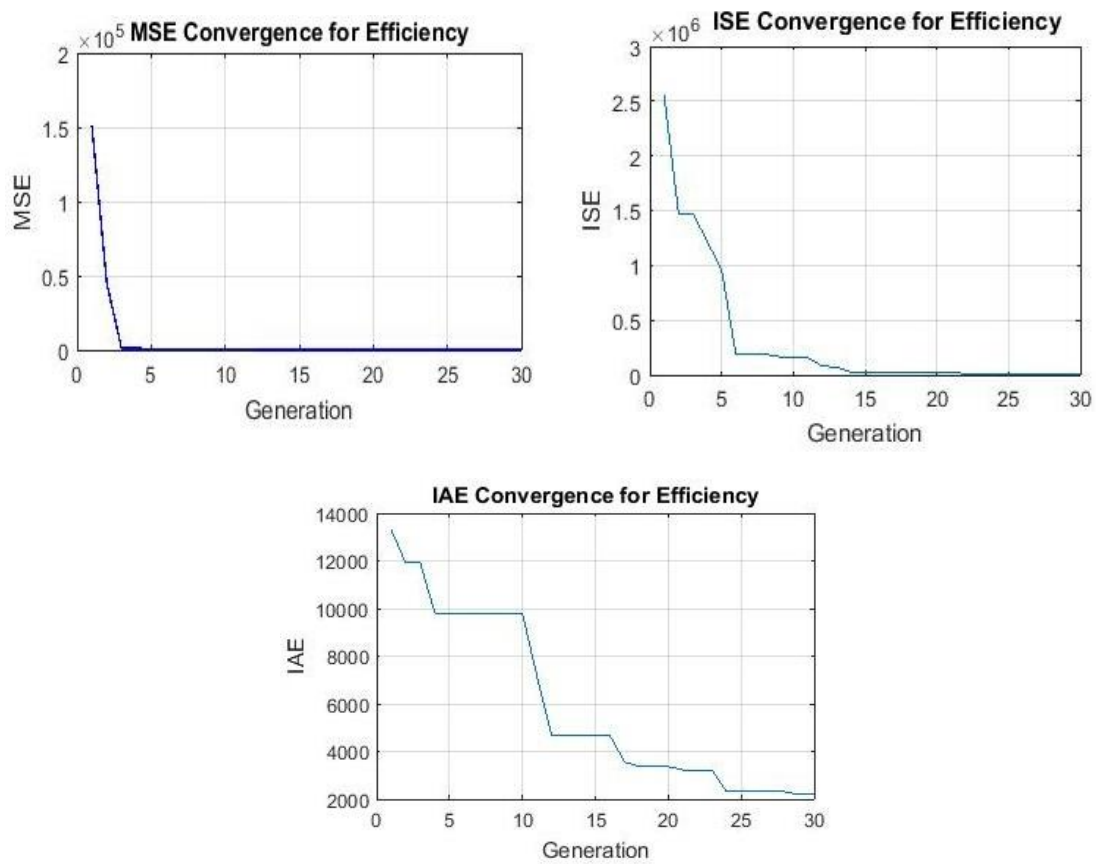


Figure 12. Validation method behavior

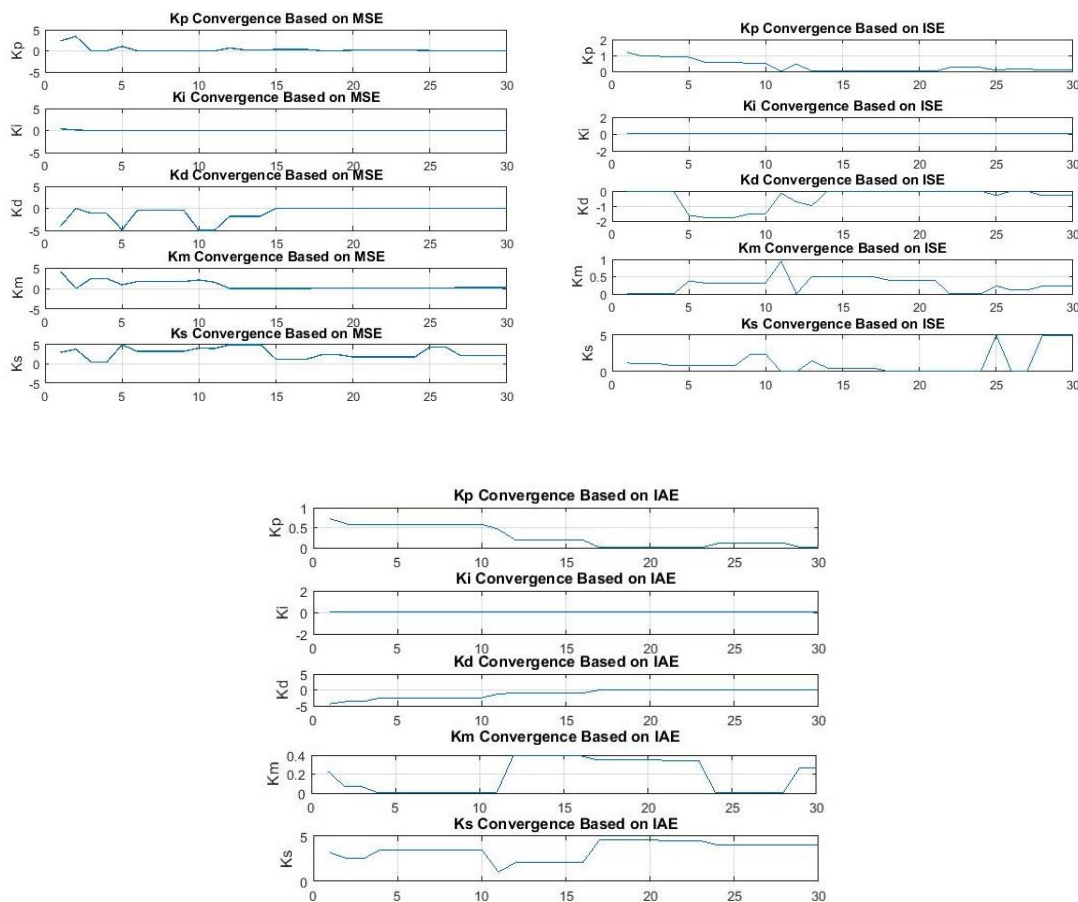


Figure 13. Actual and predicted efficiency based on validation methods

According to Table 2, it's noticed that the MSE was best validation method compared with the other methods and recorded lowest error of 0.6938 at $K_p = 0.07134$, $K_i = 0.001$, $K_d = -0.00317$, $K_m = 0.2116$ and $K_s = 2.1339$. On the other hand, the results revealed that the wind speed factor doesn't affect much compared with the other correlation factors.

Table 2. validation method performance for module temperature of PV panel

Validation methods	Lowest error	K_p	K_i	K_d	K_m	K_s
MSE	0.6938	0.07134	0.001	-0.00317	0.2116	2.1339
ISE	6.1696×10^3	0.0632	0.001	-0.3041	0.2281	4.9259
IAE	2.1860×10^3	0.001	0.001	-0.001	0.2677	4.0157

6. Conclusion

This paper presented the module temperature and efficiency characteristics of PV solar panel that relate with the Baghdad environments through predicting the correlation factors for ambient temperature, solar radiation, humidity and wind speed in order to predict the main formulas. The main advantage of this work is to build the scientific an engineering scientific concept during the design

process and before implement the experimental works in order to reduce the cost and mistake stage. Moreover, the main contribution of this work is to employ the CSA as an intelligent optimization method in this application. Firstly, the experimental setup designed and developed using Mono-crystalline and Polo-crystalline panel types with addition accessories to collect the temperature and efficiency parameters. Then, the collected data used later to predict the correlation factors with them using CSA and validate by MSE, ISE and IAE. The results revealed that the proposed optimization method was succeeded to predict the correlation factors for both of module temperature and efficiency based on MSE only. Whereas, the lowest MSE has been recorded was 0.51782 at $K_p = 1.0081$, $K_i = 0.0172$, $K_d = -0.9671$, $K_m = 0.0939$ and $K_s = 6.5531$ for module temperature of PV panel. Also, the lowest MSE has been recorded was 0.6938 at $K_p = 0.07134$, $K_i = 0.001$, $K_d = -0.00317$, $K_m = 0.2116$ and $K_s = 2.1339$ for efficiency of PV panel.

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