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Additional power conservation in 200W power plant with the application of high thermal profiled cooling liquid & improved deep learning based maximum power point tracking algorithm

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Abstract. This research work focuses to design and simulate a 200W solar power system with electrical power conservation scheme as well as thermal power conservation modeling to improve power extraction from solar power plant. Many researchers have been already designed and developed different methods to extract maximum power while there were very researches are available on improving solar power thermally and mechanically. Thermal parameters are also important while discussing about maximizing power extraction of any power plant. A specific type of coolant which have very high boiling point is proposed to be use at the bottom surface of solar panel to reduce the temperature of panel in summer. A comparison between different maximum power point tracking (MPPT) technique and proposed MPPT technique is performed. Using this proposed Thermo-electrical MPPT (TE-MPPT) with Deep Learning Algorithm model 40% power is conserved as compared to traditional solar power system models.

Keywords: ANFIS based MPPT; Deep learning based MPPT; FLC based MPPT; MPPT techniques; TE-MPPT; thermal effect of solar cell

1. Introduction

To reduce our reliance on fossil fuel it is necessary to promote renewable energy resources and provide a sustainable source of energy for rural development and industrial energy requirements fulfillment. Sun radiation is one of the prime source of renewable energy available throughout day time needed to convert in usable form with solar cells and thermal collectors. Efficiency of solar thermal systems are around 40% to 60% while efficiency of photovoltaic cells are around 10% to 20% (Bashir *et al.* 2018, Bashir *et al.* 2014). From the multiple researches it is observed that efficiency of solar power reduces with increase in temperature of solar cell. So by reducing operating temperature of solar cell, its output energy increases in significant amount (Koteswararao *et al.* 2016, Hasanuzzaman *et al.* 2016, Du *et al.* 2013). This proposed research

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work improves the efficiency of solar power system by applying a novel cooling system on the bottom surface of solar panel. This special type of antifreeze coolant is ethylene glycol (EGW) which mixed with water and used to cool electronics equipments as well as car engine. Ethylene glycol is being used for long time in automobile industries. But the choice of coolant depends upon its price, thermal stability, thermal properties, environmental temperature and application area (Mohapatra 2006).

Ethylene glycol is one of the best chemical that can be used as solar panel coolant as its thermal characteristics are much better as compared to that of water. Instead of ethylene glycol there is another coolant propylene glycol (PGW) with similar thermal property. Propylene glycol is environmental friendly and non-toxic while ethylene glycol is a toxic chemical need careful handling and disposal. Thermal performance of EGW is better as compared to that of PGW (Wilson 2009). Volumetric ratio of EGW and water should be 63/37 to achieve minimum freezing point. And a continuous decrement is recorded in freezing point of PWG as ratio of propylene glycol increases with respect to water. Because of higher viscosity of PGW more pumping power is needed to circulate this liquid in pipe. So EGW is chosen best coolant for cooling solar panel. Additionally the available solar power at its terminals can be efficiently extract using maximum power extraction methods like most basic methods; perturb and observation (P&O) and incremental conductance (IC) etc.

In this proposed research work, different MPPT techniques P&O, INC, FLC, ANFIS and DL are analyzed and compared to find out one of the best MPPT algorithm. Comparison of tradition MPPT schemes like P&O, INC, FLC and ANFIS are studied from different literatures and comparative analysis is presented while DL based MPPT and thermal enhancement is modelled and simulated.

2. Literature survey

Enhancement of efficiency of solar system and performance improvement was being attempted from starting of 1954. Hence the concept of maximum power point tracking was introduced in 1954. Maximum power point trackers are divided into two parts; electrical tracking and mechanical tracking. Mechanical tracking was further divided into two type single axis tracker and double axis tracker to trace Sun mechanically like Sun flower. Mechanical tracking is complex and costly as well as high power consuming mechanism so it led to most of development of power maximization electrically. Electrical methods of tracking maximum power are divided into three categories; off-line technique, online technique and artificial intelligence (AI) technique. These techniques are tabulated below in in Fig. 1.

Narendrian *et al.* (2014), presented a MATLAB/simulink model to design and single solar cell mathematically and plotted I-V and V-P curve for variable irradiation, temperature shunt resistance and series resistance of solar cell. These both characteristics analyzes the effects of environmental parameters on performance of solar system. Increase in irradiation increases output current of solar cell while with increase in cell temperature output power of solar cell decreases.

Salman *et al.* (2018), illustrated the MPPT technique to extract maximum available power on solar panel terminal using most basic and straight forward algorithm known as P&O MPPT algorithm. And implemented a DC-DC buck converter hardware which was controlled with MPPT algorithm implemented microcontroller and test this hardware prototype a 200W solar PV module and a lead acid battery was connected to input and output terminals of charge controller

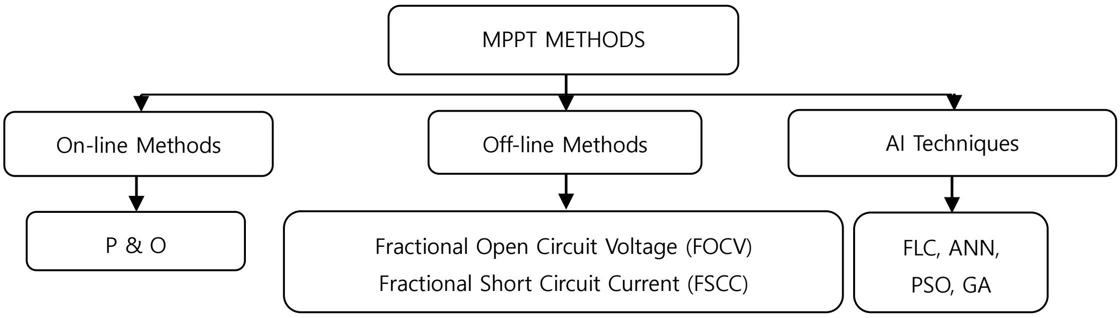

Fig. 1 MPPT methods

simultaneously. This MPPT charge controller performed more efficiently as compared to basic PWM charge controllers.

Hussein (2016), discovered a native maximum power point extraction methodology with the aid of AI based algorithm known as fuzzy logic controller to create PWM pulses for switching power converter module. This process was a closed loop structure which monitors output voltage and current of solar PV module and modifies the initial auto generated pulse duty cycle. FLC-MPPT method uses these two output parameters voltage and current at solar system load side as input and corrects the required pulse width as per required for achieving the maximum power available at solar panel terminals. FLC-MPPT has built-in comparator to find difference between previous output parameters voltage and current and instantaneous values of voltage and current to create and error signal and further error is compared with previously stored error to get difference in error. Now FLC-MPPT uses these two parameters to make decision to guide the control towards MPP point to make error zero.

Narendiran *et al*. (2016), implemented a MPPT control strategy with fuzzy logic controller (FLC) for improving the output performance of solar PV module under variable environmental condition and also under static environmental condition. These two environmental conditions shows a drastic change in output power generated by solar system without applying MPPT method while controlled output is achieved under proposed FLC-MPPT powered solar system. According to the author membership functions of fuzzy logic controller are investigated under different climate conditions to track better accuracy and response to achieve MPP point. The performance of this proposed system was compared to one the best choice of hardware developer of charge controllers that is P & O scheme and much better as compared to P&O based charge controller according simulation results.

Arora and Gaur (2015), presented the combination of two fuzzy logic controllers fuzzy logic controller and neural network controller to achieve the MPP point more efficiently. Combination of these two control strategies led to actual implementation of artificial intelligence methodology to solve complex problems where traditional methods failed to solve. The combination of these two methods is known as adaptive neuro-fuzzy interference system (ANFIS). According to the authors results comparison ANFIS found one of the best MPP point tracking methodology as compared to other MPPT techniques in terms of overshoot, settling time, overshoot, time spent tracking MPP and oscillations.

Lin *et al.* (2000), analyses the effects of ambient temperature on performance of solar system

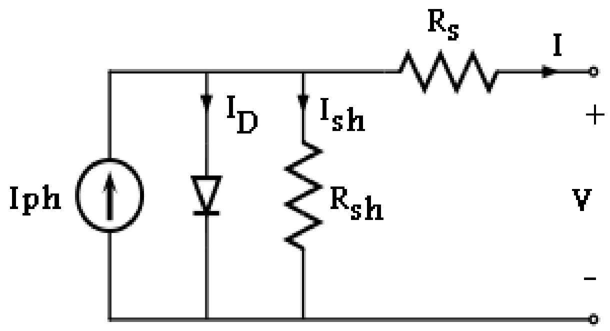

Fig. 2 PV cell equivalent circuit

and water cooling model to enhance the performance. The key analysis of this work is analysis of solar output variation with change in rate flow of water coolant. And also analyses effect of coolant and ambient temperature variations on low v A finite alue of specific dissipation.

In most of the literatures, electrical power point tracking had been implemented, while mechanical power point tracking is also important to further improving solar efficiency. There is no literature on enhancing maximum power point using heat transfer mechanism. Hence different heat transfer technologies can be applied to control solar panel bottom surface temperature using copper plating, water cooling system and a significant improvement can be exercised using EGW solution with a specified mixture ratio. Hence an improvement of 5-10% power is expected via thermal conduction.

3. Solar cell mathematical modeling

The mathematical modelling of solar can be understand with the help of its equivalent circuit diagram which is presented in Fig. 2. Solar cell is a type of current source and it has diode effects and some series and shunt resistivity so these effects are visible in cell's equivalent circuit (Tsai *et al.* 2008, Francisco *et al.* 2005).

Mathematical model of this solar is created according to the equivalent circuit by applying KVL and KCL theorems. There are three loop in which theorems are applied and parameters are calculated. $I_{ph}$is acting as current source further divided into three parts I, I_{sh} and I_D and so current at the load side I can be calculated as: (Narendiran and Sahoo 2014)

$$I = I_{ph} - I_s\left(exp\frac{q(V+R_sI)}{NKT} - 1\right) - \frac{(V+R_sI)}{R_{sh}} \quad (1)$$

In the Eq. (1), I_{ph} is current due to photons, I_s is diode's reverse saturation current, electronic charge is given by q, output voltage V is appeared at the load side terminal, Diode junction instantaneous temperature is T, K defines the Boltzmann's constant, and N is parameter varies for different cell and known as ideality factor lies between 1 to 2, shunt and series resistance effect of cell is presented by R_{sh} and R_s respectively.

The physical phenomenon of solar cell can be presented in electrical parameters I_{ph}, R_{sh}, R_s and I_s. And environmental parameters that affect performance of solar cell are irradiation sun, ambient temperature, humidity and wind speed.

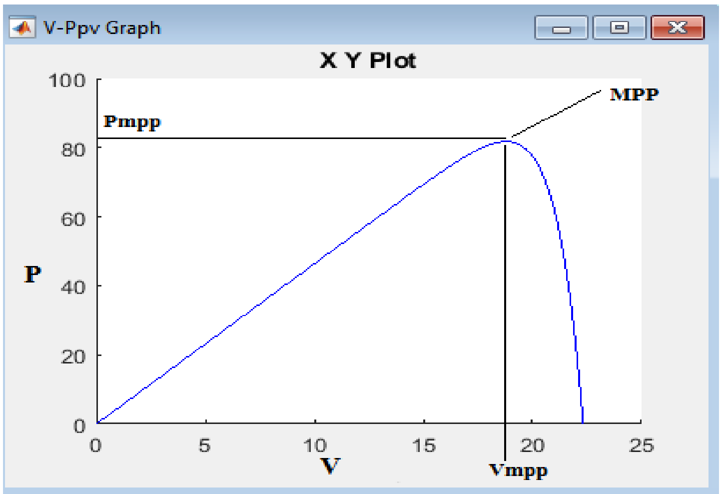

Fig. 3 V-P characteristics

Now, important factors needed to be expressed to create simulink model for analysis are photocurrent of PV cell and diode current. Eq. (2) represents the relationship between environmental parameters temperature and solar irradiation as follows (Nema *et al.* 2010)

$$I_{ph} = [I_{sc} + K_i(T - 298)]\frac{\beta}{1000} \tag{2}$$

where K_i=0.0017 A/◦C represents the temperature coefficient of cell under short circuit current and β shows solar irradiation in W/m^2.

Reverse saturation current of diode plays very important role while cell temperature exceeds beyond nominal temperature $25°C$ and expressed as (Narendiran *et al.* 2014)

$$I_s(T) = \; I_s\left(\frac{T}{T_{nom}}\right)^3 exp\left[\left(\frac{T}{T_{nom}} - 1\right)\frac{E_g}{NV_t}\right] \tag{3}$$

where T_{nom} is nominal temperature of cell, thermal voltage is V_t, and energy band gap of semiconductor is E_g.

4. MPPT Techniques

In this research work a new technology Deep learning based thermo-electric MPPT is implemented to optimize the performance of solar power plants and compared to other four MPPT techniques P&O MPPT, INC MPPT, FLC based MPPT and ANFIS based MPPT.

4.1 P&O MPPT

One of the simplest and easiest method to extract the solar power available at the terminals of solar power system in perturb and observation (P&O) method. Perturbation stands for the slight change of voltage and monitoring of output power is continuously done with current and voltage sensor. V-P curve of solar cell as shown in Fig. 3.

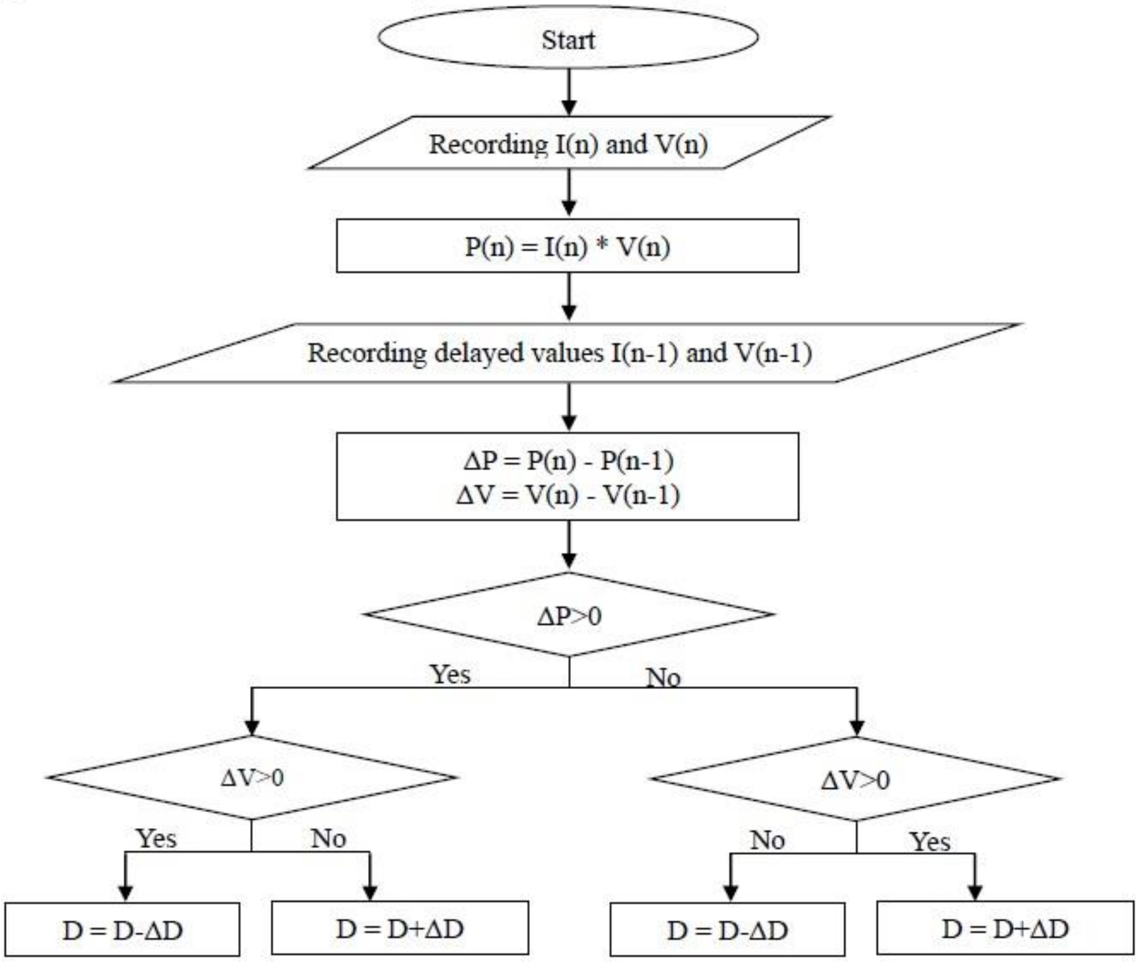

Fig. 4 P&O MPPT flow chart

According to the Eqs. (1)-(3), voltage and power V-P and V-I graph is shown in Fig. 3. Flow diagram of P&O based MPPT algorithm is presented in Fig. 4.

As per flow chart of P&O algorithm, level of operating voltage is adjusted with little change either lowering and incrementing depends upon the output power until incrementing or decrementing that means process continues until power become steady. This change in level of voltage is done by changing the duty cycle of internal resistance of DC-DC converter. So, there four conditions occurred according to the algorithm depicted in flow chart.

These four conditions are as follows:

1. $\Delta P > 0$ and $\Delta V > 0$ makes Increase in the voltage.
2. $\Delta P > 0$ and $\Delta V < 0$ makes Decrease in the voltage.
3. $\Delta P < 0$ and $\Delta V > 0$ makes Decrease in the voltage.
4. $\Delta P < 0$ and $\Delta V < 0$ makes Increase in the voltage.

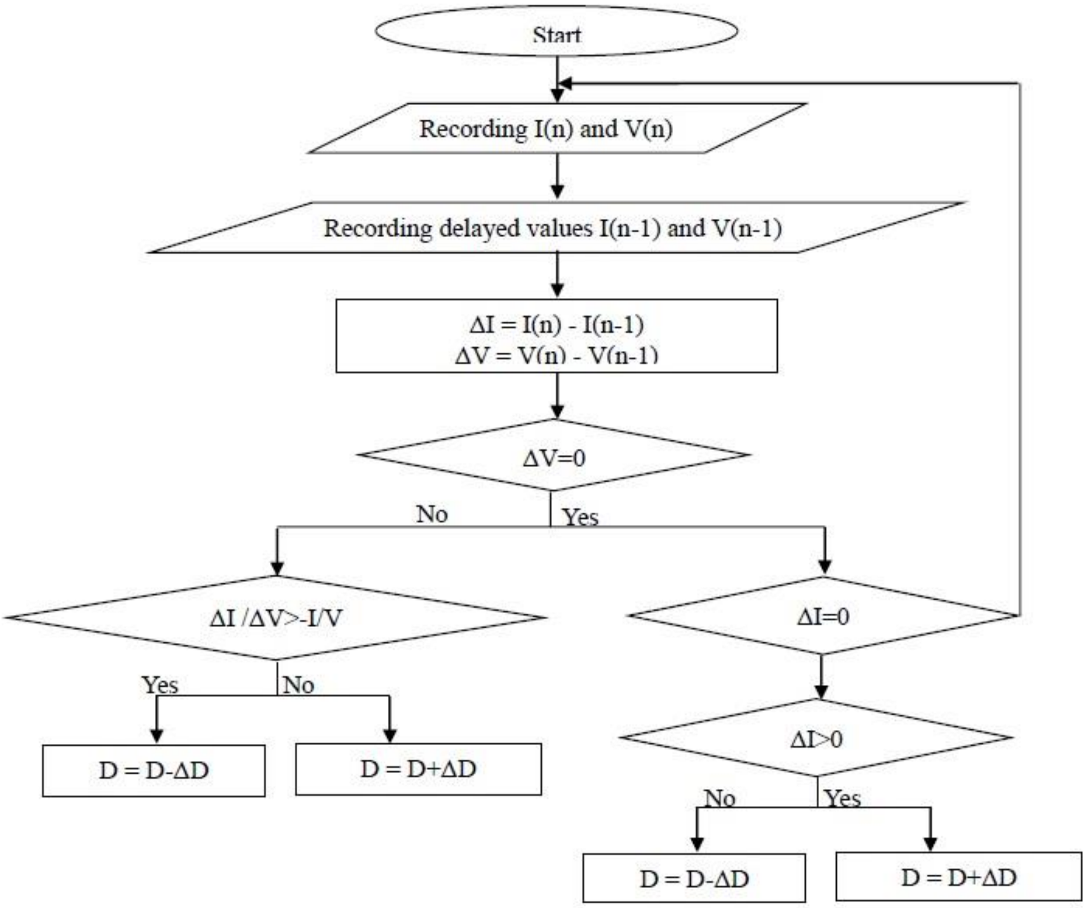

Fig. 5 Incremental conductance MPPT flow chart

P&O based MPPT algorithm is one the most traditional maximum power point tracking algorithm used in hardware modelling for MPPT based charge controller.

4.2 Incremental conductance MPPT

Incremental conductance is also similar to P&O MPPT technique as follows hill climbing algorithm but it operates in different manner as compared to P&O method. To track the maximum power point of output of solar module, it uses the gradient of power-voltage curve (Choudhary and Saxena 2014). Flow diagram of the incremental conductance MPPT is shown below in Fig. 4.

First current and voltage values are measured and stored to variable I(n) and V(n) respectively then delayed values of current and voltage are recorded after that ΔI and ΔV are calculated as

$$\Delta I = I(n) - I(n-1) \tag{4}$$

$$\Delta V = V(n) - V(n-1) \tag{5}$$

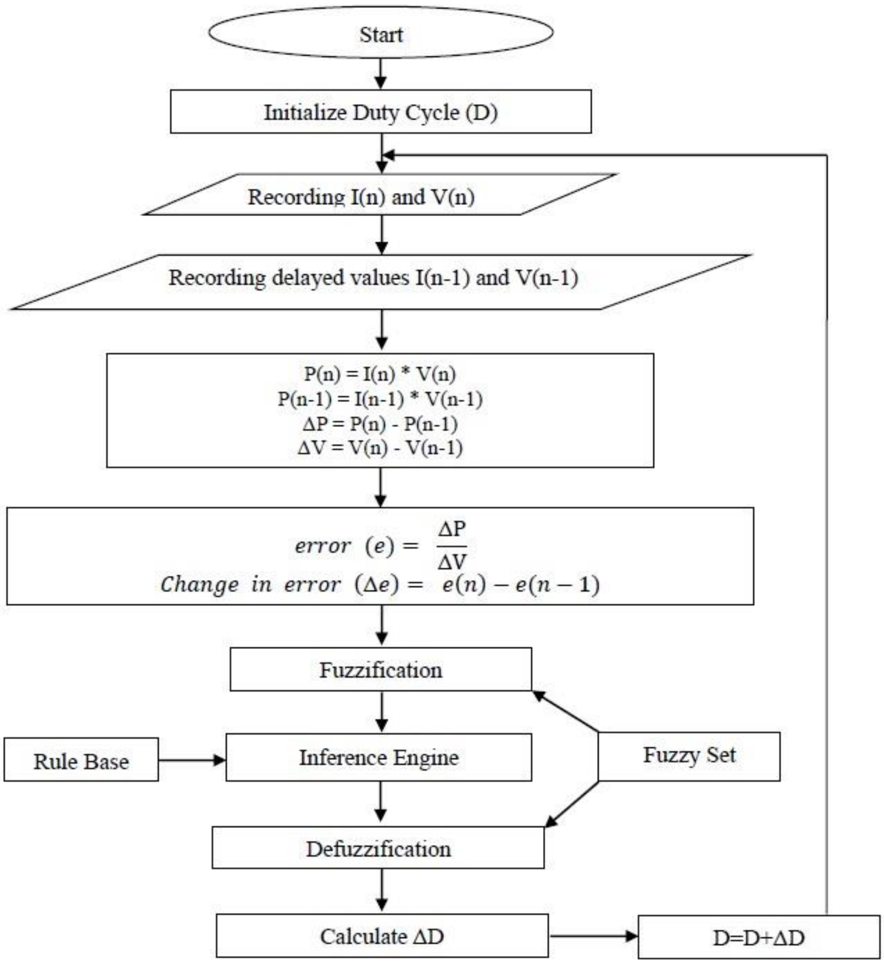

Fig. 6 FLC MPPT flow chart

If ΔV and ΔI are zero then MPP achieved and process repeated.
If ΔV is not zero, then $\Delta I / \Delta V + I/V$ is calculated.
If $\Delta I / \Delta V + I/V > 0$, then duty cycle reduces and hence voltage reduces to achieve MPP.
If $\Delta I / \Delta V + I/V < 0$, then duty cycle increases and hence voltage increases to achieve MPP.
If $\Delta I > 0$, then duty cycle increases and hence voltage increases to achieve MPP.
If $\Delta I > 0$, then duty cycle reduces and hence voltage reduces to achieve MPP.
Incremental conductance is second traditional MPPT methodology under research for hardware implementation.

4.3 FLC based MPPT

Fuzzy logic based maximum power point tracking comes under the category of AI based MPPT technology. It is most effective technique to solve the problems in case of uncertainty.

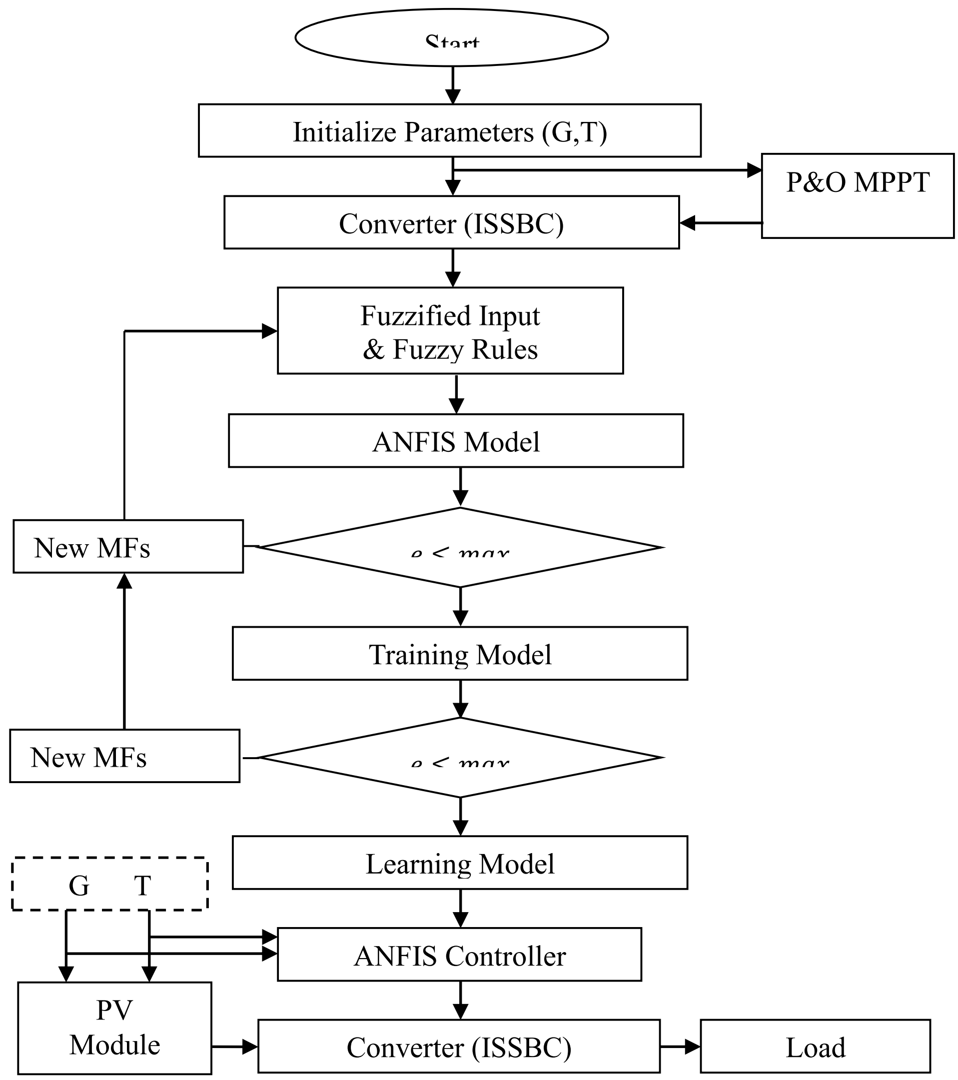

Fig. 7 ANFIS MPPT flow chart

According to the Fig. 6 the flow chart of the FLC based MPPT works in multiple steps. First value of duty cycle is initialized and current, voltage and power are measured and delayed values of power and voltage are also measured (Chatterji *et al.* 2014). Now error is calculated in Eq. (6) as shown below

$$error\ (e) = \frac{P_n - P_{n-1}}{V_n - V_{n-1}} \tag{6}$$

Change in error can be calculated as

$$Change\ in\ error\ (\Delta e) = e(n) - e(n-1) \tag{7}$$

These two parameters e and Δe are input variables of FLC interference system and it has only output ΔD.

If the error (e) is zero then MPP achieved and process continues to check again and again.

If error (e) is nonzero then ΔD changed to reduce the error.

Fuzzy logic based intelligent algorithm is mostly used where it is not possible solve the problems using if-else logics. This method efficiently handles uncertain situation as it tracks maximum power point available in V-P characteristics in very less time while traditional algorithms take lot of time to track point hence a fluctuation is observed.

4.4 ANFIS based MPPT

Combination of neural network and fuzzy inference system is known as ANFIS which is modeled with the basic data generated by fuzzy controller. The FIS output and input data is used to train the ANFIS model. So this is second step is to use dataset to create a new model with a reference model instead fuzzy model.

In ANFIS based MPPT algorithm modeling P&O is used as reference to structure the model and parameters are measured and training dataset is used to train the system to create reliable solution for retrieving maximum available power from solar module.

In this model two input parameters are current I(n) and voltage V(n) and output parameter is duty cycle D (Ramesh *et al.* 2018). Two key parameters of PV are current I(n) and voltage V(n) utilizes to produce an optimized value of duty cycled pulse D(n) used to control power converter (DC-DC).

Here P&O MPPT used as reference model and then training dataset is used to train the system and membership functions are modified accordingly. Solar irradiation (G) and temperature (T) are also taken as input and applied to ANFIS controller to monitor continuously.

5. Proposed maximum power point extraction methodology

The proposed maximum power extraction model presents the combination of thermo-electrical MPPT model which provides better power efficiency as compared to traditional MPPT models discussed earlier. In this proposed work ethylene glycol ($C_2H_2O_2$) is used with water to cool down solar cell heating. The most important fact about ethylene glycol is its concentration that is the ratio of water and ethylene glycol in EGW solution. Pure ethylene glycol has boiling point around 197.3℃, melting point is around -12.9℃ and density is $1.11 g/cm^3$. Heat transfer characteristics of EGW solution can be calculated using heat transfer rate Q_r (W) Eq. (8) (Khan *et al.* 2019).

$$Q_r = mC_p(T_{in} - T_{out}) \tag{8}$$

Where, C_p is specific heat fluid (kJ/kgK), inlet and outlet terminal temperature of EGW are presented by T_{in} & T_{out}, m presents the mass flow rate of fluid (L/min) (Khan *et al.* 2019).

Boiling point of EGW (combination of water and ethylene glycol) decrease with decrease in percentage volumetric ration of EG and water as shown in Table 1.

According to the Table1, it is observed that high concentration of EG in EGW solution provides better boiling point. But with increase in percentage of EG reduces flow rate of solution. So, more pumping power will be required to circulate high dense EGW solution. 50% volumetric ratio based data is presented in Table 2.

Table 1 Boiling Point of EGW for EG Volume % (Wang *et al.* 2013)

EG Solution (% Volume)	0	10	30	50	70	90	100
Boiling Point (°C)	100	101.1	104.4	107.2	118	142	197

Table 2 Increase in flow required for fluid temperature (Wang *et al.* 2013)

Ratio of EG & Water is 50% - 50%	
Fluid Temperature	Required Flow Increase (%)
4.4	22
37.8	16
60.0	15
82.2	14
104.4	14

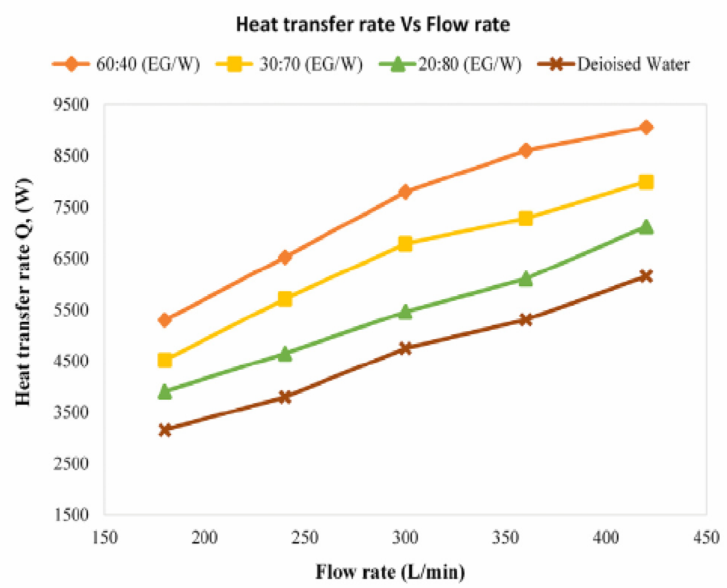

Fig. 8 Heat transfer rate characteristics (Shankara *et al.* 2022)

It is observed from Table 2 that for higher temperature of fluid comparatively lower flow rate increment is required. Hence this solution is suitable for higher temperature climate. Heat transfer performance of EGW solution for different volumetric ratio at variable flow rate is presented in Fig. 8.

From Fig. 8, it can be observed that heat transfer rate is minimum for pure water and maximum for EGW solution with EG/W ratio 60:40. So this solution mixture is best suitable for solar panel coolant application.

For variable fluid flow rate and volumetric ratio change in temperature is observed by author (Shankara *et al.* 2022) and plotted in Fig. 9. Here inlet temperature of fluid is maintained to 90°C.

With increase in flow rate, difference between temperature at inlet terminal and outlet terminal decrease because coolant takes lesser time to move from input point to exit point and this relation is calculated using Eq. (9) (Khan *et al.* 2019).

$$m = \frac{Q_r}{C_p(T_{in} - T_{out})} \tag{9}$$

Now Q_r can be calculated with relation between heat transfer coefficient h in (W/m^2k) of coolant and heat transfer rate as in Eq. (10).

$$h = \frac{Q_r}{nA\ (T_b - T_w)} \tag{10}$$

Bulk temperature of fluid (T_b) is calculated as

$$T_b = \frac{T_{in} + T_{out}}{2} \tag{11}$$

T_w is the wall temperature of the conductor.

Table 3 Simulation design parameters

Simulation Parameters	Value
Sampling Time	50uS
Solar PV Module	200 W
Irradiation Standard	1000 W/m2
Temperature	25℃
Inductor	70 mH
Boost Converter Input Capacitor	470 uF
Boost Converter Output Capacitor	470 uF
Switch	IGBT
Load	5 ohm

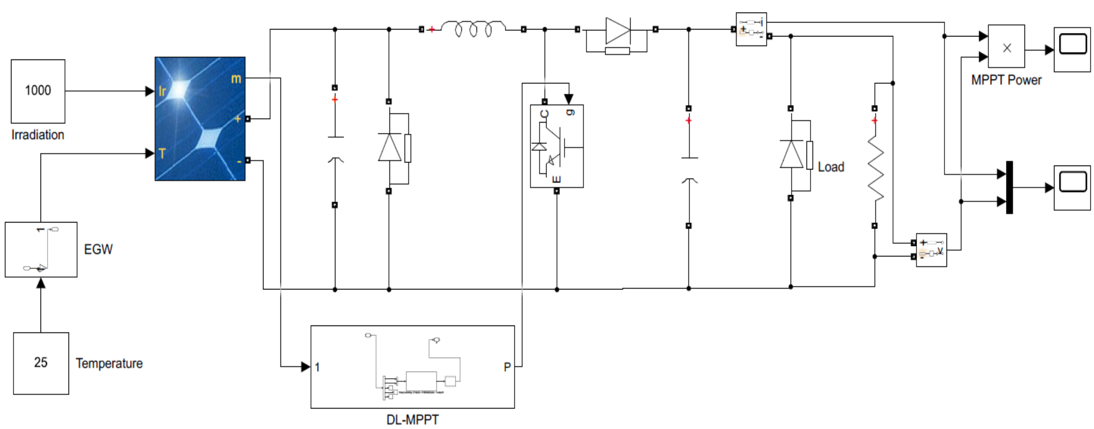

Fig. 10 Proposed system simulink model

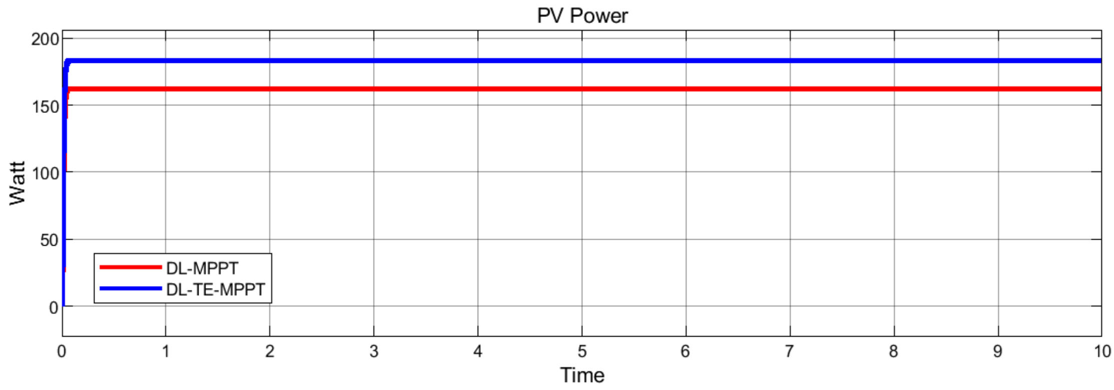

Fig. 11 DL-MPPT PV System Power with and Without Coolant

From the Fig. 9, it is observed that for flow rate between 150 & 200, maximum temperature difference is observed at EG/W ratio of 60:40. So for further implementation of MPPT simulation model EG/W ratio 60:40 is considered and fluid flow rate is 180 assumed. Initial temperature of fluid was 90 ℃ and a decrement of 25 ℃ is observed hence temperature is decreased by approximately 28%.

Now proposed model is designed and simulated on the simulink tool under MATLAB software. The proposed simulink model is consisted of four major parts; solar PV module, DC-DC converter, MPPT controls algorithm and load. Simulink model of proposed system is shown in Fig. 10. In this model a solar PV module with capacity of 2kW electrical power generation is designed and connected dc-dc boost converter which is controlled by deep learning based MPPT technique with additional PV cell cooling mechanism. This native design is known as Deep learning based Thermo-electric MPPT (TE-MPPT) model.

This system is configured with 200W solar power module and converter parameters are presented in Table 3.

In this proposed system EGW coolant is further applied as integral part of the solar cell with scaling factor of 28%.

6. Results & discussion

Proposed innovative model is combination of thermal modelling as well as electrical MPPT modelling is using deep learning algorithm and it output result is shown in Fig. 11. Deep learning based MPPT algorithm measure output voltage and current of solar PV module and train itself with previous input and output combination and produces modified width of pulses to mitigate instantaneous output power. It produces maximum power available at PV terminals that is saturated output. In high temperature environment above 25℃ ambient temperature solar back side temperature increases very rapidly and reaches upto 80℃ in hot conditions. So fast heat dissipation model reduces temperature which tends to significant enhancement in output power. Maximum power extracted using P& O algorithm is 82 watt as concluded in previous study (Salman *et al.* 2018). While proposed method simulated a great improvement using deep learning based maximum power extraction.

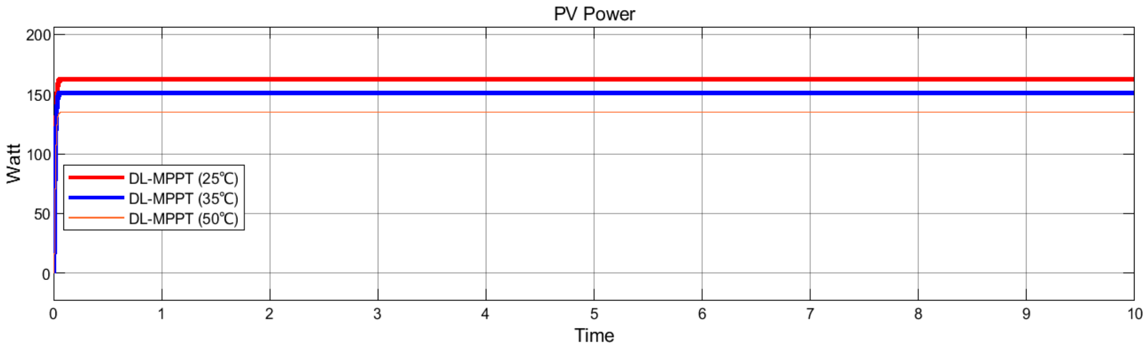

Fig. 12 Comparison of DL-MPPT power at variable temperature

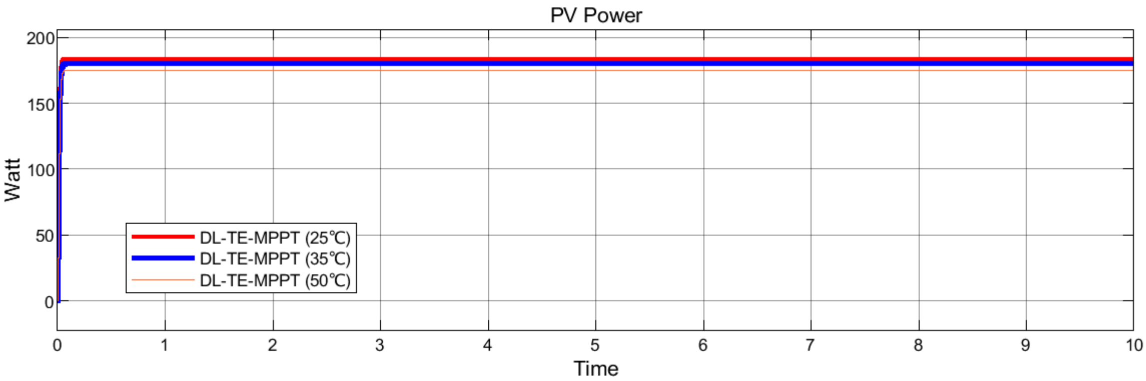

Fig. 13 Comparison of DL-TE-MPPT power at variable temperature

Fig. 11 presents output power of proposed DL based TE-MPPT and DL based MPPT without coolant at 25℃ ambient temperature. Analyzing the above graph, it concluded that previously implemented DL based MPPT model extracts 160watt power from PV module while proposed DL based MPPT model extracts 178watt power which is shows approx 11% increment in output power. Now DL based MPPT simulation is performed for different temperature and result is plotted in Fig. 12. Simulation model three different models are implemented with different temperature and constant irradiation. Ambient temperature is taken 25℃, 35℃ and 50℃ for DL based MPPT model to verify the effect of temperature on extracted solar output power.

From Fig. 12 it is concluded that solar output power decreases with increase in ambient temperature. For 50℃ ambient temperature output power recorded is 135 watt and for 35℃, it 150 watt and 160 watt is observed at nominal ambient temperature 25℃. Due to higher temperature output power is reduces to 15.6% which is a significant amount. Hence it is prime need to design a system to avoid this drastic power loss.

So to observe the effect of coolant that flow in a copper tube in bottom side of solar PV module, a simulation model is create as per the analysis of EGW solution in Tables 1-3. According to the analysis 60:40 ratio mixture of EGW solution performed best to reduce the contact temperature. Now with the same temperature variation coolant is applied to the system and results are evaluated and plotted in Fig. 13.

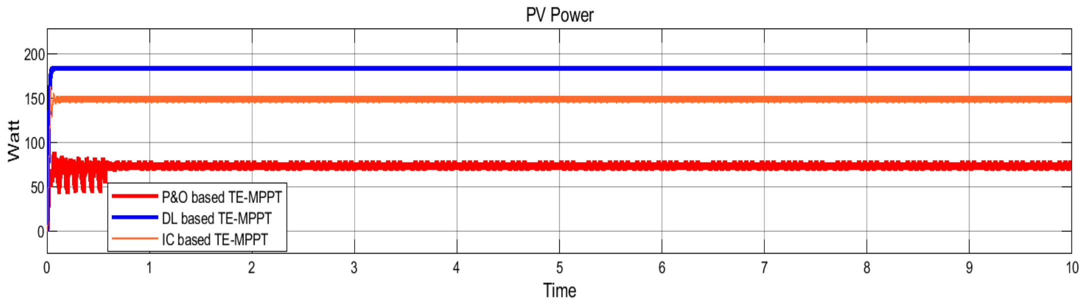

Fig. 14 Comparison of different MPPT algorithm output

Table 4 Comparative analysis

Technique	Average Output Power (W)
DL-MPPT (25℃)	160
DL-MPPT (35℃)	150
DL-MPPT (50℃)	135
DL-TE-MPPT (25℃)	181
DL-TE-MPPT (35℃)	175
DL-TE-MPPT (50℃)	170
IC-TE-MPPT (25℃)	150
P&O-TE-MPPT (25℃)	75

Table 5 Comparison of MPPT techniques (Salman *et al.* 2018)

Controllers	Tracking Efficiency (%)	Overshoot (%)	Complexity	Tuning Require
P & O	76.57 – 82.52	No	Simple	No
INC	86.41 – 88.00	Little	Simple	No
FLC	87.46 – 90.38	No	Complex	Yes
ANFIS	86.23 – 93.45	Moderate	Complex	Yes

Comparing results of Figs. 12 and 13 concludes that after application of EGW coolant to the bottom surface of solar panel a significant improvement in output power is monitored. And it can be observed that there is almost negligible effect of ambient temperature on output power extracted from PV. It only due to fast heat dissipation via coolant.

Comparative analysis of P&O, IC and DL based MPPT technique is presented in Fig. 14 according to the simulation result. Each three electrical MPPT technique is applied on thermally optimized solar PV module. According to the observation of plot, P&O based algorithm extracts

75 watt power while DL based algorithm extracts 178 watt power leading IC based algorithm having 150 watt power extracted.

From the above simulation it concluded that DL based MPPT technique is 20% more efficient as compared to IC based TE-MPPT and 60% more efficient as compared to basic P&O with EGW coolant. Table 4 concludes the comparative analysis of different algorithm with proposed algorithm.

Comparing combination of thermal based power improvement and enhancement of power electrically and model without thermal enhancement presents a drastic change in output power. An improvement of 20% recorded after application of EGW coolant. Hence overall an average improvement of 35-40% recorded with hybrid model.

One of the important features is implementation complexity, which refers to how difficult and expensive the installation is. Because it just requires the usage of one sensor, P&O has the simplest installation. The integral regulator adds to the system's complexity. INC is typically thought to have a low level of complexity. FLC has the most difficult implementation.

Table 5 presents comparison between four different MPPT techniques; it also included ANFIS MPPT technique. Comparison Table concludes that ANFIS performs best to track maximum power from solar module. Complexity of ANFIS MPPT is higher as compared to that of FLC MPPT.

7. Conclusions

Proposed MPPT method is based on artificial intelligence based power point technique method which uses the deep learning architecture with one input layer, 4 hidden layer and one output layer. This proposed model is combination of electrical maximum power point tracking and thermal power extraction mechanism. Thermal improvement of solar PV module can be performed using different types of coolants. Electrical MPPT methods P&O, IC, DL has modelled and simulated in Simulink tool, according to results DL based model has maximum efficiency that is 86% more as compared to P&O and 6.7% more as compared to that of IC method. Further liquid cooling systems were implemented to improve extracted power. Water cooling mechanism is applied previously to dissipate heat from PV back panel. In the current work most effective and efficient coolant EGW solution (60:40 ratio of ethylene glycol and water) is circulated to the back panel of PV and results of simulated models shows that 13% power has been enhanced with coolant mechanism in because a temperature difference of 25℃ has achieved. Comparison of With help of deep leaning algorithm an average 20% power increment has recorded at higher temperature, so overall 35% to 40% improvement has been achieved with proposed TE-MPPT model which is significant achievement. Comparison of P&O, FLC, INC and ANFIS MPPT algorithm shows that ANFIS shows better power output but more complexity because of training dataset is required. Hardware model of proposed TE-MPPT algorithm can be implemented in future.

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References

Arora, A. and Gaur, P. (2015), "Comparison of ann and anfis based mppt controller for grid connected pv systems", *Proceedings of the Annual IEEE India Conference (INDICON)*, New Delhi, India, December.

Bashir, M.A., Ali, H.M., Ali, M., Khalil, S. and Siddiqui, A.M. (2014), "Comparison of performance measurements of photovoltaic modules during winter months in Taxila, Pakistan", *Int. J. Photoenergy*, https://doi.org/10.1155/2014/898414.

Bashir, M.A., Ali, H.M., Amber, K.P., Bashir, M.W., Hassan, A., Imran, S. and Sajid, M. (2018), "Performance investigation of photovoltaic modules by back surface water cooling", *Therm. Sci*., **22**(6), 2401-2411. https://doi.org/ 10.2298/TSCI160215290B.

Chatterji, S., Shimi, S.L. and Kumar, A. (2014), "Fuzzy adaptive proportional-integral-derivative controller with dynamic setpoint adjustment for maximum power point tracking in solar photovoltaic system", *Syst. Sci. Control Eng*., **2**(1) 562-582. http://doi.org/10.1080/21642583.2014.956267.

Choudhary, D. and Saxena, A.R. (2014), "Incremental conductance MPPT algorithm for PV system implemented using DC-DC buck and boost converter", *Int. J. Eng. Res. Appl*., **4**(8).

Du, D., Darkwa, J. and Kokogiannakis, G. (2013), "Thermal management systems for photo voltaic (PV) installations: a critical review", *Solar Energ*., **97**, 238-254. https://doi.org/10.1016/j.solener.2013.08.018.

González-Longatt, F.M. (2005), "Model of photovoltaic module in matlab™", *Proceedings of the 2nd Conference of American Electrical, Electronic and Computer Engineering Students*, USA.

Hasanuzzaman, M., Malek, A.B.M.A., Islam, M.M., Pandey, A.K. and Rahim, N.A. (2016), "Global advancement of cooling technologies for P.V. systems: a review", *Solar Energ*., **137**, 25-45. https://doi.org/10.1016/j.solener.2016.07.010.

Hussein, S.N. (2016), "Comparison between perturb & observe, incremental conductance and fuzzy logic mppt techniques at different weather conditions", *Int. J. Innov. Res. Sci. Eng. Technol*., **5**(7), 12556-12569. https://doi.org/10.15680/ijirset.2016.0507069.

Khan, A., Ali, H.M., Nazir, R., Ali, R., Munir, A., Ahmad, B. and Ahmad, Z. (2019), "Experimental investigation of enhanced heat transfer of a car radiator using ZnO nano particles in H2O-ethylene glycol mixture", *J. Therm. Anal. Calorimetry*, **138**(5), 3007-3021. http://doi.org/10.1007/s10973-019-08320-7.

Koteswararao, B., Radha, K., Vijay, P. and Raja N. (2016), "Experimental analysis of solar panel efficiency with different modes of cooling", *Int. J. Eng. Technol*., **8**(3), 1451–1456.

Lin, C., Saunders, J. and Watkins, S. (2000), "The effect of changes in ambient and coolant radiator inlet temperatures and coolant flowrate on specific dissipation", *Proceedings of the SAE 2000 World Congress*, Detroit, Michigan, USA, March. http://doi.org/10.4271/2000-01-0579.

Mohapatra, S.C. (2006), An Overview of Liquid Coolants for Electronics Cooling, Electronics Cooling, May.

Narendiran, S. and Sahoo, S.K. (2014), "Modelling and simulation of solar photovoltaic cell for different insolation values based on matlab/simulink environment", *Appl. Mech. Mater*., **550**, 137-143. https://doi.org/10.4028/www.scientific.net/amm.550.137.

Narendiran, S., Sahoo, S.K. and Das, R. and Sahoo, A.K. (2016), "Fuzzy logic controller based maximum power point tracking for pv system", *Proceedings of the 3rd International Conference on Electrical Energy Systems (ICEES)*, Chennai, India, March.

Nema, S., Nema, R.K. and Agnihotri, G. (2010), "MATLAB/simulink based study of photovoltaic cells / modules / array and their experimental verification", *Int. J. Energ. Environ*., **1**(3), 487-500.

Ramesh, T., Saravanan, R. and Sekar S. (2018), "Analysis of ANFIS MPPT controllers for partially shaded stand alone photovoltaic system with multilevel inverter", *Int. J. Robot. Autom*., **7**(2), 140-148. http://doi.org/10.11591/ijra.v7i2.

Salman, S., Ai, X. and Zhouyang, Wu, Z. (2018), "Design of a P-&-O algorithm based MPPT charge controller for a stand-alone 200W PV system", *Protection and Control of Modern Power Systems*, **3**(1). https://doi.org/10.1186/s41601-018-0099-8.

Shankara, R.P., Banapurmath, N.R. and D'Souza, A. (2022), "An insight into the performance of radiator system using ethylene glycol-water based graphene oxide nanofluids", *Alexandria Eng. J*., **61**(7), 5155-

5167. https://doi.org/10.1016/j.aej.2021.10.037.

Tsai, H.L., Tu, C.S. and Su, Y.J. (2008), “Development of generalized photovoltaic model using matlab/simulink”, *Proceedings of the World Congress on Engineering and Computer Science WCECS*, San Francisco, USA, October.

Wang, P., Kosinski, J.J., Anderko, A., Springer, R.D., Lencka, M.M. and Liu, J. (2013), “Ethylene glycol and its mixtures with water and electrolytes: Thermodynamic and transport properties”, *Am. Chem. Soc*., **52**, 15968-15987, https://doi.org/10.1021/ie4019353.

Wilson, J. (2009), "Antifreeze Coolants, February.