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A Modified Maximum Power Point Tracking Algorithm for PV systems using ANFIS with CPE

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Abstract: The Maximum Power Point Tracking (MPPT) method applying an Adaptive Neuro-Fuzzy Interface System for a stand-alone photovoltaic (PV) system. The propound ANFIS based MPPT capability regulates the optimal operating point of a PV system which is designed in concurrence with a DC-DC converter as an interface between the PV array and the load. The system helps to trim down the hardware setup while strengthen the array power efficiency and MPPT response time.

The simulation results are provided to demonstrate the MPPT algorithm operation as well as the climatic parameters estimation (CPE) capabilities. An ANFIS based boost DC to DC converter is used to tackle power from Solar. The proposed converter architecture has diminished number of power conversion stages with less component count and minimizes losses compared with existing PV systems. This ameliorates the efficiency and the reliability of the system. The concert of the proposed MPPT technique in tracking the Maximum Power Point (MPP) is evaluated numerically in the Matlab/Simulink environment.

Key words: Photovoltaic, Maximum Power Point Tracking, Maximum Power Point, Global peak, Adaptive neuro fuzzy interface system, Climate parameter estimation

I.INTRODUCTION

The capabilities of energy transformation from a renewable energy source mostly rely on the operating point of the reorient system. Therefore the maximum power point tracking (MPPT) is of the foremost importance in renewable energy conversion systems. The objective of MPPT is entirely old but still every year numerous research papers are being published approaching towards better and faster techniques. Expeditious consumption of fossil fuel preserve, ever hikes energy demand and analyze over climate change motivate power generation from conventional energy sources. Solar photovoltaic (PV) and wind have materialized as commercial energy sources due to their ecofriendly nature and cost effectiveness. However, these sources are not accomplished in nature. Hence, it is a provocation to supply stable and uninterrupted power using these sources. This can be contrivance by productively amalgamated with energy storage elements. However, they absence from a comparatively low altering efficiency, which makes their optimization necessary. This is done by captivating their maximum power for contingent climatic environments. Popular “maximum power point tracking (MPPT)” is done through a particular control of a dc-dc converter. Abundant control techniques have been recommended depending on their difficulty, sensors used, convergence, setup, and in further aspects [2]–[8].

A Photovoltaic (PV) system instantly converts sunlight into electricity. The primary device of a PV system is the PV cell. Cells may be integrated to form panels or arrays. The voltage and current obtainable at the terminals of a PV device may directly sustain small loads such as lighting systems and DC motors. More approached applications requisite electronic converters to process the electricity from the PV device. These converters may be used to calibrate the voltage and current at the load, to dominance the power flow in grid-connected systems, and mainly to track the maximum power point (MPP) of the device.

The accustomed methods are the perturb and observe (P&O), and the incremental conductance (InCond). The first method is well known due to its hardware lucidity. It concerns by fabricating a perturbation in the voltage, which results in oscillate in the array power [3],

[18]. However, the system insurgences around the MP points, which devour energy while it cannot distinguish between the irradiance distinction and the tracker's cycle. More clarifications are completed based on an adaptive step size or optimization functions [3]–[5], [9]. The another one Incremental Conductance method has a much exactness with good adaptable to diverse climatic conditions [9]. Therefore, it is possible to reallocate when the MPP is traced within a given precision [7], [22] while differentiate the expeditious and INC and gauging if they are same.

However, it requires an increased hardware and software complexity. Much abatement are proposed using variable and modified step size algorithms [8]. A slither mode control has been used to ameliorate tracking accuracy [11] and InCond using reference voltage and direct duty ratio perturbation [12]. Finally, a model-based (MB) control is used [13]. Nowadays, intelligent systems are gradually used due to their human-like capability and ability to adjust and upgrade their performance [14], [16], [19]. Many neural networks (NN)- and fuzzy logic (FL)-based techniques are proposed. An artificial NN algorithm is developed with climatic conditions as inputs and applied to a boost tracker. Using FL theory, a feed-forward MPPT scheme, a fuzzy controller, and an adaptive P&O-FL control method are proposed [9], [15].

This paper imparts an ANFIS based MPPT method with decrease components. It calculates the expeditious and junction array conductance's. The first one is done using the array current and voltage, whereas the second one uses the array junction current, which is determined using ANFIS cell model conferred in a recent paper of the authors [17]. Still, it requires information on the climatic parameters. Hence, it is initiated ANFIS based MPPT method as an analytical. The simulation results are provided to justify the proposed ANFIS - PV based MPPT scheme capabilities.

II.PV CHARACTERISTICS AND MPPT

The mathematical model of the system is existence in below. A. PV Cell and Array Modeling PV cell is a simple p-n junction diode which transforms the irradiation into electricity. Fig. 2 shows an equivalent circuit diagram of a PV cell which consists of a light generated current source a parallel diode, shunt resistance Rsh and series resistance Rs. A is an ideal factor. In Fig. 2, ION is the diode current which can be written as:

$$I = I_{pv} - I_0\left[\exp[\frac{V+R_S I}{AV_T}\right] - 1 - \frac{V+R_S I}{R_{sh}} \ldots\ldots\ldots(1)$$

$$where\ \alpha = \frac{q}{AkT_c}, k = 1.3807 \times 10^{-23} JK^{-1}$$

is the Boltzmann's constant, q = 1.6022 × 10−19 C is the charge of electron, TC is the cell's absolute working temperature in Kelvin, A is the p-n junction ideal factor whose value is between 1 and 5, Is is the saturation current, and Vpv is the output voltage of PV array which in this case is the voltage across C, i.e., Vdc. Now, by applying Kirchhoff's Current Law (KCL) in Fig. 1, the output current (ipv) generated by PV cell can be written as,

$$i_{pv} = I_L - I_s I_s\left[exp\left[\alpha(V_{pv} + R_s i_{pv})\right] - 1\right] - \frac{v_{pv} + R_s i_{pv}}{R_{sh}} \ldots\ldots\ldots\ldots (2)$$

Where, Isc is the short circuit current, s is the solar irradiation, Ki is the cell's short circuit current coefficient and Tref is the reference temperature of the cell. The cell's saturation current Is changes with the temperature according to the following equation [19]:

$$I = N_p I_{pv} - N_p I_0\left[exp^{\left[\frac{V+\frac{N_S}{N_p}R_S I}{AN_S V_t}\right]} - 1\right] + \frac{V+\frac{N_S}{N_p}R_S I}{\frac{N_S}{N_p}R_{sh}} \ldots(3)$$

where, Np is the number of parallel connected modules and Ns is number of series connected modules, Ipv is the photovoltaic current at reference temperature and solar irradiation. Since the output voltage of PV cell is very low, a number of PV cells are combined together in series in order to attain higher voltages. A number of PV cells are put together and protect with glass, plastic, and other transparent materials to enfold from grating environment, to form a PV module. To procure the requisite voltage and power, a number of modules are connected in parallel to form a PV array. Fig. 3 shows an electrical equivalent circuit diagram of a PV array

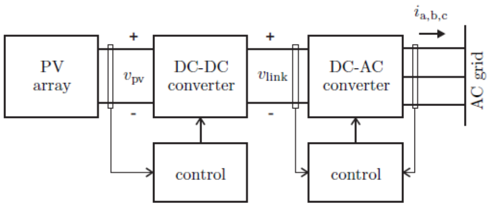

Fig1: Block diagram of the PV system.

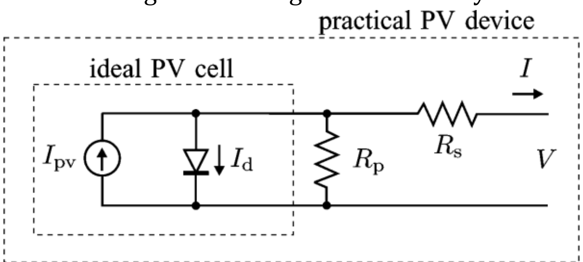

Fig2: Single diode model of PV cell

Where Ns are the number of series modules and Np is the number of modules in parallel. Id is the diode current. Ipv photovoltaic current at stc.

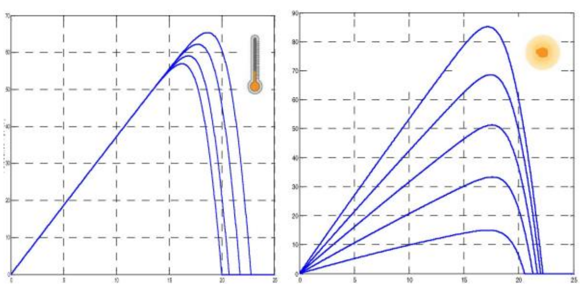

Fig3: Irradiation and temperature on P-V characteristics

III. PROPOSED METHOD

The block diagram model of ANFIS based maximum power point tracking controller is shown in below Fig. 4. Irradiance level and operating temperature of PV module are apprehend as the input training data set for the ANFIS. The ANFIS reference model gives out the crisp value of maximum available power from the PV module at a particular temperature and irradiance level. At the equivalent temperature and irradiance level, the actual output power from the PV module, is evaluated using the multiplication widening of sensed operating voltage and current.

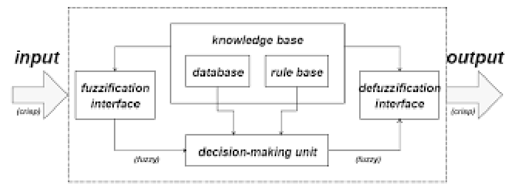

Fig4: Block diagram model of ANFIS

The control signal generated by the PID controller is given to the PWM generator. The PWM signal is initiated using high frequency of carrier signal as compared to the control or modulating signal. The frequency of carrier signal used is 50kHz.The generated PWM signals regulate the duty cycle of DC–DC converter, in order to control the operating point of the PV module.

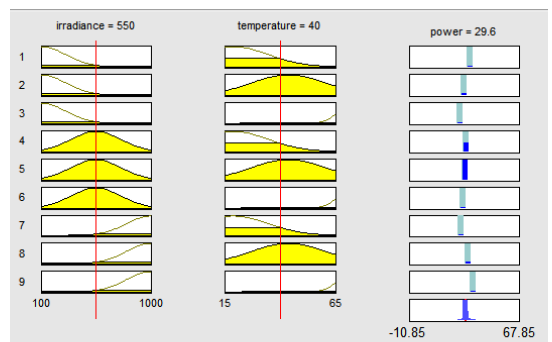

Fig. 5. Output from fuzzy rules for specific value of temperature and irradiance.

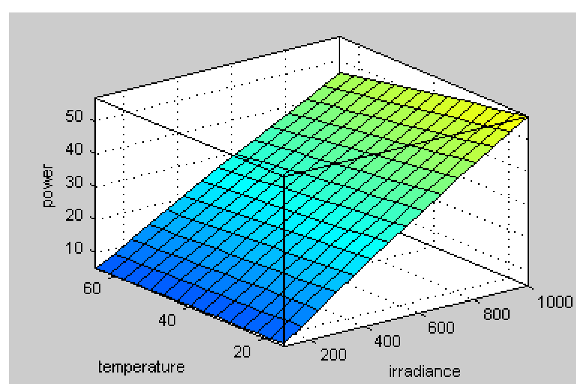

Fig. 6. Surface between two inputs (temperature and irradiance) and one output (maximum power).

Calibration of ANFIS Using the Matlab/Simulink model of PV module, the operating temperature is changing from 15 1C to 65 1C in a step of 5 1C and the solar irradiance level is changing from 100W/m2 to 1000W/m2 in a step of 50W/m2, to get the training data sets for ANFIS. Maximum available power for each pair of training data is recorded. In total 209 training data sets and 2000 epochs are used to train the ANFIS. By using given input/output dataset, the ANFIS construct s a fuzzy inference system (FIS) who membership function parameters are changed using the hybrid optimization method of training the FIS. The hybrid optimization method is a amalgamation of the least- squares type of method and the back propagation algorithm. It illustrates that the ANFIS output closely matched to the actual output of module even at 6% of training error. It has two inputs (irradiance level and operating temperature), one output and three membership functions for each input. Nine fuzzy rules are evaluated from six input membership functions. These rules are obtained according to the input and output mapping, so as to produce maximum output power for each value of input temperature and irradiance level. The ANFIS generated surface is shown in below Fig. 6. It is 3 dimensional plot between temperatures, irradiance and maximum power.

The neuro-fuzzy inference is a together of ANN and FL. The ANN recognizes the logics and conforms to them to deal with amending environments. On the next one the fuzzy inference systems (FIS) integrate the human knowledge and carry out the inference and process of decision making. Two common fuzzy models, the Mamdani and Takagi Sugeno-Kang (TSK), are defined for FIS. For the conventional we use Sugeno model for great accuracy and less tangled, convergence speed is high.

The ANFIS is only able to use the TSK fuzzy model due to its high calculative efficiency, adaptive techniques and built in optimum. The controller provides smoothness in convergence because of the fuzzy TSK inference and adaptability as a result of ANN back propagation algorithms the structure of a typical five layer ANFIS system is embellished in Fig.7

The applications of Fuzzy logic and Neuro-fuzzy methods in modeling, simulation and forecasting and supervision of PV systems have been employed to solve tangled practical problems in [12-15]. The ANFIS is hybrid method joining neural networks and fuzzy logic. The definition of membership functions called fuzzification of input parameters and following design of IF-THEN rules employ learning capability of the ANN for self-regulating fuzzy rule generation and self-adjustment of membership function.

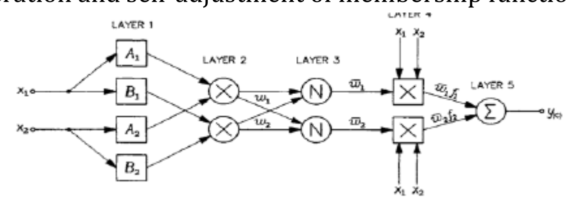

Fig. 7. A typical Five layer ANFIS system

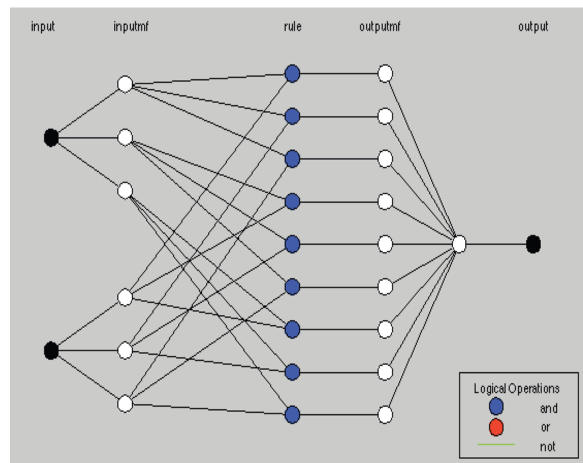

Fig. 8. ANFIS based MPPT controller structure

IV. MATLAB SIMULATION RESULTS

To evalaute the performance of the ANFIS based MPPT system a PV array characterized by a rated current of 4.15A Thus, the total output voltage of the PV array is 25V to 34 V and output current is 13.8A. The value of Cin and Cout is 34μF and 48μF. The line resistance is considered as 0.1 and the inductance is 0.6mH. Total output power is 460W

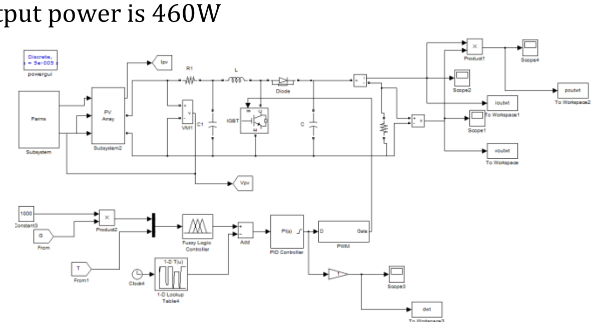

Fig 9 Complete Matlab/Simulink Model of the Proposed ANFIS based MPPT Systems.

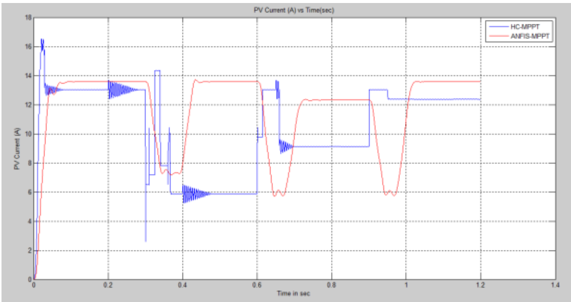

Fig 10 PV Current vs Time waveforms of a ANFIS based MPPT system

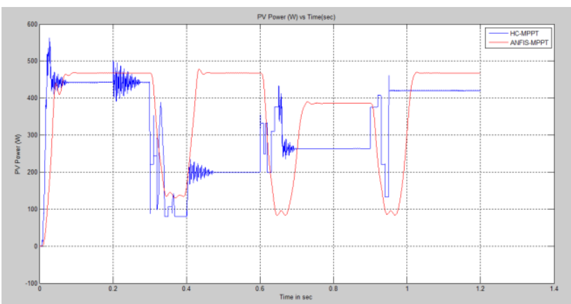

Fig 11 PV Power vs Time waveforms of a ANIFS based MPPT system

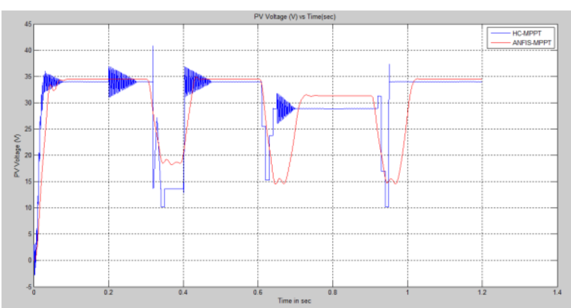

Fig 12 PV Voltage vs Time waveforms of a ANFIS based MPPT system

The MATLAB/SIMULINK representation of the ANFIS based MPPT is shown in Fig. 9. From Fig. 10 it is shown that the PV Current and time. From Fig. 11 it is shown that PV Power and time. From Fig. 12 it is shown that the PV Voltage and time. To make the input signals suitable for switches a PWM is used. All the simulations are done in the widely used MATLAB/SIMULINK environment.

In this case, the system is simulated at variable atmospheric condition where the value of solar irradiation is considered as 300Wm−2, 500Wm−2, 600Wm−2, 1000Wm−2 and the temperature as 25 degrees. At this condition, the output power of PV unit which is shown in Fig. 11 where there is some oscillations due to the nonlinear characteristics of PV system. The main intention of the Proposed ANFIS control action is to extricate maximum available power from the PV unit through MPPT and supply this power to the utility.

S.no	System	Voltage	Current	Power
1.	HC MPPT method	33V	13A	440W
2.	ANFIS based MPPT	34V	13.8A	460W

Fig 13 Comparison of proposed system with ANFIS based MPPT

V.CONCLUSIONS

As the simulation results show, the recognition of the input and output variables for an ANFIS-based MPPT controller successfully reduced the complication of the control system by abolishing the need for a PID controller. In addition to defining the temperature and the solar irradiance decreases the cost auxiliary with using current and voltage sensors that other methods employ for the current and voltage measurements. In the proposed model, using the meteorological data claimed by the local climate station helps the ANFIS-based controller to be instructed based on real values.

The conclusion of the paper corroborates that the ANFIS method can be employed efficiently if the input and output variables are recognized based on the characteristics of the system which are being controlled. This approach can diminish the complication of the control system, accordingly. The future work of this study is to evolve a grid-connected model and considerate the impacts of the inverter and z-source converter supplying different loads. As well, the developed ANFIS-controller will be evolved by combining other ambient parameters, by ensuring an automated choice of membership functions based on these conditions and will be further tested on a real PV system.

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