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Design Steps of Anfis Controller for the Application of PV Generation

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Abstract – This paper gives the steps for the design and operation of an adaptive neuro-fuzzy inference system (ANFIS)-based maximum power point tracking (MPPT) for solar photovoltaic (SPV) energy generation system. The MPPT works on the principle of adjusting the voltage of the PV modules by changing the duty ratio of the Voltage source inverter. The duty ratio of the inverter is calculated for a given solar irradiance and temperature condition by a closed-loop control scheme. The closed-loop control of the VSI regulates the duty ratio and the modulation index to effectively control the injected power and maintain the stringent voltage, current, and frequency conditions. The ANFIS is trained to generate maximum power corresponding to the given solar irradiance level and temperature. The response of the ANFIS-based control system is highly precise and offers an extremely fast response.

Key words – MPPT, ANFIS, Photovoltaic system, Voltage Source Inverter, Modulation index

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1. INTRODUCTION

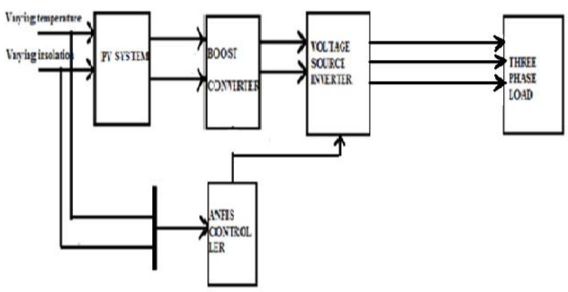
It is well known that the output power of photovoltaic (PV) panels holds highly non-linear characteristic. For a certain temperature and irradiation, there will be a specific maximum power at certain voltage so-called maximum power point (MPP). The voltage of MPP changes with the irradiation and especially the temperature varying. Thus, the system needs to operate at the MPP of PV array by controlling the inverter, no matter how much irradiation, what temperature or other conditions. Moreover, the generated energy from the PV system, which mostly provided to the utility grid, not only should be of sinusoidal current, but also must satisfy the requirements of the power grids, such

as no DC component of the inverter output current, minimization of the harmonics, as a result of no harmonic pollutions on the power grids, and so on. These requirements impose the inverter with a high-grade control. The challenge is how to meet the above requirements with minimum cost, which has to be faced for the majority of designers.

AI based methods are most suitable for improving the dynamic performance of maximum power point tracking. Considering the non-linear characteristics of solar PV module, the AI methods provide a fast, flexible and computationally demanding solution for the MPPT problem. Fuzzy logic controller and artificial neural networks are two main AI methods used for MPPT. In this paper, designing and implementation of ANFIS based MPPT scheme which is interfaced with Voltage Source Inverter presented.

ANFIS combines the advantages of neural networks and fuzzy logic and hence deals efficiently with nonlinear behavior of solar PV modules. Designing of voltage source Inverter is also carried out which is used for impedance matching and maximum power transfer between load and solar PV module.

2. BLOCK DIAGRAM OF PROPOSED SYSTEM



The Fig. illustrates the block diagram of the proposed system. MPPT is used for extracting the maximum power from the solar PV module and transferring that power to the three phase ac load. A DC-DC converter[3][4] and VSI acts as an interface between the load and the PV module. Maximum power point tracker (MPPT) used in the proposed system [5] tracks the new modified maximum power point in its corresponding curve whenever temperature and/or insolation variation occurs. The MPPT is used to adjust the modulation index of the VSI [6] in order to maintain the power extracted. An ANFIS controller is incorporated to automatically vary the modulation index of VSI in order to maintain the power extracted. Fig.1. illustrates the overall block diagram of the proposed system. The proposed system consists of a PV array [1][2], ANFIS controller, Boost converter, VSI and three phase ac load. The PV power generating system produces different voltages for varying temperature and irradiance [5][6]. By varying temperature and irradiance two hundred sets of data are generated in simulation. These data are used to train ANFIS in offline using MATLAB toolbox for the purpose of Maximum Power Point Tracking (MPPT) [7].

Voltage from the PV array is boosted using a boost converter. The boosted voltage is given to the voltage source inverter. The inverter feeds the power to the three phase ac load. The output voltage from the inverter is given to the load.

2.1 Problem Formulation

The values of voltage and currents will change as per the change in climatic condition and therefore Maximum power also. There will be a one value for the current referred as (I_{mpp}) and one value of voltage referred as (V_{mpp}) which will together define the "Maximum Power Point". By inserting a suitable converter between Photo-voltaic array and load would give a better solution for the above problem. Converter should be designed in such a way that it should change the modulation index of VSI.

Hence ANFIS controller is the feasible alternative solution to get the maximum power from the solar radiation for the change in climatic condition. In this work ANFIS controller is modelled using MATLAB/SIMULINK and connected to PV array to track the solar power and transfer it to load.

2.2 Methodology

This work is carried out to track a Maximum power point of a solar array/module. The proposed system is simulated in MATLAB/SIMULINK and implemented a prototype model which consists of a solar panel/array, controller to achieve MPP, dc-dc boost converter and inverter. In the proposed system components are modelled and simulated in MATLAB/SIMULINK for different irradiation and temperature and tabulated corresponding output power of VSI at different climatic condition.

The solar photovoltaic generated voltage is fed to the dc-dc boost converter and boost converter output is connected to the inverter and the load. Variation of the modulation index of inverter can be done using ANFIS controller the maximum power can be achieved from the solar panel across the load.

2.3 Existing system

As it is stated in problem formulation output characteristics of PV module thus array is non-linear in nature. As input temperature and irradiations changes the output power also getting altered for photovoltaic system.

To obtain the highest output from the photovoltaic module/array, it should be run on maximum point. So it becomes very essential to work the PV module/array at its highest power point in spite of change in climatic condition. The Perturb and observe (P&O) method is used for the calculation of rate of change of power with respect to voltage i.e. dP/dv to settle on the maximum power point (MPP). This method is comparatively simple in implementation, but when there is a rapid change in irradiation it starts oscillating around MPP rather than tracking it. Another method called incremental conductance method is perfect in tracking MPP quickly but algorithm is complicated, in which it uses calculation of rate of change of current with respect to voltage i.e dI/dV.

2.4 Proposed system

Because of flexibility offered by Artificial intelligence (AI) based methods, now a days AI methods are preferred for the design of control strategy for renewable energy systems. If we correctly trained the AI systems, they will be able to produce the accurate outputs. And they find their importance in the design of nonlinear systems also

The newly designed ANFIS system also uses the irradiation and temperature as input. The ANFIS tech is a combination of the Neural Network and Fuzzy logic. An effort is made to obtain the Maximum power from proposed ANFIS system (newly designed) for change in climatic condition i.e. change in solar radiance and temperature conditions.

2.5 Objectives of the Proposed Work

1. To improvise upon the existing scenario of the Power quality issues.

2. Study of ANFIS controllers and their Modelling.

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3. Enhancing the OUTPUT of the Voltage Source Inverter using ANFIS controller.

4. Reduce harmonic present in the output.

5. To obtain the maximum conversion efficiency of inverter in all climatic conditions by the use of ANFIS controller.

6. Simulation of the ANFIS controller with PV array to achieve maximum power point.

3. PROPOSED SIMULATION MODEL:

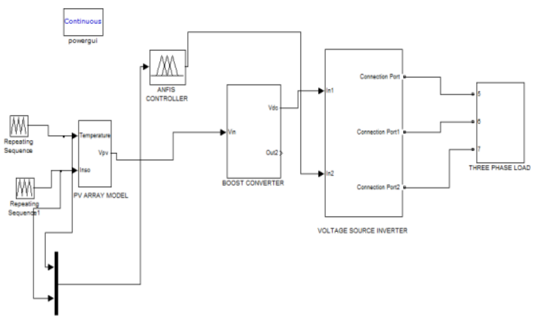


Fig.3.1 Proposed simulation module

Above one is the proposed simulation model which is consisting of PV module, Boost converter, ANFIS controller, Voltage source inverter and three phase load.

3.1 ANFIS for MPPT Tracking

The PV cell temperature varies from 10º C to 70 ºC in a step of 6ºC and the solar irradiance varies from 50 to 1000W/sq.m in a step of 50 W/sq.m. By varying these two environmental factors a set of data is generated in simulation.

The overall neuro-fuzzy structure shown in which is a five-layer network [8]. The structures shows two inputs of the solar irradiance and the cell temperature, which is translated into appropriate membership functions, three functions for the solar irradiance and three functions for temperature. These membership functions are generated by the ANFIS controller based on the prior knowledge obtained from the training data set [9].

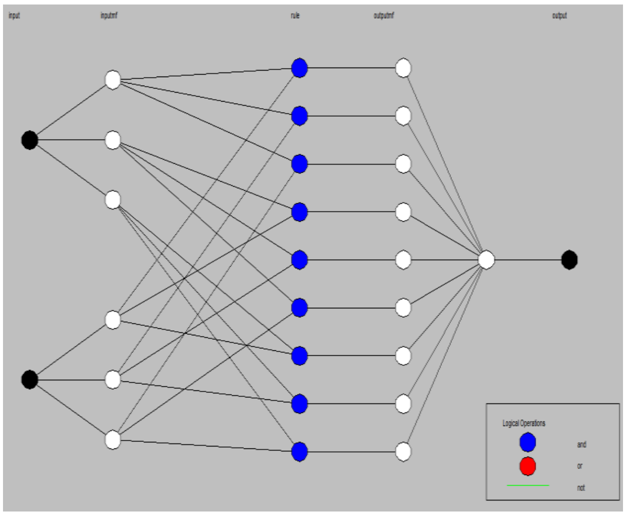


Fig.3.2 ANFIS based MPPT Algorithm

3.2 Control Strategy:

This section describes the control strategy involved to achieve the desired objective.Fig.9 illustrates the control scheme diagram involved in MPPT system using ANFIS.

3.3 PWM control

The boosted output voltage of the converter Vdc is compared with the carrier signal and the output is given as gating signal to the MOSFET switch of the boost converter.

4. STEPS FOR DESIGN OF ANFIS CONTROLLER

For the design of ANFIS controller, inputs used are temperature and irradiation. The range of temperature is so selected that which is near to the actual obtainable values .i.e for the design of controller temperature range is selected from 16 C^0 to 70 C^0. And irradiation is ranging from 50 watts/m^2 to 1000 watts/m^2.

And the system is trained for the known input and output values and system will automatically produces output for all unknown inputs. For training the system set of rule-sets are used. Those rule sets are as shown below. For the construction of rule sets simple if- and-then statements are used. There are totally 9 rules have been constructed taking three membership function for each of the input.

Membership functions for the inputs are selected as low, medium and high. The range of input temperature is selected as low for the range 16-35 C^0 and medium is of the range 30-55 C^0 and high for the range 50-70 $C^{0.}$ for selected values of input outputs will be trained.

Mr. Pradeep Hunoor[1]*, Mr. Siddalinga Nuchhi[2]

Similarly for the irradiation also inputs are selected as low, medium and high. The range of input irradiation is selected as low for the range 50-350 watts/m^2 and medium is of the range 300-750 watts/m^2 and high for the range 700-1000 watts/m^2 . for selected values of input outputs will be trained.

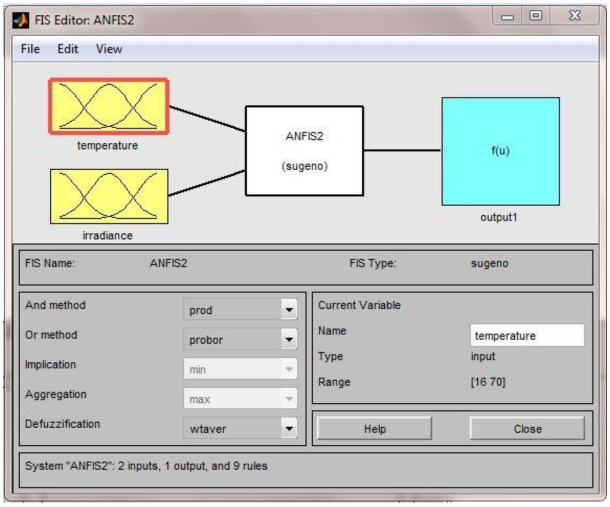


Fig 4.1 ANFIS editor window. (For Temperature membership function)

ANFIS editor window will be used for selecting the membership functions. In this window we can select no of inputs required and its associate outputs. The range of the input and outputs can be edited and can be used for the design of controller. In the above shown figure temperature membership function editing option is shown and its range is also specified. Range selected was 16 – 70 C^0.

Similarly irradiation and output membership functions and its ranges can be specified using ANFIS editor. Once if it is designed it should not be altered otherwise it will not produce desired output.

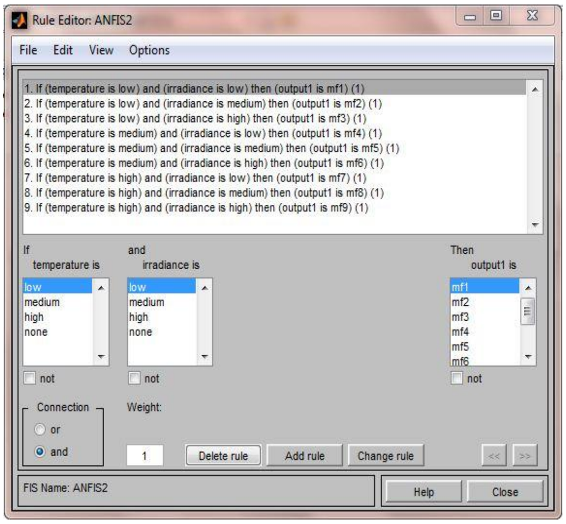


Fig. 4.2 Rule editor window.

Using rule editor window, rules can be constructed and edited as and when required during the design of controller. These are the set of statement which decides the overall operation and control of designed controller. Here the inputs and output are in linguistic values i.e. in simple English language so that it becomes very easy to edit and construct. It makes use of simple if and then statement which will enable designer to still easy to design and construct. For example rule one can be read as if temperature is low and irradiation is medium then output must be mf2 for which the value of output is already assigned. Likewise we can construct many rules as per the requirements of design.

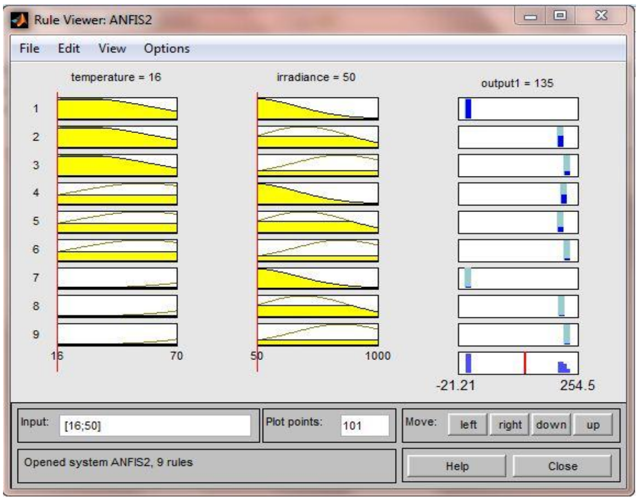


Fig 4.3 Rule viewer. (For the input temp=16 C^0 and irradiation=50 watts/m^2).

Above figure shows the rule viewer window in which we can observe the rules for any input combination. The ruler (red vertical line) can be moved and its associated output can be observed. For the above shown figure temperature is selected as 16 C^0 and temperature is selected as 50 watts/m^2. Output obtained will be 135 volts from the panel.

More filled portion indicates the high value and blank indicates the low values of input. Its associate output can be observed in the output window. For example rule number 8 can be read as if temperature is very low and irradiation is medium then output obtained is quite good.

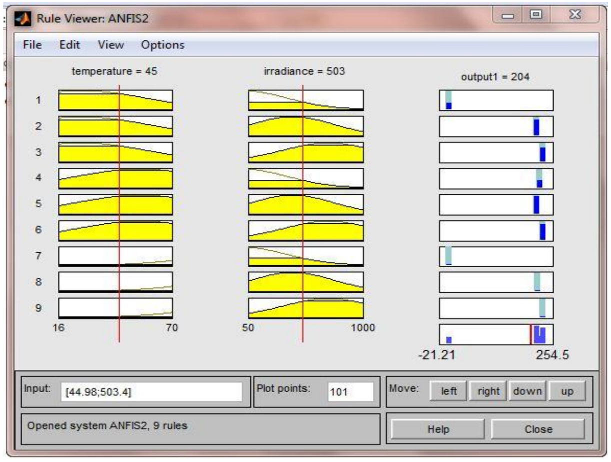


Fig 4.4 Rule viewer. (For the input temp=45 C^0 and irradiation=503 watts/m^2).

Above figure shows the rule viewer window in which we can observe the rules for any input combination. The ruler (red vertical line) can be moved and its associated output can be observed. For the above shown figure temperature is selected as 45 C^0 and temperature is selected as 503 watts/m^2. Output obtained will be 204 volts from the panel.

More filled portion indicates the high value and blank indicates the low values of input. Its associate output can be observed in the output window. For example rule number 8 can be read as if temperature is very low and irradiation is high then output obtained is high value of output membership function.

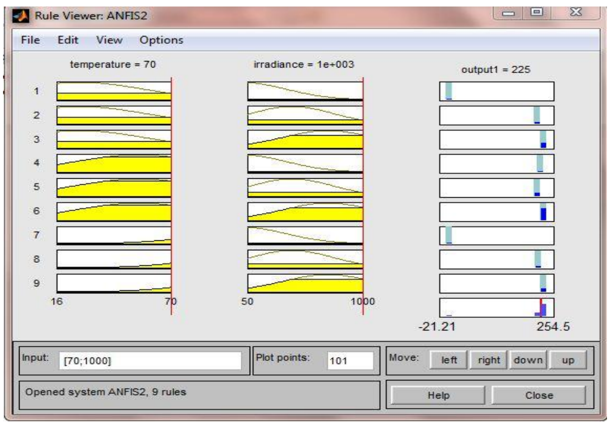
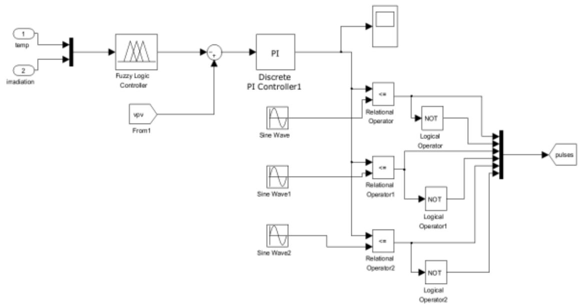


Fig 4.5 Rule viewer. (For the input temp=70 C^0 and irradiation=1000 watts/m^2).

Above figure shows the rule viewer window in which we can observe the rules for any input combination. The ruler (red vertical line) can be moved and its associated output can be observed. For the above shown figure temperature is selected as 70 C^0 and temperature is selected as 1000 watts/m^2. Output obtained will be 204 volts from the panel.

More filled portion indicates the high value and blank indicates the low values of input. Its associate output can be observed in the output window. For example rule number 8 can be read as if temperature is very low and irradiation is also low then output obtained is less value of output membership function

4.1 Simulation model for ANFIS controller



ANFIS (Adaptive Neuro-Fuzzy Inference System) is an artificial intelligent technique used to design the controller which can control the modulation index of VSI. For the design of controller Temperature and irradiations are used as input parameters. Controller will decide the modulation index of VSI depending upon the inputs and gives the maximum output. It provides a closed loop control to the output. And it continuously monitors the input and it changes dynamically the Modulation Index of VSI and acts as adaptive system.

The voltage obtained from the boost converter is then fed to the three phase voltage source inverter. The gating signals for the devices in VSI are obtained using ANFIS controller. The crisp value of output Vamp of the ANFIS controller [15] is compared with the output voltage of the boost converter. The output signal is given to the PI controller. A Proportional integral controller is a generic control loop feedback mechanism .The PI controller calculates the error value as the difference between the measured process variable (voltage) and a desired set point. The controller attempts to minimize the error by adjusting the process control outputs. The compensated signal from PI controller is given as the carrier signal for SPWM technique. The pulses obtained using SPWM are given to the three phase VSI and the desired voltage is obtained. Then it is given to the three phase ac load.

4.2 Output pulses by ANFIS controller.

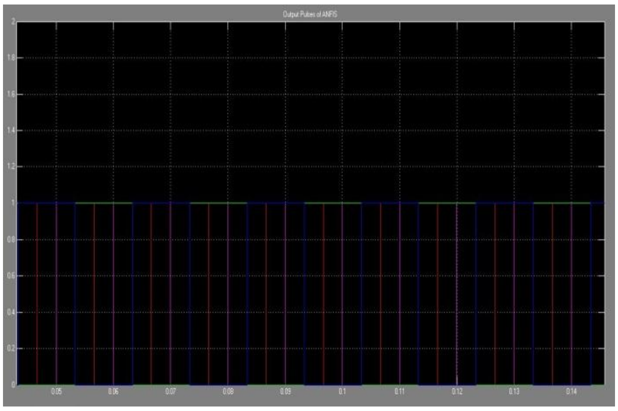


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Fig 6.9 shows the pulses generated from the ANFIS controller. Duty cycle of the pulses will change dynamically as input to the controller changes. These pulses generated by the controller are fed to the VSI to get distortion less output and to get maximum output.

5. CONCLUSION

This paper has suggested design steps for the ANFIS controller for the generation system to interface the solar power to the three phase ac load. The ANFIS controller has been implemented using MATLAB/SIMULINK software. The interface stage between the generation source and the load is accomplished by a boost converter and a voltage source inverter. voltage boost and inversion can be achieved using the proposed system. The simulation has been carried out in MATLAB/SIMULINK environment and the results have been produced.

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