Analysis of ABC Algorithm Based ANFIS Controller for PV Integrated Low Voltage Weak Grid System

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Abstract- As renewable energy technology demand increases, the PV system has received great attention. This paper analysis the Adaptive Neuro-Fuzzy Inference System (ANFIS) controller trained by Artificial Bee Colony algorithm (ABC) for grid-connected solar PV system which enhances the performances of the solar grid-connected system by providing constant power output with low disturbances. In this paper, the ANFIS control technique is tested on a single-phase single-stage grid-integrated PV topology with the nonlinear loads. The proposed system is modeled, and the simulation has been carried out in a MATLAB/SIMULINK environment.

Indexed Terms- Adaptive Neuro Fuzzy Inference System, Artificial Bee Colony algorithm, Solar and Grid integration, Maximum Power Point Tracking

I. INTRODUCTION

Always the natural resources played a very important role in the power generation area. Various resources such as Solar, Wind, Tidal, Geothermal, Hydro, etc., contribute to the power generation sector in various ways and the limited reserves of fossil fuels and global environmental concerns over their use for electric power generation have also increased the interest in the utilization of renewable energy resources. Nowadays, among renewable energy sources, the PV system gaining popularity, because it is environment-friendly, clean, produces no noise and requires less maintenance. The demand for solar energy is increased from 20% to 25% over the past 15 years and one survey said that solar energy provides around 5000 GW. Grid-connected solar energy reached 30 GW between 2015 and 2019. The Indian government had an initial target of 20GW capacity for 2022, which was achieved four years ahead of schedule. In 2015 the target was raised to 100GW of solar capacity (including 40GW from rooftop solar). Thus the role of solar energy in the production of electricity is growing day by day. The electric power generation using PV system is greatly affected by the weather conditions; the system must be designed and constructed to operate efficiently so as to ensure a stable and continuous electrical power supply without depending on the weather conditions. To achieve this and to optimize the tracked PV efficiency, a Maximum Power Point Tracking (MPPT) system is required. In addition, the success and robustness of the solar PV power generation (SPVPG) depend on the control technique, which integrates the SPVPG system to the grid as well as maintains the power quality. Power quality means it ensures reactive power compensation, power factor correction, harmonics filtering and mitigation of other power quality issues. Moreover, when solar irradiation is zero, then the DC link capacitor and VSC (Voltage Source Converter), act as a DSTATCOM, which enhances the utilization factor of it. Therefore, all responsibilities are on the control technique.

II. DESIGN METHODOLOGY

The system design consists of solar panel, single phase inverter, ANFIS control, Boost converter, single phase AC loads and electrical grid. The DC voltage generated by the solar is passed to the inverter through the boost converter where the DC output voltage is boosted to the value which can drive the inverter. Then the DC voltage is converted into the AC voltage and connected to the common AC link where the power is supplied to the load or to the grid, after passing through the inverter. The inverter converts the single phase DC to the single phase AC. By controlling the MPPT controller, we can track the MPP of a PV system. By controlling the inverter, the constant output voltage can be obtained and it is injected into the grid efficiently and safely. These controls are achieved by the ANFIS controller which is trained by the ABC algorithm (optimization algorithm). It is shown in the figure 1.

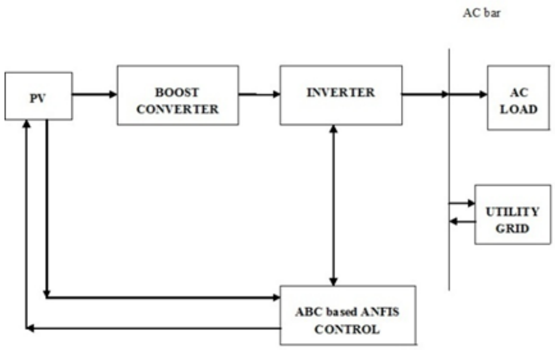

Figure 1: Proposed system design

The prime objective is that first fulfils the load demand and, after satisfying the load demand the rest power is supplied to the main grid and vice versa. To attain this, PV panel should work with full efficiency. This is controlled by the controller and in addition, in this process, the responsibilities of the control technique are power conversion from DC to AC, to follow the grid code for synchronization to the grid, improvement of power quality of the supply power, to act as a DSTATCOM (Distribution Static Compensator) when solar irradiation is zero, and power management. Moreover, during this process, power quality is improved at the grid; it provides power factor improvement, reactive power support, harmonics filtering and mitigation of other power quality issues.

III. PV SYSTEM

In Figure 2, the PV cell equivalent circuit is depicted. Characteristic of one solar array is reported as following equation:

$$I = IL - I0[\exp\left(\frac{V + RsI}{Vn}\right) - 1] - \left(\frac{V + RsI}{Rsh}\right)$$

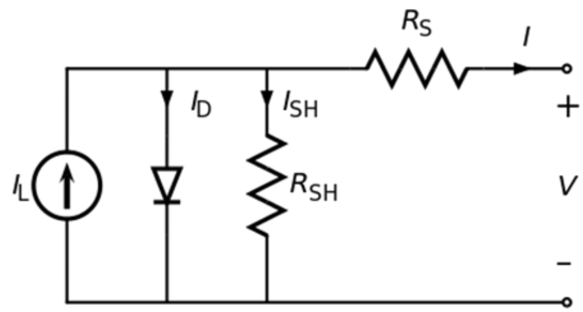

Figure 2: Structure of PV System

Where, I represents the photovoltaic current, V represents the photovoltaic voltage, Ipv is the light generated current, the ideality factor can be represented by n, Rsh and Rs are the parallel and series resistance. Vth is the thermal voltage of diodes. The name-plate details are reported in Table 1.

Table 1 (PV Panel design)

I_{MP} (Rated current)	8A
V_{MP} (Rated voltage)	35V
P_{MAX} (Rated power)	280W
V_{OC} (Open circuit voltage)	45V
I_{SC} (Short circuit current)	8A
N_P (Parallel cells number)	50
N_S (Series cells number)	8

Where,

- I_0 = Output Current
- I_l = Photo generated Current
- I_d = Diode Current
- I_{sh} = Shunt Current
- I_S = Series Current
- V = Voltage across the output terminals

Here the mentioned PV system was connected to the utility grid through the inverter which is controlled by the ANFIS controller.

IV. ANFIS

ANFIS is a hybrid artificial intelligence algorithm created by combining learning ability of neural networks and inference feature of fuzzy logic. ANFIS structure contains input-output data pairs in fuzzy inference system and IF-THEN rules. ANFIS is trained by using the existing input-output data pairs for the solution of available problems. Thus, ANFIS is used since it enables artificial neural networks to be benefited from expert opinions in many estimation problems. Structure of ANFIS consists of five layers. These layers are explained below:

Layer 1: This is known as fuzzification layer. This layer consists of an adaptive node with a node function. We have:

$Q1, i = \mu Ai(x) \quad \text{For } i = 1,2 \ldots (1)$
$Q1, i = \mu Bi - 2(y) \quad \text{For } i = 3,4 \ldots (2)$

Output of this layer is its membership value. Membership functions for A can be any proper parameterized membership function. Each parameter is regarded as a default parameter.

Layer 2: This is known as Rule layer. And this layer has been called with an "n" and the output of each node is the product of multiplying all incoming signals for that node. These nodes perform the fuzzy AND operation, and we have:

$Q2, i = wi = \mu Ai(x)\mu Bi(y)$
$\text{for } i = 1,2 \ldots (3)$

Layer 3: This is known as normalisation layer. Each node in this layer has been labelled with an "N". Nodes calculate the normalized output of each rule. Then we have:

$Q3, i = wi2 = \frac{wi}{W1+W2} \quad \text{for } i = 1,2 \ldots (4)$

Layer 4: This layer is known as defuzzification layer. Each node in this layer is associated with a node function. Then we have:

$Q4, i = wifi = wi(pix + qiy + ri) \quad (5)$

Where, Wi represents the normalized firing strength of the third layer and {pi, qi, ri} are parameters sets of the node i.

Layer 5: This is known as summation layer. The single existing node in this layer is labelled as Σ. It computes the sum of all its input signals and sends them to the output section.

$$Q5, i = \sum wifi = \frac{\sum Wifi}{\sum Wi} \qquad (6)$$

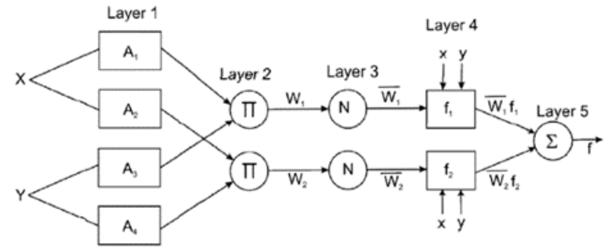

Figure 3: Structure of ANFIS

Where, Q5i is the output of the node (i) in the fifth layer. For this reason, first, all existing rules will be established in the layer 1. For example, if we have two inputs, each of which has three membership functions, then we must form 9 rules. This is shown in Figure 3.

V. ABC algorithm

Artificial Bee Colony (ABC) is one of the most recently defined algorithms motivated by the intelligent behavior of honey bees. ABC as an optimization tool provides a population-based search procedure in which individuals called foods positions are modified by the artificial bees with time and the bee's aim is to discover the places of food sources with high nectar amount and finally the one with the highest nectar. Here it is used to train the ANFIS controller to obtain a better solution.

Steps of ABC

The main steps of the algorithm are given below..,

STEP-1: Initial food sources are produced for all employed bees

STEP-2: REPEAT

In this process, each employed bee goes to a food source in her memory and determines a closest source, then evaluates its nectar amount and dances in the hive. Then each onlooker watches the dance of employed bees and chooses one of their sources depending on the dances, and then goes to that source. After choosing a neighbor around that, she evaluates its nectar amount. After that, the abandoned food sources are determined and are replaced with the new food sources discovered by scouts. And finally, the best food source found so far is registered.

STEP-3: UNTIL (requirements are met)

VI. SIMULATION RESULTS

The simulation model of the proposed ABC based ANFIS controlled grid connected PV system is developed using the MATLAB and it is shown in figure 4.

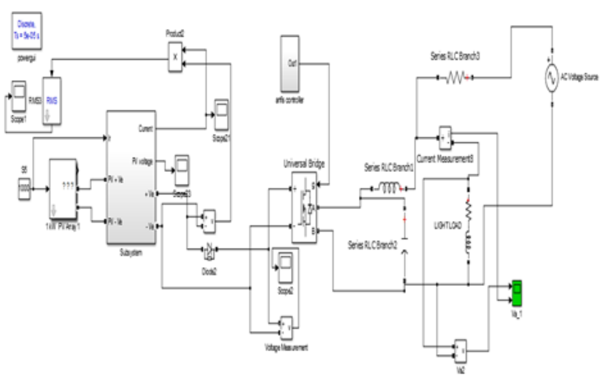

Figure 4: Simulation model of the system

PV system used to supply the load or grid through the inverter and it is controlled by the ANFIS controller. In this work single phase RL load is connected to the system for testing purpose. During integration, for PV power conversion into AC form, load feeding, and synchronization, a single-phase VSC is used. The RC filter and interfacing inductor are used for harmonics and switching ripples mitigation. ANFIS controller is trained by the proposed ABC algorithm to obtain better PV output and fault free grid synchronization. The controller used to extract the maximum power output from the PV panel which is shown in the below simulation model of the proposed controller for MPPT tracking (Figure 5) and output waveform (Figure 6).

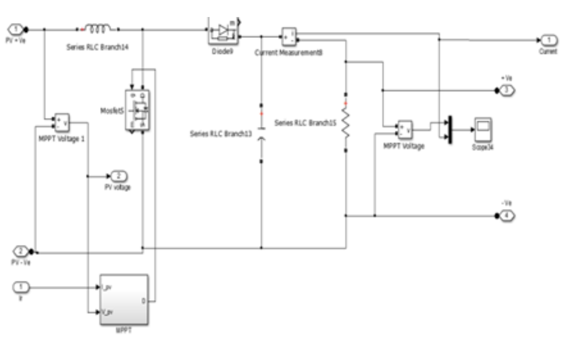

Figure 5: Subsystem (MPPT) model

The subsystem contains the MPPT control with boost converter. The Maximum power is tracked irrespective of change in irradiance of solar by the ANFIS control. The output is viewed from the scope block. The rating of PV panel used is V_{OC}=44.4999V, I_{SC}=8.199A, V_{MP}=35V and we attain the maximum power irrespective of weather conditions with the help of MPPT control technique.

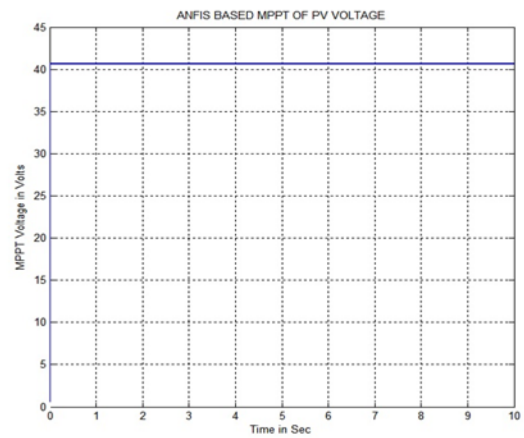

Figure 6: MPPT output

The successful grid integration means it should match the phase of the grid and maintain the same voltage profile of the grid with fewer oscillations. It is achieved by the proposed controller. By the figure 7, we knew that the controller achieved the secured grid integration with no outages.

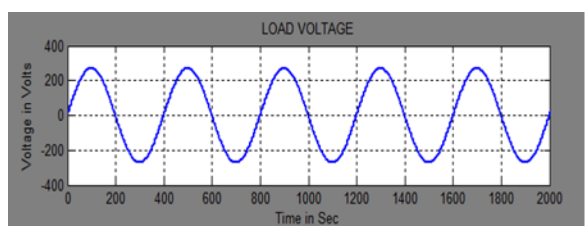

Figure 7: Load output

VII. CONCLUSION

A novel approach of ANFIS controller which is trained by the optimization algorithm for grid integrated solar PV system has been developed using MATLAB/SIMULINK software. This single layer ANFIS structure has a very simple architecture and it is trained by Artificial BEE Colony algorithm easily which reduces the computational burden. Therefore, it is easy in implementation. The interface stage between the PV source and the load is accomplished by a boost converter and a voltage source inverter. ANFIS controller gives the maximum power output from the PV by controlling the MPPT and it gives the constant output voltage to integrate the PV with the grid safely and efficiently. Thus the performance of the PV integrated low voltage grid system was improved. In addition, the utilization factor of the system was improved by enabling the system as DSTATCOM. The simulation has been carried out in MATLAB/SIMULINK environment and the results have been produced.

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