A Control System Used to Improve Energy Production from Alternative Sources with DC/DC Integration using ANFIS

BINCY.B.BABU, N.R.NAHARAJ, Dr.S.S.SIVARAJU
Bincy.asn@gmail.com

Abstract - **Electricity is one the most essential needs for humans. Conversion of solar energy into electricity not only improves generation of electricity but also reduces pollution due to fossil fuels. Various renewable sources such as solar energy, wind energy etc are the sources of power generation. Solar Energy is a good choice for electric power generation. The Earth receives 174 petawatts (PW) of incoming solar radiation (insulation) at the upper atmosphere. About 30% is reflected back to space while the rest is absorbed by clouds, oceans and land masses. The solar energy is directly converted into electrical energy by solar PV module. The output power of a PV panel array depends on the PV voltage and weather conditions. The ratio between output power and cost, DC/DC converters are used to obtain maximum power from the PV panel array using MPPT.**

Key words- **ANFIS, MPPT, VSI**

I. INTRODUCTION

Solar energy is the radiant light and heat from the sun, is harnessed using a variety of ever-evolving technologies such while solar heating, PV, concentrated solar powered energy, solar architecture and unnatural photosynthesis. MPPT algorithms are necessary in PV applications because the MPP of a solar panel varies with the irradiation and temperature, so the use of MPPT algorithms is required in order to obtain the maximum power from a solar array. Over the past decades many methods to find the MPP have been developed and published. These techniques differ in many aspects such as required sensors, complexity, cost, range of effectiveness, convergence speed, correct tracking when irradiation and/or temperature change, hardware needed for the implementation or popularity, among others.

The nature of Fuzzy control is non-linear and adaptive and it is a practical alternative for a variety control applications. The concept of Fuzzy Logic (FL) was conceived by LotfiZadeh, a professor at the University of California at Berkley. According to him, it not as a control methodology, but as a way of processing data by allowing partial set membership function rather than crisp (figure-1). There are four main elements in the fuzzy logic controller system structure named as: Fuzzifier, Rule base, Inference engine and defuzzyfier.

II. SYSTEM DESCRIPTION

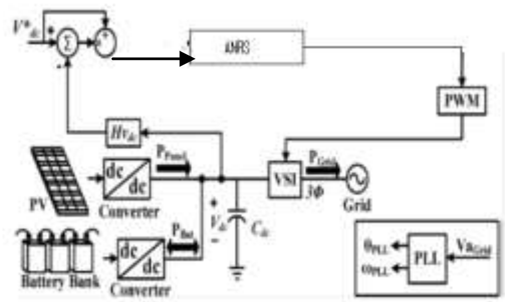

Fig 1: ANFIS based controller structure

A neuro-fuzzy technique called Adaptive network based fuzzy inference system (ANFIS) has been used as a prime tool in the present work. Adaptive network based fuzzy inference system (ANFIS) is a neuro fuzzy technique where the fusion is made between the neural network and the fuzzy inference system. In ANFIS the parameters can be estimated in such a way that both the Sugeno and Tsukamoto fuzzy models are represented by the ANFIS architecture.

Artificial intelligence systems which can make decisions like humans by adapting themselves to the situations and taking correct decisions automatically for future similar situations. Neural networks, fuzzy systems, and neuro-fuzzy systems are the examples of the artificial intelligence systems. The concept of fuzzy systems was described by Zadeh using fuzzy sets in 1965. The primary mechanism of fuzzy systems is based on conditional if-then rules, called fuzzy rules, which use fuzzy sets as linguistic terms in antecedent and conclusion parts. A collection of these fuzzy if-then rules can be determined from human experts or alternatively can be generated from observed data. The main advantage of such fuzzy systems is the easiness to interpret knowledge in the rule base. Neural networks are the systems that get inspiration from biological neuron systems and mathematical theories for learning. They are characterized by their learning ability with a parallel-distributed structure and also can be considered as black box modeling.

It is constituted of solar PV module, DC-DC boost converter, and ANFIS reference model. In this method the voltage from the PV module is step up using DC-DC converter. The voltage from the DC-DC converter in DC IS converted to AC using Inverter and given to grid. In order to regulate the voltage at the grid an ANFIS controller is used where the potentials of all the input output data points are calculated as functions of their Euclidian distances from all the other data points. The points having a potential above a certain preset value are considered as cluster centers. After the cluster centers are ascertained the initial fuzzy model can be subsequently extracted as the centers will also give an indication of the number of linguistic variables. The cluster estimation method for determining the number of rules and initial rule parameters is briefly described below. Irradiance level and operating temperature are taken as the input for the ANFIS .The ANFIS reference model gives out the crisp value of maximum available power from the PV module at a specific temperature and irradiance level. The actual output power from the PV module, at same temperature and irradiance level, is calculated and the error is given ANFIS to generate control signals. The control signal generated is given to the PWM generator. The generated PWM signals control the duty cycle of DC-DC boost converter, in order to adjust the operating point of the PV module.

ANFIS is capable of developing the input-output mapping of training data sets when it is trained with sufficient number of epochs. By adjusting the values of membership functions, ANFIS generates the set of fuzzy rules in order to produce appropriate output for different values of inputs. Parameters of membership functions are adjusted or changed till the error is reduced to minimum value. Once all the parameters of membership function are adjusted . The DC-DC boost converters are used to convert the unregulated DC input voltage, supplied by PV modules, to a controlled DC output at a higher voltage level required by the loads in Fig4.2. They generally perform the conversion by applying a DC voltage across an inductor for a period of time (usually in range of 20 kHz to 5 MHz) which causes current to flow through it and store energy magnetically, then switching this voltage off and causing the stored energy to be transferred to the voltage output in a controlled manner.

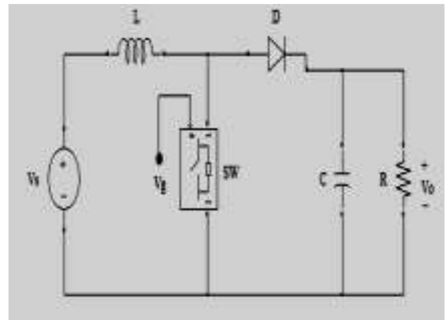

Fig 2: Boost converter

(i) Selection of the inductor (L).

Large inductance values tend to increase the start-up time slightly while small inductance values allow the coil current to ramp up to higher levels before the switch turns off. Boost inductance is selected based on the maximum allowed ripple current at minimum duty cycle, D and at maximum input voltage, Vs. The boost converter operates in the continuous conduction mode for value of inductance L $>L_b$ in equation 1

$$L_b = \frac{(1-D^2)\times D}{2f_s} \qquad (1)$$

Where, L_b is the critical inductance, defined as the inductance at the boundary edge between continuous and discontinuous modes of converter; R is the equivalent load and $f_s$is the switching frequency of IGBT.

A .SYSTEM DESIGN

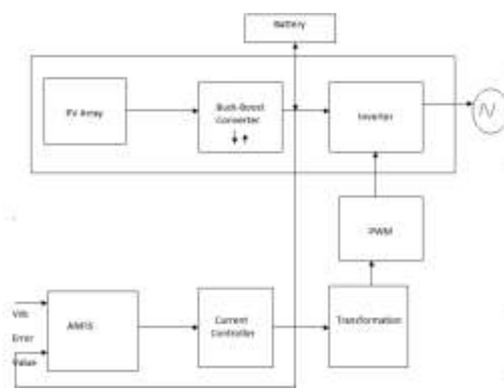

Fig 3: Block Diagram

The inverter will be connected to ANFIS to regulate the DC link voltage. Battery will be also connected to maintain the voltage level in battery .The output from PV, temperature and irradiance level will be compared and given to ANFIS. The reference voltage and error value will be given as input to ANFIS. The current controller controls the voltage and given to transformation and PWM for removing the error in pulses.

Then voltage will be given to inverter and to Grid. ANFIS is capable of developing the input-output mapping of training data sets when it is trained with sufficient number of epochs. By adjusting the values of membership functions, ANFIS generates the set of fuzzy rules in order to produce appropriate output for different values of inputs. Parameters of membership functions are adjusted or changed till the error is reduced to minimum value. Once all the parameters of membership function are adjusted, the ANFIS model becomes learning model which is ready to be used in MPPT control scheme. But before using ANFIS learning model for MPPT control, its results are checked by using checking data which is different from training data. Again if error produced is more than desired value, parameters of membership functions are adjusted to bring down the error. DC-DC boost converter is designed to be placed between solar PV module and load in order to transfer maximum power to load by changing duty cycle of dc-dc boost converter.

B. DESIGN OF ANFIS

Mat lab/Simulink model of PV module is used to generate the training data set for ANFIS by varying the operating temperature in steps of 5°C from 15°C to 65°C and the solar irradiance level in a step of 50 W/m2from 100 W/m2to 1000 W/m2. For each pair of operating temperature and solar irradiance, maximum available power of PV module is recorded. Thus in total 209 training data sets and 2000 epochs are used to train the ANFIS reference model. The training error is reduced to approximately 6%. ANFIS constructs a fuzzy inference system (FIS) by using input/output data sets and membership function parameters of FIS are tuned using the hybrid optimization method which is a combination of least-squares type of method and back propagation algorithm.

It is a five layer network with two inputs (irradiance level and operating temperature) and maximum power as one output. Each input parameter has three membership functions which are learned by ANFIS method. According to input output mapping of data sets, nine fuzzy rules are derived so as to produce maximum output power for each value of input temperature and irradiance level. The ANFIS surface depicts that the maximum available power of solar PV module increases with increase in irradiance level and moderate temperature which verifies the non-linear behavior of PV module.

III. SIMULATION RESULTS

In the Fig 4 it shows the PV voltage variations during the simulation.

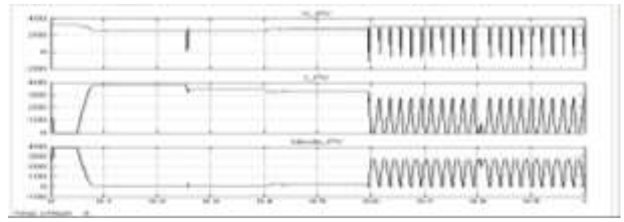

Fig 4 :PV Voltage

In Fig 5 it shows the second bus voltage obtained during the simulation.

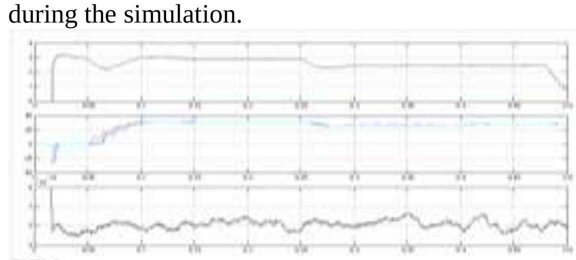

Fig 5: Second Bus voltage

Fig 5 shows the simulation result seen in fourth ,second and first bus connector respectively. Here in Fig 6 it shows the maximum power obtained.

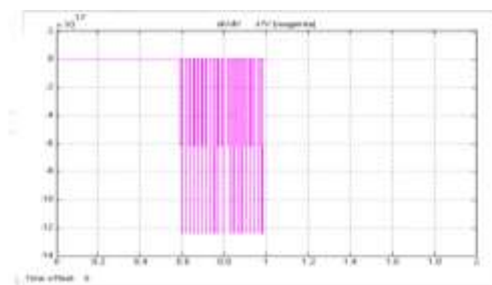

Fig 6: MPPT

In Fig 7 it shows the Grid voltage, the maximum voltage obtained during the experiment.

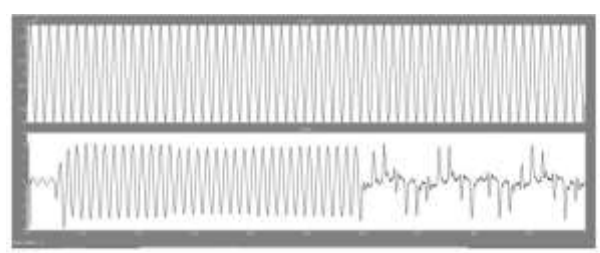

Fig 7: Grid voltage

In the Fig 7 it shows the current variations in Boost converter are in terms of power, output voltage, duty cycle and irradiance.

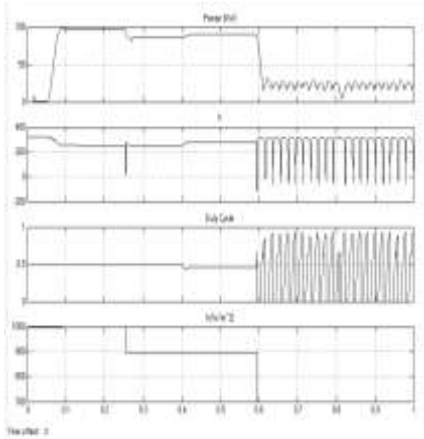

Fig 8 : Boost converter output

In Fig10 it shows the inverter voltage.

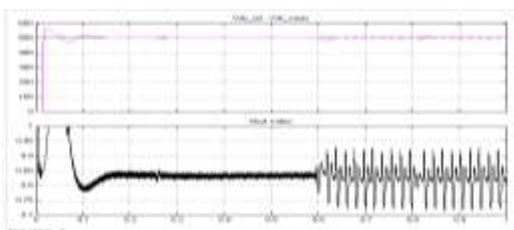

Fig 10 : Inverter voltage

In the Fig 10 it shows the bus voltage. The value will range upto 450volts.

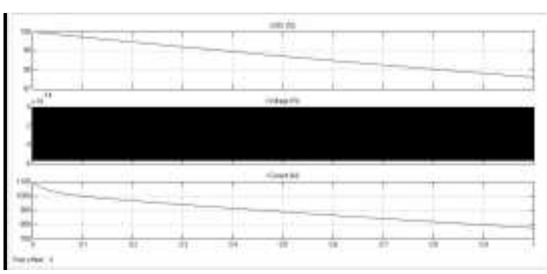

Fig 11: Battery voltage

In Fig 12 it shows the harmonics level, here it shows that harmonics level is reduced to 0.33%.In the existing system harmonics level is 3%.In proposed system it reduced to 0.33%.

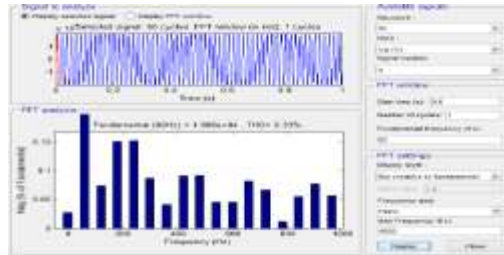

Fig 12: Harmonics level

IV. CONCLUSION

In this paper, design and implementation of ANFIS control scheme for boost converter is presented. The simulation is done using MATLAB software package and the operation is investigated. Simulation results reveal that ANFIS control scheme is effective and efficient to track maximum available power from PV module. ANFIS control scheme is significantly fast. The Harmonic level has decreased to 0.03% from3%. Output power has better efficiency and can obtain constant output. The rate of charge stored in the battery is increased. The charging and discharging is more efficient. The irradiance of the battery will be low.

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