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A Neuro-Fuzzy Approach based MPPT for Mutli-Junction Photo-Voltaic Arrays

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Abstract*— Photovoltaic cells have been there in the energy sector for a very long time now. But, only recently have they seen extensive utilisation in terms of commercial aspects. The recent advancements in the technology and the reduction of fossil fuel resources have further contributed to the cause. But still, there lies several challenges to it. One of the major obstacles in this field is to detect the highest power output from cell. High Peak Power Transfer methods can be projected in the literature for same. Perturb and Observe and Incremental Conductance etc are some to name a few. This paper focuses on a novel approach of utilising a neuro-fuzzy approach to solve the MPPT problem in multi-junction photo-voltaic cell. The multi-junction photovoltaic cell was assumed to provide better output in terms of voltage.
***Keywords*—component; formatting; style; styling; insert (key words)**

I. INTRODUCTION

Nowadays, consumption of energy is increasing, idea of exploring renewable energy sources are also growing. Due to our limited energy sources, renewable energy sources are the future. Significant processes are made over the later years in development and research of [1] the renewable power systems such as sea, wind, solar energy and wave systems. With these resources, the sun power energy can be used nowadays as most reliable, and environmental friendly energy source. Although sun power energy systems can be suffer with high costs and low efficiencies. To control these problems, maximum power can be extracted from PV panel while using the MPPT methods to optimize an efficiency of all the PV system. The photovoltaic technology can be made attractive option because the features various merits like as low maintenance requirement, [2] environmental friendliness and absence of fuel cost. The efficiency of energy alteration in a PV generation arrangement may low down because sun power cell exhibits to the nonlinear voltage and current and power versus voltage characteristics. These nonlinear characteristics hold weather functions conditions like as panel hotness and solar insolation. This is used to sustain the maximum power point tracking algorithm, proficient operation which can give quick reaction and pull out the [9] maximum power from PV arrays in the real time becomes significant in PGSs. The multi-junction solar cells can be supposed to provide better efficiency as opposed to their single junction counterparts. Neuro-Fuzzy based algorithm is designed utilising Neural behaviour and fuzzy logic. The firing angle's optimal value is calculated and fed to the Boost converter. In this paper a novel Adaptive Neuro-Fuzzy Inference System for Maximum Peak Power Transfer technique for multi-junction solar cells is proposed. The results are compared to that of an incremental conductance technique and it is found that ANFIS based MPPT performs quite better than its other counterparts in terms of transient state and the magnitude of voltage obtained.

II. SYSTEM MODELING

A. Operating of cell

Photovoltaic cells area unit those devices which may absorb the daylight and convert into the power. These star cells could also be unremarkably created with the chemical element that's most precious components on the world. [3] The silicon is pure and actual poor conductor of the electricity that contains four outer valence electrons kind the tetrahedral crystal lattices.

The made lepton clouds area unit the crystalline sheets that are stressed to incorporate the trace amounts of the components that have three or five shell outer electrons that may alter the electrons to maneuver. These nuclei components match at intervals crystal lattice, but the only three shell outer electrons, that have few electrons to the balance out, and "positive holes" float with the lepton [4] cloud.

B. Multi-Junction cell

These multi-junction star cells are often found within the 2 configurations in series/tandem or in parallel. For these thin-film star cells with hetero-junctions, for the improved performances all layers [5] contain the lattice constants/ crystalline structures.

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Moreover, the discontinuities in lattice constants area unit result in dislocations or defects at interface which will be most well-liked to the recombination sites. In parallel configuration that is termed the multi-terminal bicycle for every cell which will be optimized severally, however whole system are often a lot of difficult. Moreover, [7]series/ bicycle of star cells are often used; that consists of the distinct tangency of sun power cells that area unit set one when alternative one, each utilised half of star spectrum could permit to the passage through alternative part. The star cells area unit high larger [11] band gap that the parameter is often shrivelled increasingly in followed cells.

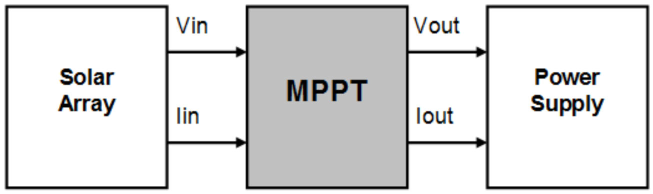

Figure 1: Block diagram of MPPT

Various MPPT strategies are acceptable for the fast dynamical environments which are square measure projected in every analog and digital form. The discussion is concerned to merits and demerits of the analog MPPT ways can be presented [1] in the TrishanEsram and Patrick (2011). From analog MPPT ways give faster response than digital as a result of metric of analog loop may larger. However, most analog MPPT ways are required for analog multipliers which are the unit of power-consumption and measurement expensive. On opposite hand, various low-cost power microcontrollers approach with integral hardware digital multipliers unit of the dimension out from IC vendors such as TX Instruments and micro chip. Therefore, digital execution of the MPPT has been well acknowledged in the medium and high power PV systems digital controllers unit of the measurement normally used. More so, digital implementation allows some options such as user interfaces and protection modes. Some researchers are worked on the digital MPPT schemes that are satisfactory for rapid dynamical environments.

Several current ways of the resolution MPPT draw back unit of measurement wide worked in the trade. An algorithmic rule has named perturb and observe MPPT methodology [2]. The methodology can be utilized additional perturbance component among current and voltage array to the constantly check if or not the system has get the nominal current or voltage price. If voltage can be changed to offer the direction per turbance and thus power output can be hyperbolic synchronic, that can be suggested the electric receptacle is attained with further such perturbance for voltage; on opposite hand, if facility output decreases with constant voltage perturbance that implies to the electric receptacle that can be found the current or voltage. The PO MPPT algorithmic rule must implement at an inexpensive worth, which has a constant technique that uses the oscillations to trace the most electric receptacle system which is already among steady state. The underlying issue results of Perturb & Observe MPPT may be hard to acknowledge the provision of the perturbance throughout system operational. Sometimes, the perturbance is the atmosphere modification and generally, the inherent generated perturbance. The result of noise or perturbance constantly that existed among the system, Perturb & Observe system can never be stable at the value.

In Hung-I Hsieh, Jen-Hao Hsieh, [3] voltage-based MPPT current-based MPPT approaches unit of the measurement is presented. Every unit of measurement can be simple and fast. Hence, these ways can track the low efficiencies for low irradiation levels. In this, K.H. Hussein (2004), a strategy has been projected supported to the analysis and derivation of the I–V characteristics of PV panel by [4] natural exponent index. This process offers the closer track speed than eminence of hill-climbing methodology, the used index is exclusively too complicate for total calculation exploitation in an economical 8- or 16-bit lC. In C.Thulasiyammal, MPPT management rules unit of the measurement can be supported the forecast line which links the MPP and optimum current. One of the parameter got to be non-inheritable through hill-climbing methodology that generates [5] commercially impractical. Noppadol Khaehintung and Phaophak Sirisuk (2008) extended previous analog RCC method to the digital domain for MPP track. The projected digital implementation could be plenty of versatile, smaller quantity expensive, ton of durable quite such as analog RCC methodology, inductive and physical phenomenon parasitic elements may have impact on the facility of RCC to drive system toward being MPP. To subsume the exchange between the steady-state performance and so the speed of track, C. S. Chin, P. Neelakantan, et al. (2011)steepest descent methodology, [6] variable step-size ways, parabolic prediction technique and FLC-based approach square measure projected for MPP.

These ways can display the faster dynamic response power tool to steady state than the normal MPPT algorithms. Though, traditional ways can be utilized to output samples a couple of steady-state set points to work out the progressive price of the

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management variable. As a result, operational purpose can be organized system ought to expect all transients to be settled before recording the data. Therefore, track speed of ways has been restricted to the dynamics of system. In quest of controller can be projected [7] in Panom Petchjatuporn, Phaophak Sirisuk, et al., et al. (2010) speedy supply convergence and sensible [] steady-state presentation with the protected stability for number of parameters. The quite RCC methodology, E controller has been desired voltage and current ripple data, that unit of the measurement only few years of typical current and voltage. Consequently, lofty resolution analog to digital convertor has been essential to augment the worth of system. A a lesser amount of complicate manner of the track MPP comes in the course of estimation technique to hold offline module characterization. In S. Yuvarajan and JulineShoeb (2008), link between the [8] values of panel current and voltage at MPP can be used to accelerate speed of the MPPT algorithmic rule. The conception is shown in Prof.Dr.IlhamiColak (2011) is extended to the digital sphere of influence [9]. The displayed methods model nonlinear I–V characteristics of device exploitation numerical approximations. To improve the polynomial interpolation, track efficiency procedure is to imitate MPP locus. A pair of emulation outcome – piecewise line isometric and segments equation – unit of measurement won't to correct model MPP locus.

The S. G. Tesfahunegn et al. proposed the progressive physical phenomenon algorithmic rule (INC) [10] position to the most electric receptacle, per link between facilitate versus voltage, where the derivation of power with voltage can be ideally adequate zero. Various literatures are reported of robustness performance with the worth of code quality and hardware. As matter of reality like as condition can not be specific fulfilled because of division errors and noise live error. Meanwhile, Yuncong Jiang, Ahmed Hassan et al. INC algorithmic rule to boot can increase computation time of the MPPT algorithmic rule. [11] Besides the Perturb & Observe and so the INC algorithms, there unit of measurement many various advanced algorithms square measure addressed, like formal logic and so neural network-based algorithms. These ways unit of measurement acceptable for resolution certain specific problems; however, ArashShafiei et al. the idea of the system is irresistibly [12] sophisticated among code and hardware construction of device. Once the foremost electric receptacle is obtained, the correlation can be adequate zero. RCC methodology copes with several drawbacks of different algorithms. Multiple advantageous choices of the RCC, to the alternative given ways square measure mentioned and generalized in literature [12].

C. THEORY OF CELL

The problem of drawing maximum power from solar panel which is to be solved using MPPT technique and improvement algorithm needs to be formulated so better performance. The basic equation can be described mathematically the IV characteristic of PV cell is

$$I_{pv} = I_g - I_S\left(\exp\left(\frac{q(V_{pv} + I_{pv} \cdot R_S)}{nkT}\right) - 1\right)$$

Where, n can be ideality factor, q is electron charge, k can be Boltzmann's constant, T can be temperature in the Kelvin, RS the equivalent series resistance and Ipv, Ig and Is make the panel current, photo generated current, and saturation currents, respectively.

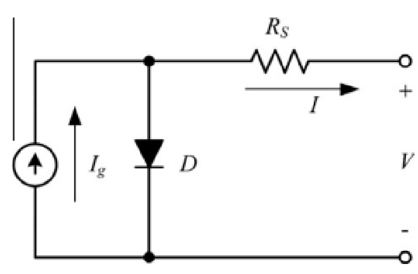

Figure 2: Equivalent circuit of PV cell

In this, MPPT algorithm routine can be calculated in dynamic and static ways; static MPPT competence can depict the ability of MPPT algorithm to unearth and hold the MPP under unvarying environment conditions, where as dynamic MPPT efficiency has been distinct and the ability in tracking MPP to assume about the environmental conditions. The static MPP tracking efficiency gSTATIC is shown as

$$\eta_{STATIC} = \frac{P_O}{P_{MAX}} \times 100\%$$

Where, PO is an average output power that can be attained under the steady state and PMAX may the utmost power of the PV panel which is beneath the definite environmental conditions.

III. OBJECTIVES

The problem has to be solved using Modified Firefly algorithm and PSO technique. An algorithm for the improvement of the same needs to be designed. The major objectives of the thesis can be listed as:

A. Analysis of the several algorithms used for MPPT technique used in literature

B. Development of MATLAB/SIMULINK model for application of different approaches for MPPT.

C. Development of a Neuro-Fuzzy algorithm and application of the developed ANFIS algorithm for improvement of MPPT technique.

D. Comparison of result with Incremental Conductance approach.

IV. PROPOSED METHODOLOGY

In this proposed methodology, we use ANFIS model to improve the MPPT technique. This model can be simulated in algorithm that can implement and control the included load.

A. Multi-Junction Solar cell model

First of all Multi-Junction Solar Cell can be designed by combination of characteristics of PV cell.

B. ANFIS

Adaptive control and neuron fuzzy control are both highly developed methods intended for time-varying and non-linear process. Nonlinear systems and linked control issues which will be then momentarily reviewed. Neural network and fuzzy model is explained as universal structures for reminiscent of non-linear functions and dynamic procedures. On basis of the evaluation of the two methods, neuron fuzzy model will be proposed as a promising skill for the control and adaptive control of nonlinear processes.

All computations can be presented in a diagram form. ANFIS normally has 5 layers of neurons of which neurons in similar layers have same working function family.

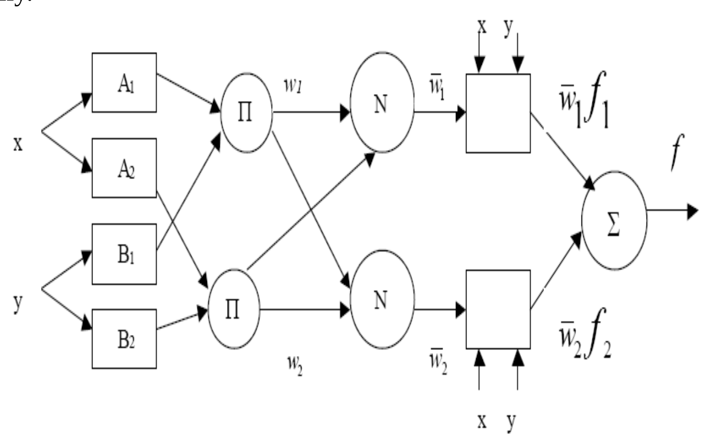

Figure 3: Structure of the ANFIS network

C. Initial Inference in ANFIS

Initial inference is found in ANFIS for creating membership function using k-Means clustering which is simple and has nice convergence but there are some problems with this. Complexity is more in comparison with others and performance of the algorithm degrades when the higher dimensions. In our work we use density based improved k-Means clustering algorithm. Density based improved k-Means clustering algorithm performs very well as compared to others. It provides initial inference for different membership function.

Algorithmic steps for applied density based improved k means clustering algorithm

1) Determine the centroid points randomly.
2) Calculate the Euclidean distance of each data point.
3) Calculate centroid of each cluster.
4) Maintain table of density around each data point.
5) Use initial inference provided by density based k means clustering algorithm for different membership function.

D. *Learning Approach*

Gradient Learning Algorithm is utilised in our methodology which works on the principle of learning based on the sign and magnitude of the slope of the curve to be predicted. One is required to move in the direction opposite of the steepest descent and the steepest descent path is followed. The minimum of the function f(x,y) may be found starting at initial point using the gradient learning method. In this method one can move in oppose direction of starting gradient unless the f(x,y) can stop the decrement which become the level along with direction to the travel. In this, stop point makes the beginning point where ∇f has re-evaluated and newest direction has been followed. This process will repeat until bottom will be reached.

V. RESULTS

All the results have been simulated on 4 GB RAM, 2.7 GHz processor based system using MATLAB R 2013b. The whole model is described below.

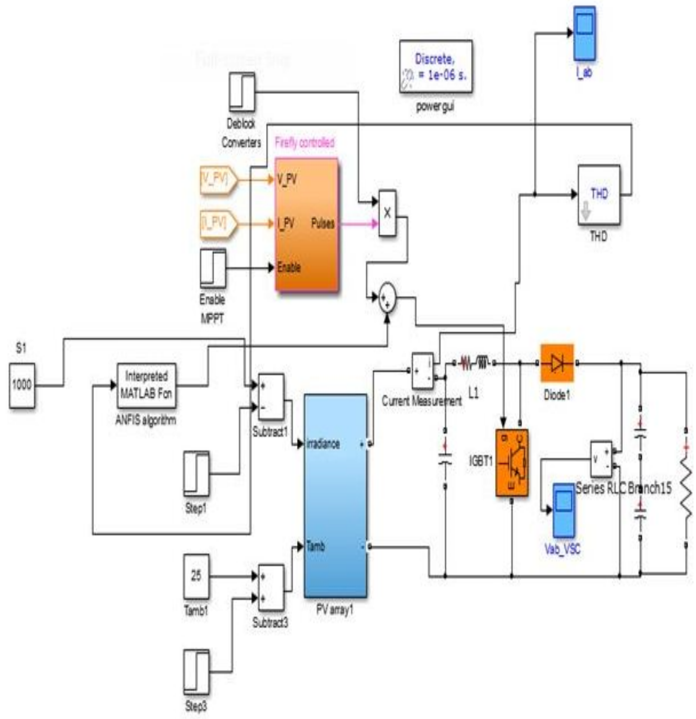

Figure 4: MATLAB/SIMULINK model of ANFIS based technique

The photo-voltaic cell is depicted below. It comprises of multi-junction which has been designed and constructed using subsystems for implementation of the various model equations.The results of Incremental Conductance technique as in figure below for the output voltage is shown below. As it is observed that the voltage rise after a certain initial threshold and after certain time achieves around a certain value.

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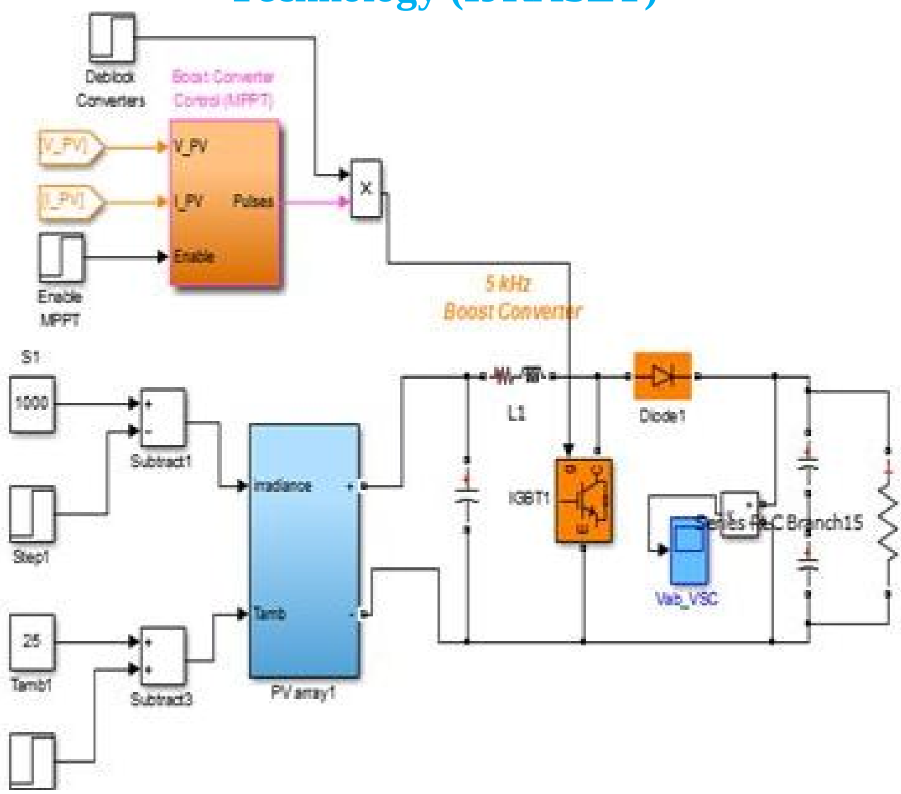

Figure 5: Incremental conductance technique

The below figure represents the voltage using our porposed approach and it is observed that the modeified firefly approach performs better than the Incremental Conductance approach.

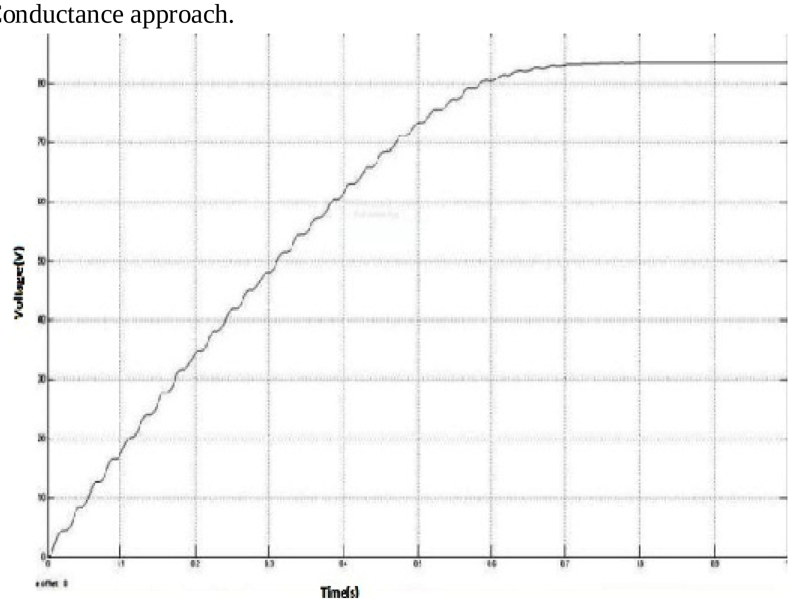

Figure 6 : Voltage output of ANFIS based MPPT

The voltage output increases during the transient state smoothly and after sometime it reaches a constant value. This is quite expected and the transient state is found to be quite smooth which is a desired property in terms of switching losses.

As compared to the incremental conductance whose voltage output is given below, ANFIS performs better.

The voltage increases gradually but the transients are quite high and also the transients are not smooth. This is a disadvantage as there is more losses in terms of damage to the switches in real time implementation. Also the voltage starts decreasing after certain time and a constant dc source is not obtained which was obtained in ANFIS based MPPT approach.

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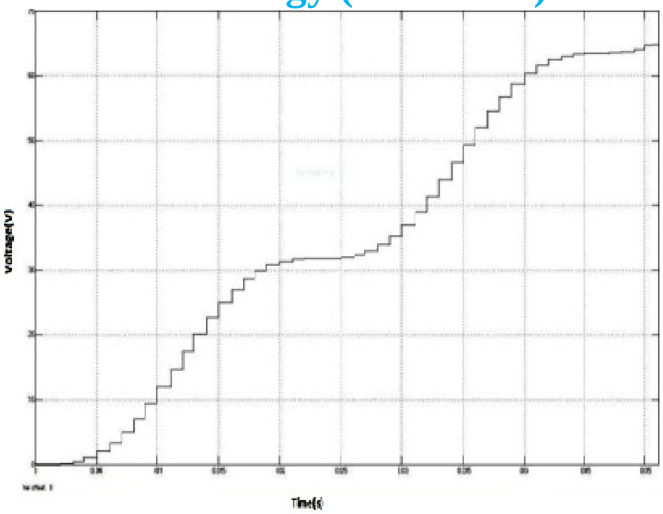

Figure 7 : The voltage output of I&C based approach

The performance is better for ANFIS MPPT technique in terms of both rise to the voltage and the voltage magnitude. While we achieve a voltage magnitutde of 32 V in ANFIS, only 27 V is obtained using the I&C approach for all other initial conditions remaining same.

VI. CONCLUSION AND FUTURE SCOPE

This thesis proposed a novel approach of utilising a firefly approach to solve the MPPT problem in multi-junction photo-voltaic cell. The multi-junction photovoltaic cell was assumed to provide better output in terms of voltage. The model for adaptive Neuro-Fuzzy system can be designed and developed. The ANFIS model is used to train itself and track the voltage output based on the THD values of the output. The THD of the voltage was fed as input to Neuro model trained firing angle of the boost converter connected to it is computed. The solar cell model was designed and given to boost converter. The converter output was analysed. An incremental conductance technique was also implemented for comparison purpose.

The result of ANFIS algorithm was found to be quite better than the I&C in terms of output voltage magnitude and the transients. The transient state in ANFIS trained MPPT it quite smooth comparatively. Also when the current is compared, the oscillations die out very fast in case of ANFIS algorithm while in I&C approach it is more or less sustained.

In future this algorithm can be improved using other techniques and approaches. Also real time implementation of the algorithms can be done and hardware testing can be done.

Hybrid with other algorithms can be utilised and the performances can be compared. Also clustering and other gradient learning methods can be utilised and the model can be tested for grid connection.

MPPT method	Pv array voltage (V)	Converter Output Voltage (V)	Transient die out time (sec)	Dc output voltage obtained?	Efficiency?
ANFIS based MPPT	86.8	83.67	0.8	yes	55.66%
I&C	86.8	65.5	1	no	47.83%

Table 1: Comparison between conventional technique and ANFIS MPPT

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