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A Comparative Review on Maximum Power Point Tracking Techniques for utility grid connected Photovoltaic Systems

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ABSTRACT:

It is a well-known fact that the dependency of non-renewable sources needs to be reduce to deal with global warming. Solar energy is one such option which is in abundance in India. Solar PV cell are utilised to trap this energy and convert it to electrical energy. The PV cell has the ability to convert near about of 20 % of solar energy to electrical energy. The output of PV cell depends on solar irradiation and panel temperature and panel terminal voltage, based on which MPP can be attained. Hence work is to be done to achieve that point operation for MPPT.

Keyword:MPPT, solar PV, INC, ANFIS, Boost converter, Utility grid, MATLAB/Simulink.

1.Overview

In recent times, continuous efforts are made to increase the contribution of renewables to reduce dependency on fossil fuel-based resources around the globe for the generation of electric power. The solar PV system is one such option, which is gaining its contribution globally each year. Its increase in popularity is due to a reduction in its cost due to technological enhancement. At present globally, 4800 GW is generated using Solar PV. A growth of around 60% was observed in the case of grid-connected solar PV systems; at present contributing around 21 GW.Even today, the majority of energy generation done using non-renewable energy sources due to the cost of generation. However, these sources lead to a major threat of global warming. Furthermore, these sources are responsible for a variety of additional types of pollution, all of which contribute to ecological degradation. As a result, renewable energy sources such as solar are becoming more important. In a country like India, solar radiation is abundant throughout the country at most times of the year.Furthermore, turning solar energy to electrical energy is a rather simple procedure. Solar PV systems that are both grid-connected and dispersed have significant advantages. Because of the large potential of solar energy in the Indian subcontinent, the Indian government has set a goal of achieving a defined limit of renewables in India of roughly 175 GW by 2022, with solar-based systems accounting for around 65 percent of the absolute limit. The goal of this project is to learn about MPPT and how to apply it to a PV panel in Matlab software to determine where the PV panel will give the most power.

2.Literature review

The detailed literature review in the area of PV solar, other renewable energy resources and MPPT method/techniques to track maximum power are presented in this chapter. The various studies show that a solar panel converts 21-40% of energy incident on it to electricalenergy. A Maximum Power Point Tracking algorithm is necessary to increase the efficiency of the solar panel.

Yong Li, Sarminah Samad [1] in 2020 discussed the use of a combined system for generating power had expanded dramatically. The combination of a photovoltaic (PV) system and an energy storage system has gotten a lot of interest in this regard. In this regard, this study presents a control system for a grid-connected combined energy system that consists of a PV and a battery..

Xun Ge et al. [2] in 2020 discussed that the paper develops a control scheme for a hybrid energy system, including a photovoltaic (PV) panel and a battery energy storage (BES) system. The capital cost of PV systems is considerably high today and it has been continuously trying to mitigate the manufacturing cost and also, several research works have been devoted to developing effective methods to maximize the power output of these generation systems.

Maximum power point trackers (MPPT) are necessary to achieve optimal solar power, according to **N. Priyadarshi et al. [3]** in 2019. This work proposes an intelligent fuzzy particle swarm optimization (FPSO) MPPT algorithm to accomplish this goal. A ripple factor compensation-based modified space vector pulse width modulation (SVPWM) approach was also used to gate an inverter control scheme. The suggested system's

performance is tested under a variety of situations, including sun irradiation, partial shadow, and loading.

M. Kermadi E. M. Berkouk [4] in 2019 discussed, a modified maximum power point tracking (MPPT) algorithm based on particle swarm optimization (PSO) technique is proposed. Under partial shadowing, this algorithm seeks to maximise the power extracted from a photovoltaic (PV) system with Lithium-ion (Li-ion) battery (PSC). Using a variable sample time, the proposed technique tries to reduce the amount of time wasted during the exploration phase. This is accomplished by integrating a comparator between the PSO algorithm's reference voltage and the PV array's output voltage.

The integration of photovoltaic (PV) systems with three-phase four-wire (3P4W) distribution networks has faced many obstacles, according to **Emad M. Ahmed et al. [5]** in 2019. These challenges include existing imbalanced loads, reactive power generation, and harmonics content. This research proposes a multifunctional distributed maximum power point (MPPT) controller for PV system grid integration..

The performance of a photovoltaic (PV) module is primarily determined by array configuration, irradiance, and module temperature, according to **K. Ding, X. Bian, H. Liu, and T.Peng [6**] in 2019. It's critical to comprehend the relationship between these impacts and the PV array's output power.

In 2018, **Rozana Alik and Awang Jusoh [7]** discuss the influence of partial shadowing on PV systems and offer an improved Perturb and Observe (P&O) algorithm that includes a checking mechanism. To clarify the global maximum power point, this verification method compared all existing peaks on the PV curve (GMPP). The duty cycle of the boost converter is calculated using voltage at MPP (VMPP), which is determined using a variable step size P&O technique.

The experimental construction of a grid-connected photovoltaic (PV) system utilising the dSPACE DS 1104 control board was discussed by **Neeraj Priyadarshi [8**] in 2018. An adaptive Neuro-Fuzzy inference system (ANFIS)-based maximum power point tracking (MPPT) technique is suggested to achieve excellent tracking efficiency. The system's performance is increased by fuzzy logic control (FLC), which generates the switching signal for the inverter's power switches.

In 2017, **Alivarani Mohapatra et al. [9]** published a clear and well-organized overview of several maximum power point tracking (MPPT) algorithms used in photovoltaic (PV) generating systems that can be used in partial shade. To date, a wide range of algorithms, PV modelling methodologies, PV array layouts, and controller topologies have been investigated.

R. Benkercha S. Moulahoum I. Colak [10] in 2017 discussed that the Grid Connected Photovoltaic System (GCPV) has become more used system in renewable energy. Several researches have been carried out to improve the efficiency and the decrease of energy losses. One of the important components used to increase the efficiency is the DC/DC boost converter.

3.PHOTO VOLTAIC (PV) SYSTEM

In this chapter the modeling and design of overall system such as PV system, boost converter, load and MPPT controller has been presented.

i. Photovoltaic Cell

Photoelectric cell is the semiconductor system that changes light to electrical power by photovoltaic. If energy (power) of photon of brightness is superior than the band gap, then an electron of the system is emitted also flow of an electron of system forms current. But the photovoltaic cell is different type of photo diode, when the light of sun falls down on device of cell is converted. Voltage or current by photo effect however this cell is always forward biased. Translation of photo - voltaic energy to electrical and thermal power of system have been use for many years. To conversion the PV power to electrical, photo voltaic are used. Photovoltaic modules make use of the photoelectric effect in order to directly perform the above conversion. Solar panels convert solar radiation to electricity with efficiencies in the vary of 5% to 20%, of system depend on form of the photovoltaic cell. Polycrystalline silicon PV cells offer the highest range of possibilities for applications. For consequence of their modest price relative to the mono crystalline silicon cells, and their considerable stability and efficiency (about 15%).

II Equivalent circuit and MathematicalModel

A current source type PV model is discussed in this section. The equivalent circuit is also shown.

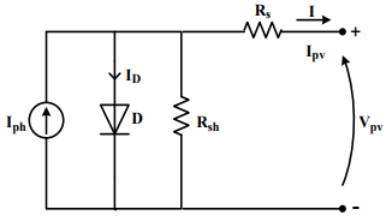

Fig. 1: The equivalent circuit of a PV array.

Where, R_S is the array series resistance in Ohm,
R_P is the array parallel resistance in Ohm,
I and V are the output current and voltage of the array in Ampere and Volt.

$$I = N_p \times I_{ph} - N_s I_{rs} \left[e^{\left(\frac{q \times V}{A \times K \times T}\right)-1} - \left(\frac{V + I \times R_s}{R_{sh}}\right)\right] (1)$$

Where, I_{ph} is photo current in Amp,
I_{rs} is saturation current in Amp,
N_S and N_p are the number of series and parallel modules respectively,
q is charge on electron in coulomb,
A is diode ideality factor,
T is cell Temperature with change in irradiation in degree kelvin.
Now,

$$I_{ph} = I_{scr} + K_i \times (T - T_r) \times S \quad (2)$$

$$I_{rs} = I_{rr} \times \left(\frac{T}{T_r}\right)^3 \times e^{\left(\frac{q \times E_g}{K \times A} \times \left(\frac{1}{T_r} - \frac{1}{T}\right)\right)} \quad (3)$$

Were,
I_{scr} is Short circuit current at reference Temperature in Amp,
I_{rr} is reverse saturation current in Amp,
T_r is reference temperature in Kelvin,
S is solar irradiance in mW/Sq. cm,
K_i is S.C. current Temp. coefficient in (Amp/Kelvin),

K is Boltzmann's constant,

E_g is band gap energy of semiconductor used cell in joules, also,

$$E_g = E_{g0} - \left(\frac{\alpha \times T^2}{T + \beta}\right) \times q \quad (4)$$

Where, E_{go} = band gap at 0k and,

$$V_{oc} = \left(\frac{A \times K \times T}{q}\right) \times \ln\left(\frac{I_{ph}}{I_{rs}}\right) \quad (5)$$

4. An Overview for Maximum Power PointTracking

Due to miss-match between power generated by Solar PV system and load connected, the efficiency of system is very poor. Certain methods needed to incorporate with system to increase efficiency. Such type of methodology of improving/maximizing power generation of PV system is known as Maximum power Point Tracking. Since, the V-I characteristic of Solar PV system is non-linear by nature, in order to make it utilizable for load, boost converters are used along with panel. The synchronization between load and generation can be done by modifying duty cycle of this converter using MPP.

In order to plan the control system, the configuration of PV system is to be understand first. Different configuration of PV systems is possible like the most basic one comprised of PV systems suppling power directly to inverter which is further connected to grid. Another type of connection is possible in which instead of suppling whole amount of power to grid, a part is kept to be stored in battery bank storage. A third type of configuration is also possible in which full generated power is stored in battery bank. The advantage of such system is that we don't need to connect each panel with a separate inverter instead we can have a centralized connection of single micro inverter for all increasing efficiency by 20 %.

The MPPT systems are connected to those conversion devices of system which have the ability to modulate current or voltage of supply generated by PV panel. This power electronic based device has the responsibility to convert supply in the form according to load demand. As discussed earlier the MPPT section is performed with converter section. The point where MPP occurs have a certain value of current and voltage termed as Impp and Vmpp. The product this two will eventually give value of maximum power.

4.1 Incremental Conductance (INC) Algorithm

This technique of MPPT works with a simple hypothesis that "ratio of change in output conductance is equal to the negative output conductance or Instantaneous conductance"

Since we know the relation, P = V I
The above relation is differentiated on both sides, which gives

$$\frac{\partial P}{\partial V} = -\frac{\partial (VI)}{\partial V}$$

AtMPP,as ∂P/∂V = 0, on substituting above value will give

$$\frac{\partial I}{\partial V} = -\frac{I}{V}$$

The LHS gives the value of instantaneous conductance of PV panel whereas right side gives instantaneous value. When LHS= RHS, MPPT is achieved. In this method both parameters are taken in to account hence the effect on error of variation of solar light is eliminated. The primereason behind using INC method is its cost effectiveness. Hence, in this technique the duty cycle is regulated by PWM control of a dc-dc boost converter until the above condition is satisfied. The Flow chart of INC MPPT is shownbelow.

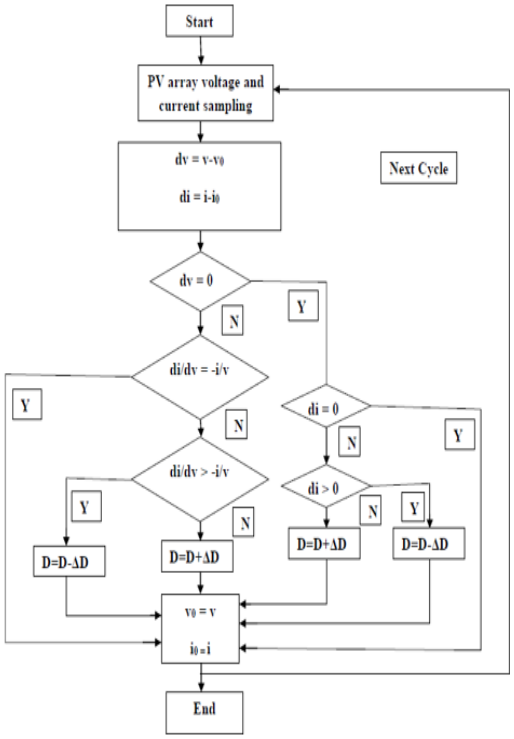

Fig. 2 Incremental conductance MPPT algorithm flow chart

4.2 Genetic Algorithm

- **ANFIS**

ANFIS stands for Adaptive Neuro-Fuzzy Inference System. The ANFIS controller combines the advantages of fuzzy controller as well as quick response and adaptability nature of ANN Fundamentally, ANFIS is about taking a fuzzy inference system (FIS) and tuning it with a back propagation algorithm based on some collection of input-output data. This allows your fuzzy systems to learn. A network structure facilitates the computation of the gradient vector for parameters in a fuzzy inference system. Once the gradient vector is obtained, a number of optimization routines is applied to reduce an error measure. This process is called learning by example in the neural network literature.

- Some Constraints are as follows: -

Since ANFIS is much more complex than the fuzzy inference systems discussed so far, all the available fuzzy inference system options cannot be used. Specifically, ANFIS only supports Sugeno systems subject to the following constraints:

- First, order Sugeno-type systems.
- Single output derived by weighted average defuzzification.
- Unity weight for each rule.

An error occurs if your FIS matrix for ANFIS learning does not comply with these constraints. Moreover, ANFIS is highly specialized for speed and cannot accept all the customization options that basic fuzzy inference allows, that is, one cannot make own membership functions and defuzzification functions; that to make do with the ones provided.

The fuzzy inference system that has been considered is a model that maps:

– Input characteristics to input membership functions,
– Input membership function to rules,
– Rules to a set of output characteristics,
– Output characteristics to output membership functions, and
– The output membership function to a single-valued output, or
– A decision associated with the output.

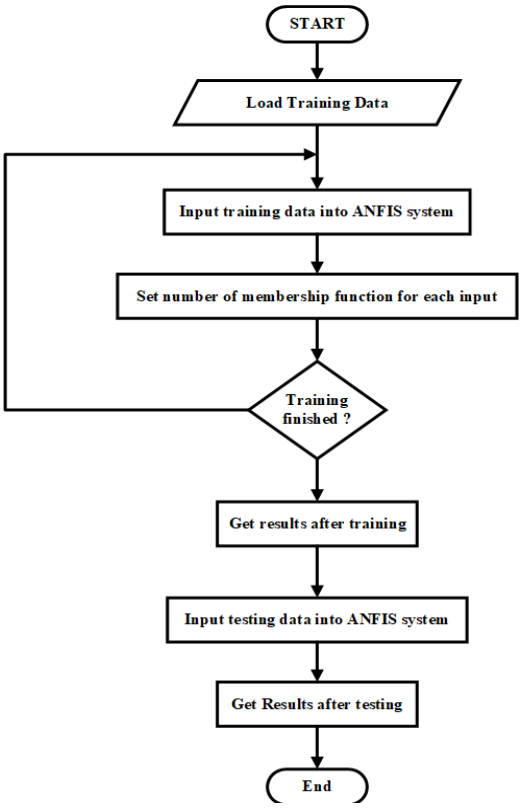

Figure 3: ANFIS algorithm flowchart

5. Conclusion

In this paper an attempt is made to discuss various work done in the field of Maximum power point tracking. A literature review of various paper is presented in second section. This followed with a brief introduction to MPPT and its mathematical modeling. Following these two methods for optimizing called INC and ANFIS are discussed.

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