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Study and Design of Stand-Alone Photovoltaic System to Maximizing Efficiency Solar Power Using Fuzzy Logic Algorithm

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ABSTRACT
This research focuses on the design of a small stand-alone solar power system, presents a maximum power point tracking (MPPT) using fuzzy logic. Since the PV array characteristic is hardly nonlinear, conventional control technique could be inefficient for an optimal use of these systems. Therefore, fuzzy logic controller is proposed to ensure the transfer of the maximum power to the system.
MATLAB software is used to simulate the proposed solution. Results show that the current of PV after implementing fuzzy logic controller is more efficient, which means that more power transfer to the system.
***Keywords:* —** PV Systems, Fuzzy Logic Algorithm, Maximum Power Point Tracking (MPPT).

I. INTRODUCTION

Global energy demands are increasing at a rapid rate. This has led to high consumption of fossil fuels, with negative environmental consequences, including global warming, acid rain and the depletion of the ozone layer. The diversification of energy resources is crucial in order to overcome the negative impact of fossil fuel energy technologies that threaten the ecological stability of the earth. Furthermore, rising fuel prices and the growing scarcity of fossil fuel may have negative economic and political effects on many countries in the near future. Many countries have adopted new energy policies to encourage investment in alternative energy sources such as biomass, solar, wind, and mini-hydro power. Solar energy is one of the most significant sources of renewable energy and promises to grow its share in the near future. An international energy agency study, which examined world energy consumption, estimates that about 30 to 60 Terawatt of solar energy per year will be needed by 2050 [1].
Photovoltaic (PV) is a technical name in which radiant (photon) energy from the sun is converted to direct current (dc) Electrical Energy. Photovoltaic generators have a nonlinear voltage-current characteristic with a unique Maximum Power Point (MPP), which depends on the temperature and irradiance condition. When these conditions are changed, the operating point and MPP will be changed. Therefore, Maximum Power Point Tracking (MPPT) controller is required to ensure that the maximum available power is obtained from the panel. In this paper, Fuzzy Logic control is proposed to achieve MPPT. It can be experimentally verified by modeling the PV system with the proposed MPPT algorithm in Matlab /Simulink Software. The stability and robustness of the proposed controller are investigated to load variations and environment changes [2].

II. PHOTOVOLTAIC SYSTEMS COMPONENTS:

The standard stand-alone PV system as shown in fig. 1 consists of the following parts[3]:

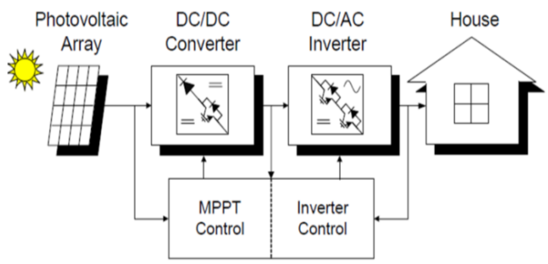

Fig. 1 Basic scheme of the Stand-alone PV system

A. *PV Panel:*

PV cells can mainly be categorized as follows: Mono-crystalline, Poly-crystalline, and Thin film solar panels. Table 1 shows PV surface required to generate 1KW for each type of PV cells [4].

TABLE I

PV Surface required to generate 1KW

PV type	Surface required
Monocrystalline silicon solar panels	5 - 8 m2
Polycrystalline silicon solar panels	7 - 9 m2
Thin film solar panels	9 - 11 m2

Single photovoltaic cell provides a voltage of about 0.6V. Therefore, sufficient for limited applications, a group of PV cells is connected in one frame and connected to one another in serial or parallel. It called PV solar panels or module. The module is usually composed of 36 cells on the sequence (12[V] model), or of 72 cells referred to as the (24[V] model) [1].

B. DC/DC converter:

The DC power is used as an interface between PV panels and loads. PV output is used as input, and the circuit is adjusted to provide the required output as it is controlled to maintain voltage and constant output current.

There are three types of DC-DC converter:

- Buck converter (Step-down converter).
- Boost converter (Step-up converter).
- Buck-Boost converter (Step-down/step-up converter).

We choose Boost converter in this research. Fig. 2 represents the equivalent circuit of the Boost converter circuit. It can be operated in two modes, which depends on the energy storage capacities and the relative length of the switching period. Those two methods are CCM (Continuous Conduction Mode) and DCM (Discontinuous Conduction Mode), where CCM is for efficient power conversion and DCM is for low power conversion ,CCM is used in the research. In continuous conduction mode, the boost power stage assumes two states per switching cycle. In the on state, T is on and D is off. In the off state, T is off and D is on[3,5].

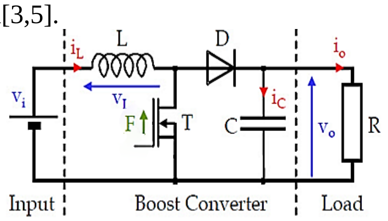

Fig. 2 Basic DC Voltage Boost Converter Circuit

C. DC/AC Inverter:

The mold is a device that converts the constant voltage to an alternating voltage. Its idea is to convert the stored battery voltage from the PV panels to the 220V alternating voltage to feed the household loads. We can control the mold output either by changing the input voltage or changing the gain of the capacitor.There are two types of Solar Panel Power Inverters:

- Stand Alone (Off-Grid) Inverters.
- Grid Tie (Synchronous) Inverters [3,6].

III. MAXIMUM POWER POINT TRACKING (MPPT) ALGORETHEMS

One of the drawbacks on solar system is the high cost installation and its efficiency. Maximum power point trackers are used to extract the correct amount of current to run the system at maximum power point (MPP). A complete solar panel equipped with an MPPT system includes a solar panel, an MPPT algorithm, and a DC-DC converter topology. Several MPPT algorithms have been proposed in the literature to track the maximum power of a PV system. These include the Perturb and Observe (PO) method, the Incremental Conductance (IC) method, the Constant Voltage (CV) method, and the fuzzy logic (FL) technique. These MPPT algorithms can be loaded onto either in a personal computer or a microcontroller to perform maximum power tracking functions. However, they differ in terms of speed, range of effectiveness, cost, the number of sensors required, complexity and popularity. The literature notes that existing classical algorithms used in the MPPT techniques can be: Fast to respond due to transient changes; or Accurately to track, but not simultaneously [7,8,9].

IV. DESIGN THE FUZZY CONTROLLER:

Fuzzy logic controller (FLC) was found to be an efficient tool to control nonlinear systems; many applications of fuzzy logic control are reported in the various engineering fields including industrial processes and consumer products.

Many model-based fuzzy control approaches are applied in PV systems categories such as Mamdani models and Sugeno models [7].

The principal design elements in a general fuzzy logic control are Fuzzification, Control rule base establishment, and Defuzzification as shown in Fig. 3.

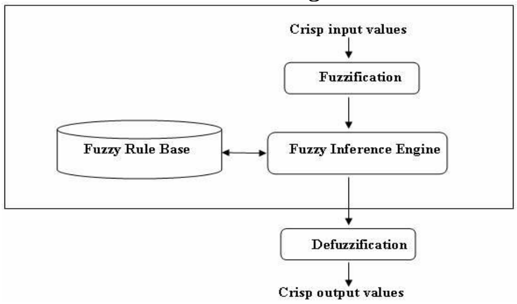

Fig. 3. Model of Fuzzy Inference Processing

Fuzzy logic control as shown in fig. 3 generally consists of three stages:

1. Fuzzification:

The fuzzifier converts the crisp input to a linguistic variable using the membership functions stored in the fuzzy knowledge base.Numerical input variables are converted into linguistic variables based on a membership function five fuzzy levels are used: NB (negative big), NS (negative small), ZE (zero), PS (positive small), and PB (positive big). The inputs are error E and change in error ΔE.

2. Rule base table:

The rule base holds the knowledge, in the form of a set of rules, of how best to control the system. The inference mechanism determines the extent to which each rule is relevant to the current situation as characterized by the input and draws decisions using the current inputs and the information in the rule-base. Fuzzy logic controller output, which is typically a change in duty ratio ΔD of the power converter, can be looked up in rules for the designed controller are which listed in TABLE II .

TABLE I
Fuzzy control Rules

E/ΔE	NB	NS	ZE	PS	PB
NB	ZE	ZE	NB	NB	NB
NS	ZE	ZE	NS	NS	NS
ZE	NS	ZE	ZE	ZE	PS
PS	PS	PS	PS	ZE	ZE
PB	PB	PB	PB	ZE	ZE

3. Defuzzification:

defuzzifier converts the fuzzy output of the inference mechanism to a crisp using membership functions into an analog signal that will control the power converter to the MPP.

V. SIMULATION AND RESULTS

Simulation has been done on a simplified model as shown in fig. 4.

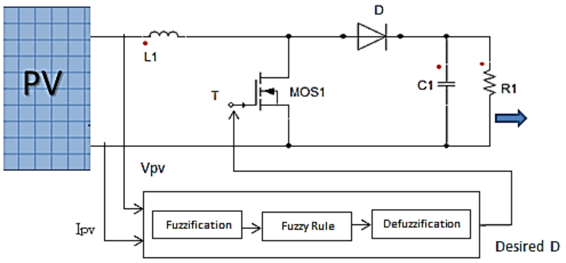

fig. 4 PVs model with Fuzzy logic MPPT algorithm

Fig.4 and Fig.5 shows the error and change of error respectively the difference between them is so little and the percentage of error is about 0.013 which give high performance of the FLC output.

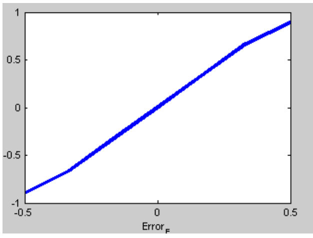

Fig.4 Input – error

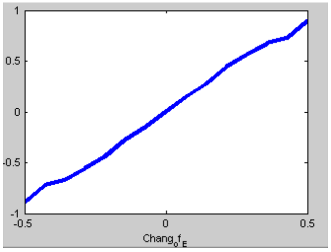

Fig.5 Input - change in error

Fig. 6 illustrates the deference between the values before applying fuzzy controller (reference value of power) and after applying FLC (desired value of power). We can see that the desired value on the proposed system increases by decreasing the error which make the power increase.

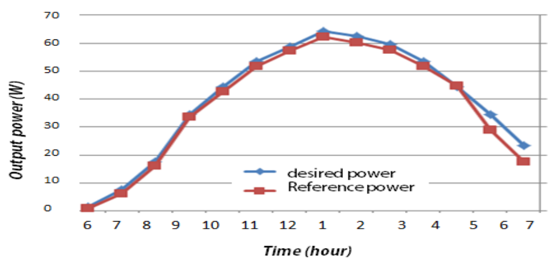

Fig. 6 Values of reference and desired power

V. CONCLUSIONS AND CONTRIBUTION

In this research, we presented information about solar power system which is a Photovoltaic technology, Fuzzy Logic Control and how to implement it to increase the efficiency of the system. The proposed system was controlled using a fuzzy logic controller to get the maximum power available at the output of the PV array by making regulation of the PV current. PV current feeding the DC/ DC converter in order to get a regulated current by minimizing the duty cycle of the converter, fuzzy logic controller regulates this current and get the desired current which is better response then feed it to the inverter. This controller was tested using MATLAB software program. The study showed that the fuzzy logic controller was better in response and it increased the system's efficiency comparing with other methods [10].

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