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Implementation of DSP-Controlled PV System Using Fuzzy Logic And Dual-MPPT Control

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Abstract__ **In this paper proposes a new digital control scheme for a photovoltaic (PV) system using fuzzy-logic and a dual (MPPT) controller. To obtain the maximum electricity from the solar cells, the PV modules have two MPPT controllers. The dc voltage and current are controlled to track the maximum power point, where the PV modules feed the maximum output power. A MPPT technique is used to operate in the optimum power condition .The first MPPT controller is an astronomical two-axis sun tracker, which is designed to track the sun over both the azimuth and elevation angles and obtain maximum solar radiation at all times. The second MPPT controller controls the power converter between the PV panel and the load and also it implements a new fuzzy-logic controller (FLC) based perturb and observe (P&O) scheme to keep the system power operating point at its maximum. The proposed control scheme achieves stable operation in the entire region of the PV panel and eliminates the resulting oscillations around the maximum power operating point.**

Keywords—Digital signal processor, fuzzy logic controller (FLC), maximum power point tracking (MPPT), physical tracking, standalone photovoltaic (PV) system.

I. INTRODUCTION

Renewable energy is the energy which comes from natural resources such as sunlight, wind, rain, tides and geothermal heat. These resources are renewable and can be naturally replenished. Therefore, for all practical purposes, these resources can be considered to be inexhaustible, unlike dwindling conventional fossil fuels. The global energy crunch has provided a renewed impetus to the growth and development of Clean and Renewable Energy sources. Clean Development Mechanisms (CDMs) are being adopted by organizations all across the globe. Apart from the rapidly decreasing reserves of fossil fuels in the world, another major factor working against fossil fuels is the pollution associated with their combustion. Contrastingly, renewable energy sources are known to be much cleaner and produce energy without the harmful effects of pollution unlike their conventional counterparts. A photovoltaic cell or photoelectric cell is a semiconductor device that converts light to electrical energy by photovoltaic effect. If the energy of photon of light is greater than the band gap then the electron is emitted and the flow of electrons creates current. However a photovoltaic cell is different from a photodiode. In a photodiode light falls on n channel of the semiconductor junction and gets converted into current or voltage signal but a photovoltaic cell is always forward biased.

Usually a number of PV modules are arranged in series and parallel to meet the energy requirements. PV modules of different sizes are commercially available (generally sized from 60W to 170W). For example, a typical small scale desalination plant requires a few thousand watts of power.

The tracking mechanisms can be classified into three types, namely, passive method, optical method, and the astronomical method. The general features that characterize an efficient tracking mechanism are: ability to cover a wide range of space, robustness against wind disturbances, and low-power consumption.

Passive tracking is based on the heating properties of gas matters such as Freon. The tracker is

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composed of two cylindrical tubes fitted on the edges of the panel; these tubes are filled with a fluid under partial pressure. Sun heat will increase the sun side. This type of system is relatively cheap and needs little maintenance. However, it has lower efficiency compared to other types of trackers, especially at low temperatures, moreover they have not yet been widely accepted by consumers.

The second method of tracking is the optical or electro-optic trackers. This method uses feedback sensors such as photo-sensors, current, voltage sensors, and auxiliary cells to determine the panel reference position .A closed-loop position control system based on fuzzy logic or PID is used to produce the actuators control commands. The drawback for such a system is that it is very sensitive to atmospheric conditions (clouds shading) and might not be able to continue tracking the sun in a cloudy day.

The third tracking method is the astronomical method, which employs the longitude and latitude data of a given location to determine the sun current position. The main advantage of this method over the optical method is that it involves simpler programming, reduced implementation cost, and lower power consumption as the need for additional sensors is eliminated. This method also provides high degree of accuracy and is not sensitive to atmospheric conditions.

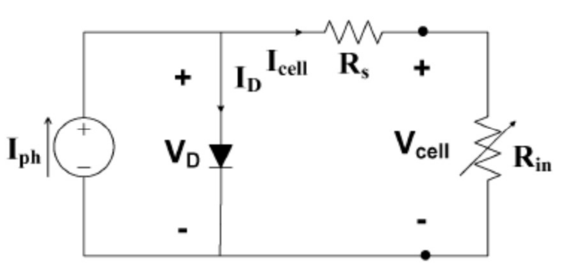

Fig. 1. PV system circuit model.

The literature is rich with various MPPT techniques varying in implementation complexity, cost, adjustability to different PV systems, and overall produced efficiency.

This paper proposes a new DSP controlled dual-MPPT scheme based on fuzzy logic control (FLC). The first MPPT controller is an astronomical two-axis sun tracker that keeps maximum radiation on the panel throughout the day. The second controller implements a new fuzzy-based MPPT technique to adaptively change the P&O perturbation step size depending on the PV system operating point and the current step size. The proposed control scheme achieves stable operation in the entire region of the PV panel and eliminates therefore the resulting oscillations around the maximum power operating point. The small signal analysis model of the power converter is presented along with a Lyapunov-based stability analysis of the PV system.

II. PV SYSTEM DESCRIPTION

The proposed standalone photovoltaic system consists of four main blocks: PV panel, solar tracker, DC/DC converter (charger), and the MPPT controller. The following sections will describe the modeling of each component.

A.PV Panel Model

The PV panel model used in our analysis is the single-diode model. This model represents the illuminated solar cell in its simplest form as a PN junction, as shown in Fig. 1

$$V_{cell}=V_D-I_{cell}R_s \quad (1)$$

$$I_{cell}= I_{ph}-I_D=I_{ph}-I_o(e^{K_{pv}(V_{pv}+I_{pv}R_s)})-1 \quad (2)$$

I_{ph} is the photocurrent given

$$I_{ph}=(I_{sc}+K_i(T-T_r))$$

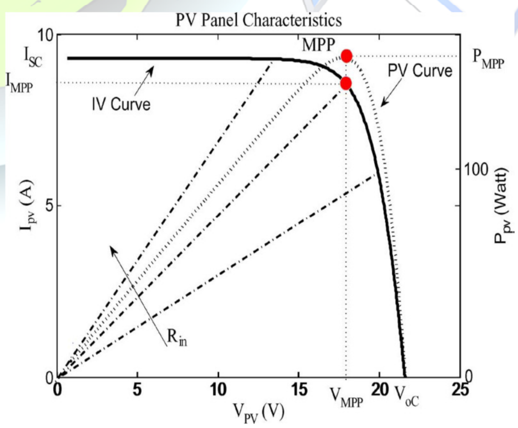

Fig. 2. PV panel characteristics.

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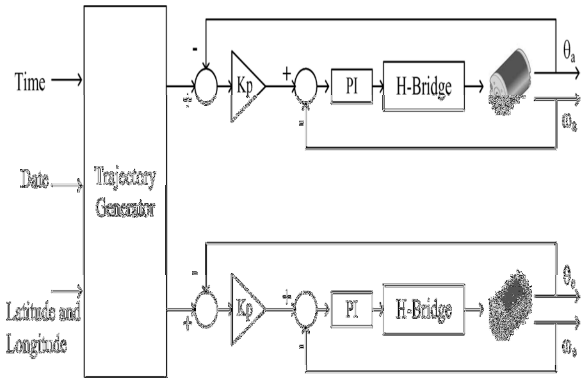

Fig. 3. Block diagram of the control system

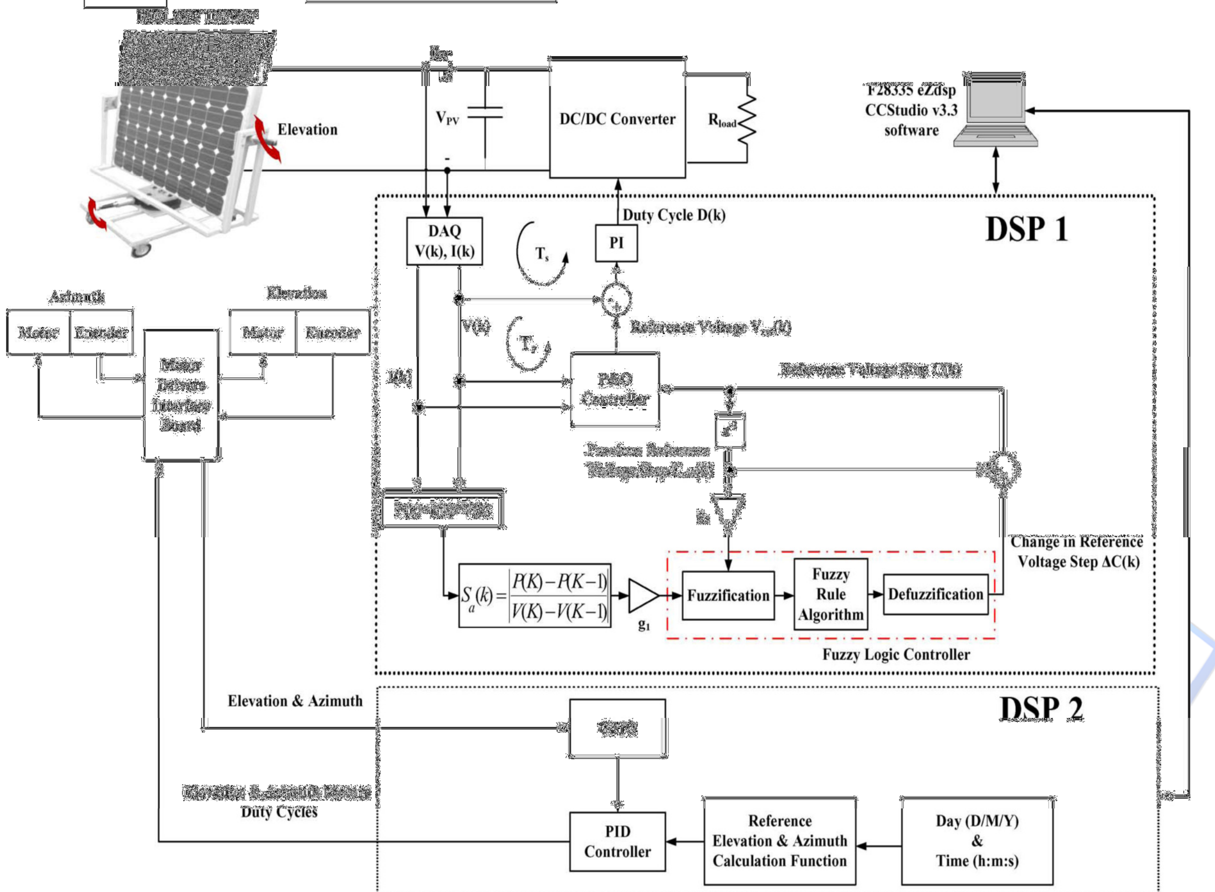

Figure 4. The proposed DSP-based standalone solar energy system.

B. Solar Tracker

In order to track the sun trajectory, a two-axis tracker with a 150-Watt PV panel was manufactured, as illustrated in Fig. 4. The tracker base has a rotary table mechanism with a DC motor and a worm gear drive that rotates the panel about the vertical axis. The rotary table includes in addition a thrust bearing that is able to support the load caused by the weight of the structure. The panel is held using a frame, which is mounted on top of the rotary table.

The panel is tilted around the horizontal axis using another DC motor connected to the panel through a gear with a ratio 240:1. The tracker is controlled

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using an astronomical angular trajectory generation. Given the date, time, latitude, and longitude of the current location of the system, the DSP controller calculates the sun reference azimuth and elevation angles using pre implemented equations. The panel azimuth and elevation angles are next controlled to follow their reference values using digital closed loop position control, as shown in Fig. Incremental optical encoders are connected to the motor shafts
to provide the angular position and speed information to the DSP to implement the control algorithm.

C.*Power Converter Model*

The developed standalone PV system uses a buck converter as a power processing unit. The buck converter circuit consists of a MOSFET switch and a diode, in addition to a filter circuit based on a capacitor and an inductor as shown in Fig. 6. The circuit is controlled through a PWM signal generated by the MPPT controller.

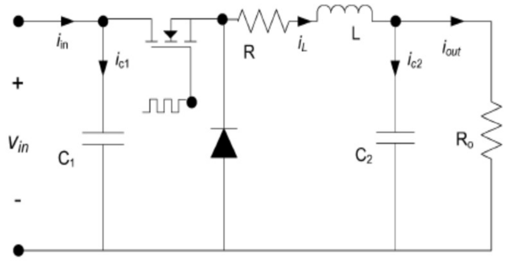

Fig 4 buck boost circuit diagram

III. DUAL-MPPT SYSTEM

The proposed DSP-based standalone photovoltaic system consists of two main subsystems; an astronomical two-axis tracker combined with an MPPT-based buck converter

A.FLC-Based MPPT

The proposed MPPT controller builds upon the simplicity of the P&O technique but eliminates the resulting steady state oscillations by adaptively modifying the reference voltage perturbation step-size C using a fuzzy logic controller. The PV panel power is computed from the panel voltage and current and then the absolute value of the power slope $S_a=dP_{PV/d}V_{PV}$ is computed and fed to the FLC along with the old step value C_{old}.

B. P&O Algorithm

The principle of P&O is to perturbation by acting decrease or increase on the PWM duty cycle of boost converter and then observing the direction of change of PV output power, If at any instant j the output PV power P (j) & voltage V (j) is greater than the previous computed power P (j−1) & V (j-1), then the direction of perturbation is maintained otherwise it is reversed [10, 11]. The flow chart of algorithm has 4 cases as shown

When ΔP <0 & V(j)>V(j-1), this yields to D (j+1) = D (j) – SD
When ΔP <0 & V(j)<V(j-1), this yields to D (j+1) = D (j) + SD
When ΔP >0 & V(j)<V(j-1), this yields to D (j+1) = D (j) - SD
When ΔP >0 & V(j)<V(j-1), this yields to D (j+1) = D (j) + SD

Where SD is chosen value by trial and error in simulation. A simulation of the P&O algorithm has been implemented by using MATLAB.

Defuzzification of the inference engine, which evaluates the rules based on a set of control actions for a given fuzzy inputs set. This operation converts the inferred fuzzy control action into a numerical value at the output by forming the union of the outputs resulting from each rule. The centre of Area (COA) algorithm is used for defuzzification of output duty control parameter. i.e. If E is NB and CE is ZO then crisp D is PB, it means that if the operating point is far away from the MPP by the right side, and the variation of the slope of the curve is almost Zero; then increase the duty cycle

C. Fuzzy Logic Controller

Fuzzy logic is one of the most powerful control methods. It is known by multi-rules-based resolution and multivariable consideration. Fuzzy MPPT is popular for over last decade. Fuzzy logic controllers (FLC) have the advantages of working with imprecise inputs, no need to have accurate mathematical model, and it can handle the nonlinearity. The FLC consists of two inputs and ooutput. The two FLC input variables are the error (E) and change of error (CE) that expressed by equation

E(j)=Ppv(j)-Ppv(j-1)/Vpv(j-1) (3)

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CE(j)=E(j)-E(j-1) (4)

The fuzzification is the process of converting the system actual inputs values E and CE into linguistic fuzzy sets using fuzzy membership function. These variables are expressed in terms of five linguistic variables (such as ZE (zero), PB (positive big), PS (positive small), NB (negative big), NS (negative small)) using basic fuzzy subsets.

Fuzzy rule base is a collection of if-then rules that contain all the information for the controlled parameters. It is set according to professional

Table II FLC rules base

E \ CE	NB	NS	ZE	PS	PB
NB	ZE	ZE	PB	PB	PB
NS	ZE	ZE	PS	PS	PS
ZE	PS	ZE	ZE	ZE	NS
PS	NS	NS	NS	ZE	ZE
PB	NB	NB	NB	ZE	ZE

VI. EXPERIMENTAL RESULTS

The experiment is completed with MATLAB simulation. The experimental waveform of duty cycle, PV power and output power were shown below. PV power is 54 V and by using MPPT got the power as 68V

D. PID Controller

A proportional–integral–derivative controller (PID controller) is a generic control loop feedback mechanism (controller) widely used in industrial control systems – a PID is the most commonly used feedback controller. A PID controller calculates an "error" value as the difference between a measured process variable and a desired set point. The controller attempts to minimize the error by adjusting the process control inputs.

K_p, K_i, K_d are the tuning knobs, are adjusted to obtain the desired output. The following speed control example is used to demonstrate the effect of increase/decrease the gain, K_p, K_i, K_d

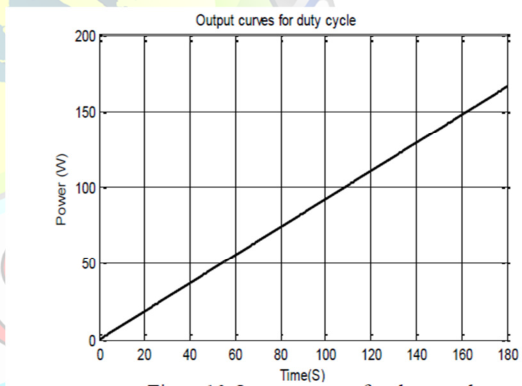

Figure6 Output curves for duty cycle

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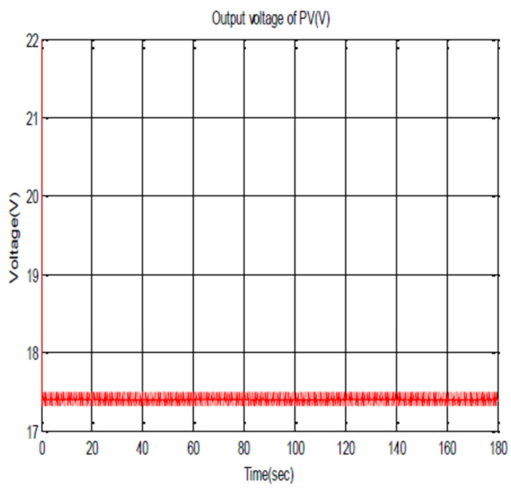

Figure 7 Output voltage of PV (V)

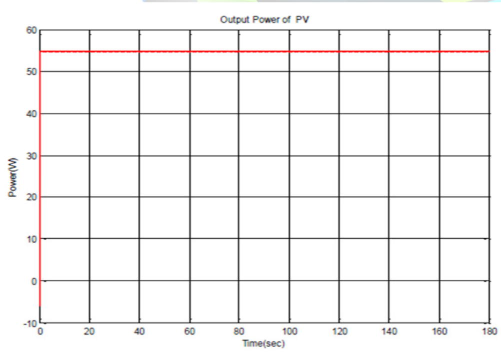

Fig 8 Output power of PV

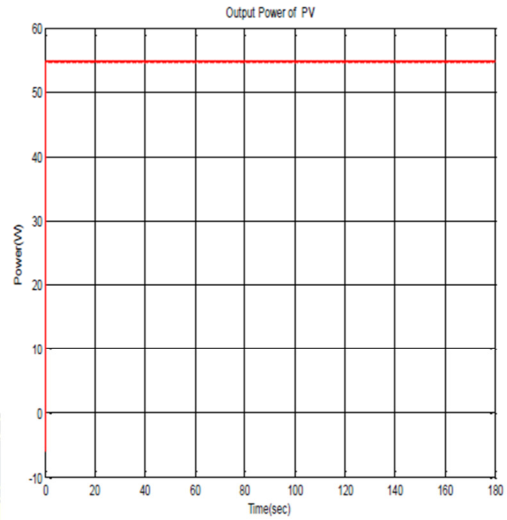

Fig 9 Output Power(W)

V CONCLUSION

This paper presents a new digital control scheme for a standalone photovoltaic system using fuzzy-logic and a dual-MPPT controller. The MPPT controller is combined with a dual-axis panel tracking controller to improve the efficiency of the overall system. The proposed control scheme takes the power slope of the PV panel curve and the old voltage perturbation step as its inputs and outputs the change in the new P&O step size. The FLC output is gradually updated in order to avoid exceeding the MPP in the opposite direction leading to oscillations. The PID controller and FLC was implemented on a DSP software code composer studio. The proposed technique is able to reduce the steady state oscillations and enhance the operating point convergence speed.

VI FUTURE WORK

- To make the system more advanced, by adding one more control loop.
- Which results in an increase in the efficiency, as the system demonstrates a faster dynamic performance and better regulated PV output voltage compared to P&O.

- The use of modified adaptive techniques and the introduction of three-point weight comparison P&O algorithm are suggested.

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