



Load Frequency Control Using Fuzzy Logic Controller of a Three Area System Consisting of a Grid Connected PV System, Hydro and Thermal Systems

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ABSTRACT: In this paper the load frequency control of the three area system consisting of thermal, hydro and photovoltaic system. Using modified hill climbing algorithm, the maximum power point tracking is performed in photovoltaic. Combining fuzzy logic with hill climbing algorithm the modified hill climbing is performed. Boost converter is used for this analysis. Using single phase inverter the obtained DC output is converted to AC output. By using sinusoidal pulse width modulation the Grid connection is performed. Transfer function model of the thermal, hydro is interfaced with the photovoltaic system. Load frequency control of this three area system and simulation of the entire system is performed in the MATLAB SIMULINK.

KEYWORDS: PhotoVoltaic (PV), Maximum Power Point Tracking (MPPT), Hill Climbing, Load Frequency Control (LFC), Area Controlled Error (ACE), Sinusoidal Pulse Width Modulation (SPWM)

I. INTRODUCTION

Renewable energy is the energy given by the natural resources like sunlight, wind, tides, geothermal heat etc. These resources are endless resources as compared to the other conventional fossil fuels. So now a days, the world is promoting to use the renewable energy sources. Clean Development Mechanisms(CDMs) are being adopted by organizations all across the globe[1]. It is possible to reduce the pollution rate into a significant level by using the renewable energy sources. The cost of production of conventional energy sources is increasing per day. So the solar energy is getting a suitable replacement for it. These solar energy is pollution less, spreads all over the earth and abundant. Parallel and series combination of PV cells are called as PV arrays. By using the solar isolation and temperature the PV cells are generating the electrical energy. Active or passive are the main two classifications for the solar technologies. Depending upon the changeover, the way they catch and distribute sunlight Active solar proficiencies use photovoltaic arrays, pumps and fans to convert sunlight into executable outputs. It is convert to the electrical energy the most useful form of energy. Using the solar photovoltaic cell this is achieved. About 13%-17% is the efficiency of solar photovoltaic cells with single crystal silicon[1], [3] In a grid connected system during the day time the major part of the load is supplied by the PV array and when the sunlight is not sufficient then the power to the load is taken from the grid [2], [3].

II. GRID CONNECTED SOLAR SYSTEM

The conversion efficiency of the PV panel is very low. So the tracking efficiency of the PV system has to be improved by using the MPPT algorithm it is possible to regulate the input side. And the output voltage will remains constant irrespective to the external conditions. The DC voltage is taken as the output from the MPPT.

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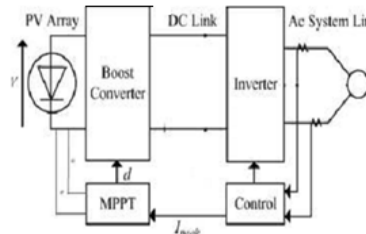


Fig. 1. Block Diagram of PV System

In fig 1 DC output voltage have to convert to AC voltage in order to perform the grid connection. So the single phase inverter is here use to convert the DC output voltage to AC voltage. In order to perform the grid connection SPWM technique is also used.

A. SOLAR CELL PANEL

Solar cell panel works on the principle of photo voltaic effect. A solar cell consists of a semiconductor where the front and reverse side have been processed. So that the front side normally has a surplus of free electrons while the reverse side has a deficit [3]. Bound electrons in the solar cell can absorb a photon and thereby become mobile. Thus the absorbed photon caught by the field in the interface and transported to the front side of the cells [3]. If the front-and reverse side are connected with an electrical circuit, the electron can do useful work in a light bulb, electrical motor and computer. Solar cells give an output voltage of approximately 0.3-0.6V depending on the technology [3],[4].

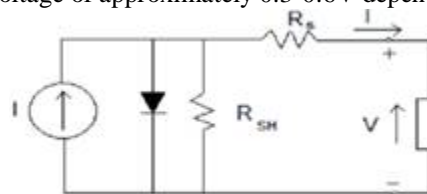


Fig. 2. Equivalent circuit of solar cell

In fig 2 equivalent circuit of a solar cell is as shown in the figure 2. Solar panel can be modeled with the help of equation,

$$I = I_1 - I_0 \left(e^{\frac{q(V-IR_S)}{AkT}} - 1 \right) - \frac{V-IR_S}{R_{SH}} \quad (1)$$

$$I_1 = \left(\frac{\lambda}{1000} \right) [I_{sc} + k_1(T - 25)] \quad (2)$$

Where,

I_0 = Solar cell output current , I = Dark saturation current, I_1 = Photo current, I_{sc} = Short circuit current v = Solar cell output voltage, k = Boltzmann constant, q = Charge of electron, A = Diode quality factor

T = Temperature in Kelvin, λ = Irradiance

Depending up on the temperature and the irradiance, power is generated [3],[4]. It is directly proportional to the irradiance and inversely proportional to temperature. This can be shown in figure 3,4.

B. MAXIMUM POWER POINT TRACKING

Maximum Power Point Tracking (MPPT) is a method used to harness the maximum power from a solar panel. PV panel arrays are nonlinear in nature. [4],[5],[10]. It depends up on factors like temperature and irradiance. The input voltage regulation is provided by MPPT. To improve the PV panel efficiency the MPPT algorithm is implemented otherwise the efficiency of PV panel is less than 50%.

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According to maximum power transfer theorem, the power output of a circuit is maximum when the Thevenin impedance of the circuit (source impedance) matches with the load impedance. [4][5] Hence our problem of tracking the maximum power point reduces to an impedance matching problem.

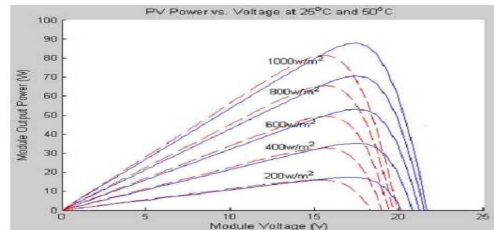


Fig.3. Temperature and irradiance effect on P-V characteristics

By varying the duty cycle of the DC match the source impedance with load impedance is based on the Power versus Voltage characteristic of a solar panel shown in Fig. 3. The point on the curve where the power is maximized is called the Maximum Power Point (MPP) of the solar panel.

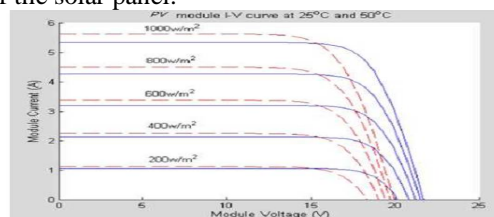


Fig. 4 Temperature and irradiance effect on I-V characteristics

load. Another advantage of this technique is that, if an up/down converter is used for the maximum power point tracker; power can then be delivered to loads with higher or lower voltage than the solar panel, enabling new applications for the same solar panel. Here in this method fuzzy logic control is combined with the hill climbing method to eliminate the disadvantage of both the method. Fuzzy logic controller will take care of the dynamic characteristic [4],[5],[10] of the PV panel while hill climbing algorithm will take care of the static characteristic of the PV panel will take care by the hill climbing algorithm method.

Hill climbing algorithm used in constant weather conditions while the fuzzy logic controller will be used in the changing weather condition. This method improves the tracking speed as compared to when fuzzy logic and hill climbing methods are used alone separately.

III. FUZZY LOGIC CONTROLLER

In this proposed method change in power and change in current are taken as the input to the fuzzy logic controller while change in duty cycle is taken as the output of the fuzzy logic controller. The output thus obtained is given as the firing pulse of the boost converter and the boost converter will regulate the voltage.

$$\Delta P = P(K) - P(K - 1) \quad (3)$$

$$\Delta I = I(K) - I(K - 1) \quad (4)$$

$$\Delta D = D(K) - D(K - 1) \quad (5)$$

Where,

ΔP = Change in power

ΔI = Change in current

ΔD = Change in duty cycle

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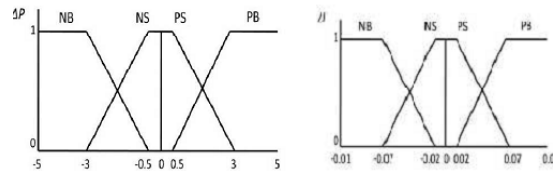


Fig. 5. Membership function for inputs ΔP and ΔI

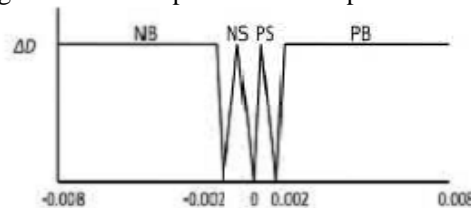


Fig. 6. Membership function ΔD

Inputs change in power and current and the output change in duty cycle are divided into four fuzzy subsets. Namely, negative big(NB), negative small(NS), positive small(PS), positive big(PB). Mamdani’s method with Max-Min is used for the Fuzzy combination [4],[5]. Defuzzification is the last stage of fuzzy controller. Center of Area Algorithm is used here for Defuzzification

ΔI	PB	PS	NB	NS
ΔP	PB	PS	NB	NS
PB	PB	PB	NB	NB
PS	PS	PS	NS	NS
NB	NB	NB	PB	PB
NS	NS	NS	PS	PS

Table 1. fuzzy rule base

Overall system of an grid connected PV system, hydro and thermal system is connected together and shown by fig 7

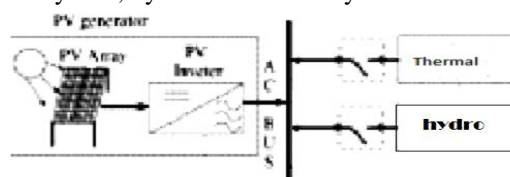


Fig 7 overall system

IV. LFC OF THREE AREA SYSTEM CONSISTS OF THERMAL, HYDRO AND PV SYSTEM

Changes in the power system load, affect mainly the system frequency and real power. [8] Mainly deals with the control of the system frequency and real power. Load frequency control is the basis of many advanced concepts of the large scale control of the power system. The reasons for keeping a strict limit on the system frequency variation were

- The speed of the alternating current motors depends on the frequency of the power supply.
- If the normal frequency is 50 Hertz and the system frequency falls below 47.5 Hertz or goes up above 52.5 Hertz then the blades of the turbine are likely to get damaged so as to prevent the stalling of the generator
- The under frequency operation of the power transformer is not desirable.

If we implement the PV panel alone will result in the fluctuation.[6][7] At night we cannot able to access PV panel. It will also results in the voltage fluctuation. So we will incorporate PV panel with battery or other sources or generator. Here we are going to take the system of PV System with thermal and hydro as shown in figure 7 .

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A. PV PANEL MODEL

In three area system model we have to create the transfer function model of the each system.[6][7] PV system consists of the PV panel, MPPT, Inverter, Filter. Transfer function model of the each unit has to find out and to create a single transfer function model. The transfer function model of the PV panel can be find out from the equation 1 and 2.

B. THERMAL

The main parts in the thermal generator are Generator, Turbine , Governor , Reheater. We have to consider the transfer function model of the each unit to form the model. [6][7].

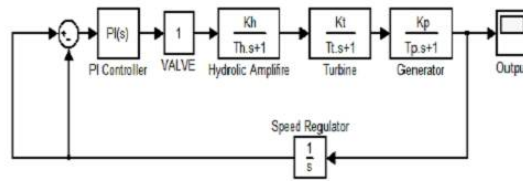


Fig 8 Thermal generator model

C. HYDRO

Hydro plants are modelled the same way as thermal plants. The input to the hydro turbine is water instead of steam. Initial droop characteristics owing to reduced pressure on turbine on opening the gate valve has to be compensated.

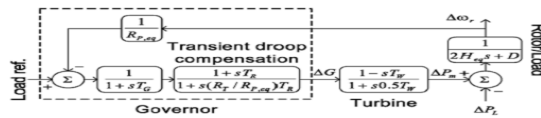


Fig 9. Hydro generator model

Fig 9, Hydro turbines have peculiar response due to water inertia; a change in gate position produces an initial turbine power change which is opposite to that sought. For stable control performance, a large transient (temporary) droop with a long resettling time is therefore required in the forms of transient droop compensation.

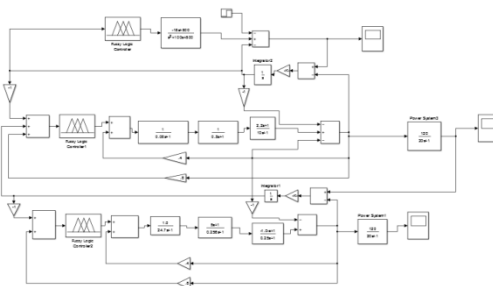


fig 10, fuzzy controller model

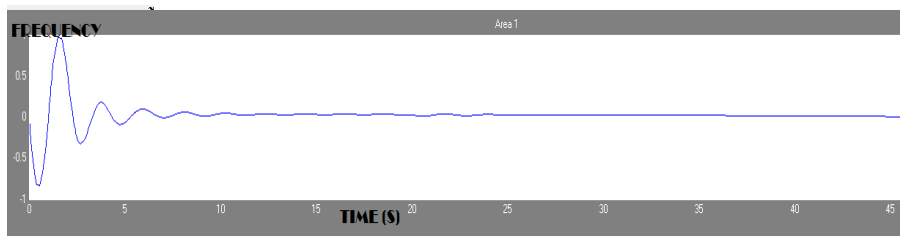


fig 11 Output of thermal generator



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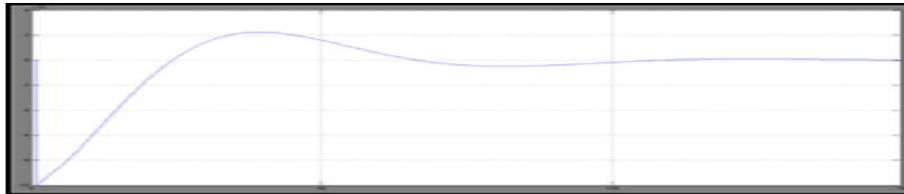


Fig 12 Output of PV system

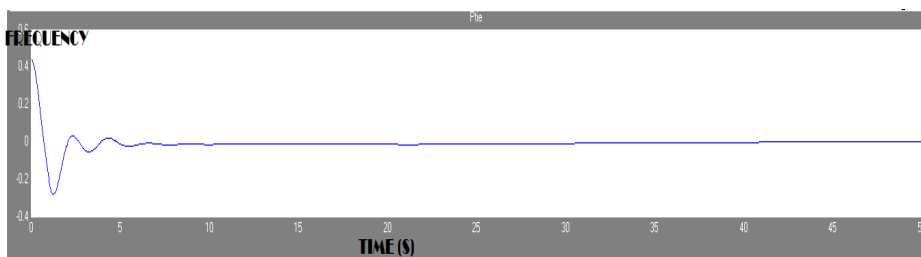


Fig 13 . Output of hydro generator

V. CONCLUSION

Maximum power point tracking was done for the PV system using fuzzy logic controller and then grid connection was performed using SPWM technique. Transfer function model of this system was taken and interfaced with thermal generator and hydro generators. Outputs are simulated by MATLAB .

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