Innovative Solar Microgrid For Farmers with Fuzzy PID based MPPT

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Abstract : In developing country India, despite of being the primary occupation, farmers face a lot of problems with availability of power supply and irrigation leading to economical crisis. Considering their problems, Gov. of India introduced KUSUM scheme, under which the farmers generate their own required electric power through solar and fulfill their need along with getting incentives by feeding the power to grid.

In this paper, we have proposed a model for above discussed problem which includes a solar microgrid. We have used Fuzzy PID controlled MPPT and a battery storage to stabilize the output of PV. The simulation results of voltages and power are discussed along with the future scope of this model.

***IndexTerms* – Fuzzy PID, Microgrid, MPPT, PV, Solar.**

I. INTRODUCTION

Energy is one of the key factors of development in any country. The world is facing a lack of energy, and this poses a great problem. The consumption of electrical energy is continuously increasing all over the world due to growing global energy demand. With the increase in population and technology the demand of energy are growing with exponential rate. Depletion of conventional fossil fuels and greenhouse gas emission has led to intensive use of renewable energy sources. Significant progress has been made over the last few years in the research and development of renewable energy systems such as wind, sea wave and solar energy systems. [1] Solar generators are now playing an ever-increasingly important role in delivering electric energy to the power grid. With tradition sources of energy dry up gradually, the solar energy already becomes the new sources of energy developing a potential as it is one of the most reliable, daily available, and environment friendly renewable energy source. [2]

Photovoltaic (PV) energy is widely used by stand-alone systems, especially in remote areas where it is not practical or safe to connect a stand-alone system to hardware. PV module also has many advantages like absence of moving parts, silent operation, low maintenance cost, operational simplicity, small footprint, compact area and commercial abundance. [3] Although, it is subject to weather conditions which affect the power produced. The output voltage and the voltage-current relationships on the PV depend on various levels of solar radiance and various cell temperatures. [4]. This is why a temperature raise decreases the open-circuit voltage while the increase of the solar irradiation produces the elevation of the short-circuit current. The main disadvantage of PV is low energy conversion efficiency. to increase the efficiency of the photovoltaic module, it must be used at the Point of Maximum Power (MPP) [5]

An important feature of PV generators is that its current-voltage characteristic has a single point of maximum power MPP, defined by a given voltage VMP and current IMP; this point moves according to the weather conditions and the nature of the load to which it is connected. [6] Maximum power point (MPP) tracking is a crucial technique that tracks the optimal point and therefore increases power output. In the literature, many techniques have been proposed to ensure continuous maximum power. [7]

The model represented in this paper is by specially taking the farmers of India in consideration, as they are facing lack of electricity problem and economical issues because of uncultivated land resulting from lower ground level water. We are proposing a scheme to make the farmers individual for their electrical needs and to help them generate some revenue through their own microgrid to compensate the loss they are facing due to uncultivated lands.

Microgrid is a small-scale unit power grid that can operate independently or connected with main electrical grid. Any small scale localized station with its own power resources qualifies as a microgrid. It system is primary source for distribution system which is used to supply the electrical power to the local loads. The concept of the microgrid has come from the increase in DG penetration depth and the presence of multiple DG units in electrical proximity to one another. [8]

Since the I-V characteristics of a PV cell varies non-linearly with radiation and temperature, it is essential to operate a PV system to a specific point to extract maximum power. [9] PV system consists of several components including solar panels, solar inverter, mounting cabling and other electrical accessories. They range from small rooftop mounted or building integrated systems with few kW capacities to several kW large utility scale power stations.

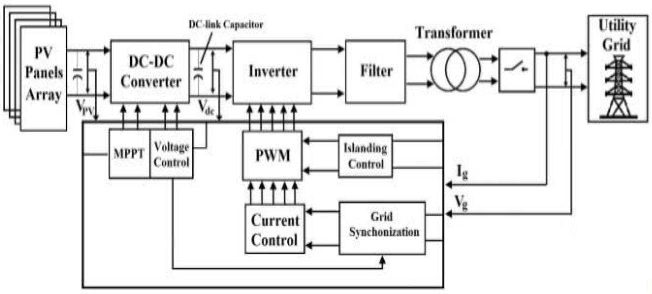

Fig.1 PV-inverter with basic control structure

Solar Cell Representation

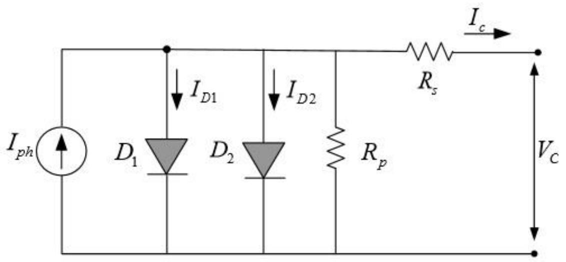

Fig.2 Equivalent circuit of PV cell

Equations arising from this model are given by the following ones:
The photovoltaic current delivered from the PV cell has as expression:
Ipv = Ise -Id -Ish
The current generated by the photovoltaic cell is equal to Isc expression given by
Ise = (Iee + K/(T -Tref))G/ Gn
PN junction current Id expression is given by
Id = Is [exp (Vpv+Rs/pv) -1]
The resistance current of Rsh is equal to
Ish – (Vpv+Rs*Ipv) /Rsh
Where
Icc: Short circuit current.
D: Diode representing the PN junction.
Rsh: Shunt resistance characterizing the leakage of current junction.
Rs: Serial resistance representing the connections and the contacts resistance.
T: Temperature
Tref : Reference Temperature (25CO).
G: Irradiation.
Gn : Reference irradiation (1000 W/m2).
Electrical characteristics Current-Voltage (I-V) and Power-Voltage (P-V) of photovoltaic cell are shown

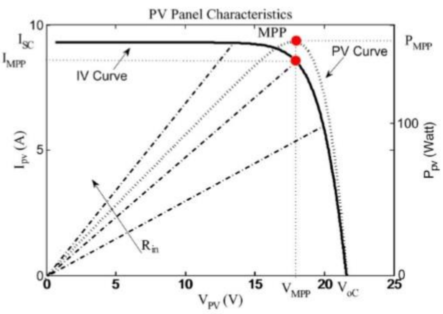

Fig.3 Electrical characteristics of PV cell

This point varies with irradiation and temperature changes. So, it is crucial to control the DC-DC converter switch periodically via an MPPT controller to have optimal energy of PV panel.

DC-DC Boost

The boost converter operates in two states. Firstly, the switch Tr is open (0 < t < dT) the diode is blocked at this time, and the current in the boosting inductance increases linearly. Secondly the switch Tr is blocked (dT < t < T) the energy stored in the inductor is released by the diode to the output circuit

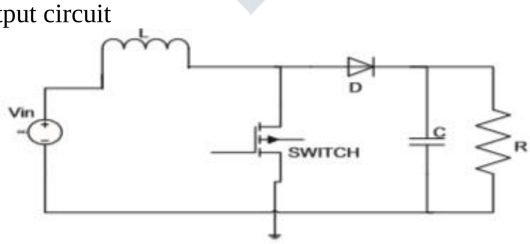

Fig.4 DC – DC boost converter ckt

This leads to following equation
Vo/Vin = D/(1-D)
The inductance L and the capacitor C of the boost converter are given by the following equations,

$$\Delta I_L = V_{e\_\min} D / f_s L$$

$$L = \frac{V_e (V_s - V_e)}{\Delta I_L f_s V_s}$$

$$C = (I_s D)/(f_s \Delta V_s)$$

II. LITERATURE REVIEW

Maximum Power Point Technique

There are numerous methods of the Maximum Power Point Tracking (MPPT) in the literature. Notably, Perturb and Observe (P&O), Incremental of Conductance (INC), Hill Climbing (HC), Particle Swarm Optimization (PSO) based P&O, Fuzzy Logic Controller (FLC) and Neural Network (NN) can be found. These methods vary in convergence speed, oscillations around the MPP, algorithm complexity, computational costs and electronic requirements [10]-[14].[p] among these "Perturb and Observe" is mainly used. [6] Fuzzy logic is used especially in photovoltaic systems, and mainly in monitoring the maximum power [8]. In [10, 11] a method of tracking the MPP of a PV system uses a controller based on direct fuzzy logic is discussed. In [12], the fuzzy control (fuzzy control, FC) method was compared to the Perturb and Observe method. A comparison of several aspects of the main MPPT techniques was discussed in [15]. The authors conclude that Perturb and Observe (Perturb and Observe, P&O) is the most widely used method thanks to its simplicity of implementation.[6]

Given below are the flowcharts of P&O and Fuzzy Logic MPPT controller

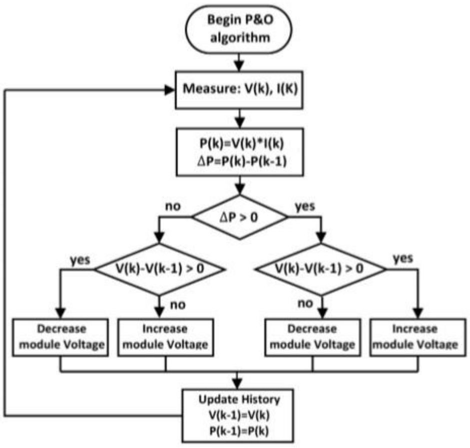

Fig.5 Flowchart of P&O algorithm

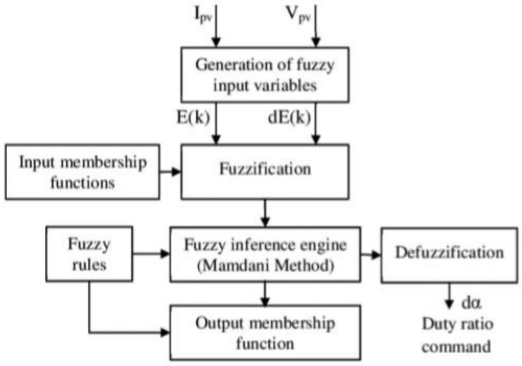

Fig.6 Flowchart of Fuzzy Logic algorithm

The conclusions of [16,6] The fuzzy logic MPPT guarantees a fast response time with very low relative ripple rate and proves that it is robust to atmospheric variations. Hence, in our system we implement a Fuzzy Logic Based MPPT DC-DC Converter.

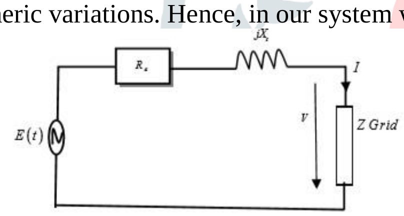

Fig.7 Representation of Power System

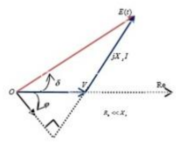

Fig.8 Phasor dia. of Power System

φ is the angle power between the grid voltage and the inverter output. And, δ is the load angle between the grid voltage and the inverter output voltage

The relationships of inverter and grid voltages are expressed:

$E(t) = V + (R_a + jX_s) I$

The active power (P) and the reactive power (Q) can be expressed as, considering $R_a << X_s$

$$P = \frac{1}{2} V_m I_m \cos\varphi = VI\cos\varphi = \frac{V}{X_s} E \sin\delta$$

$$Q = \frac{1}{2} V_m I_m \sin\varphi = UI\sin\varphi = \frac{V}{X_s}(E\sin\delta - V)$$

A PID controller may be considered as an extreme form of a phase lead-lag compensator with one pole at the origin and the other at infinity. Similarly, its cousins, the PI and the PD controllers, can also be regarded as extreme forms of phase-lag and phase-lead compensators, respectively. A standard PID controller is also known as the "three-term" controller, whose transfer function is generally written in the "parallel form" given by[17]

$$G(s) = K_P + K_I \frac{1}{s} + K_D s = K_P\left(1 + \frac{1}{T_I s} + T_D s\right)$$

where is the proportional gain, the integral gain, the derivative gain, the integral time constant and, the derivative time constant. The "three-term" functionalities are highlighted by the following.

• The proportional term—providing an overall control action proportional to the error signal through the all-pass gain factor.
• The integral term—reducing steady-state errors through low-frequency compensation by an integrator.
• The derivative term—improving transient response through high-frequency compensation by a differentiator.

Fuzzy logic control technique is an advantageous technique which is recently used in maximum power point tracking systems. it is robust and an efficient technique which operates at the optimal point without oscillations. Its concept relies on fuzzy sets and linguistic rules. Indeed, this intelligent technique has been introduced because it treats the non linearity of the system and it does not require an accurate mathematical model. [18]

Fuzzy controller is made up of two parts, general PID control and fuzzy consequence. The essential of fuzzy consequence is a fuzzy controller, but its input is the warp e and the change of warp ec, the output are KP,KI, KD [19]

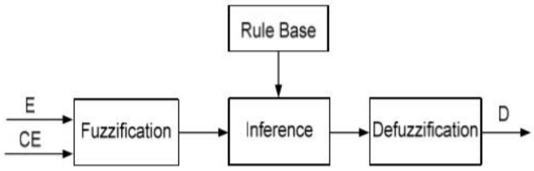

Fig.9 Structure of Fuzzy-PID logic Controller

The first fuzzification stage aims to convert numerical input variables into linguistic variables. In the second stage, a rule inference table is made while considering Sugeno inference theory, providing finally a concrete output value. [18]

The FLC analyzes the PV output power for each sample (time_k). It then determines the change of power with respect to the voltage (dp / dv). If this result is greater than zero, the algorithm changes the duty cycle of the Pulse Width Modulation (PWM) to increase the voltage to the maximum power (dp / dv = 0). If this result is less than zero, the algorithm changes the duty cycle of the PWM to decrease the voltage until the power is maximal. [5]

Fuzzification is the operation that transforms real values (net values) into fuzzy values. Fuzzy values are rankings that are sets of membership functions.

The input variables are defined by

$$E(k)=\frac{\Delta P_{pv}}{\Delta I_{pv}}=\frac{P_{pv}(k)-P_{pv}(k-1)}{I_{pv}(k)-I_{pv}(k-1)}$$

$$CE(k)=E(k)-E(k-1)$$

where Ppv and Vpv are, respectively, the power and voltage of the PV panel

The variable E (k) indicates whether the operating point at time k is situated to the left or right of the MPP, and the variable CE (k) indicates the direction of travel of this point.

The input e(t) is configured for 7 degrees with NB= Big Negative, NM=Medium Negative, NS=Small Negative, ZO=Zero, PS= Small Positive, PM=Medium Positive, PB=Big Positive

the fuzzy MPPT algorithm must be provided with a rule base. The conditions of these rules are logical expressions 'if ... then ...'. The method used for formulating the fuzzy rules is the experience and the expertise.

A rule base consisting of 49 rules is designed [4] , the inputs are E and dE/dt and the output is change in duty ratio. . Fig. 9 is the plot results from 25 rules. The output variable is the change duty ratio command, which is transmitted to the DC–DC converter to drive the load. The change duty ratio membership is given by

E(t)= { NB, NM, NS, ZO, PS, PM, PB}

E(t)= {-100,100}

dE/dt= { NB, NM, NS, ZO, PS, PM, PB}

dE(t/dt)= {-100,100}

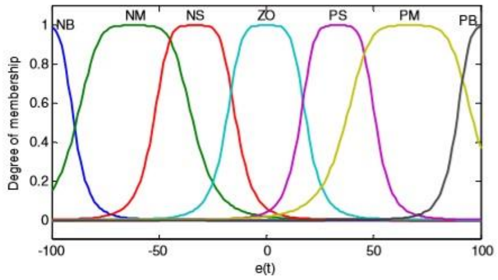

Fig.10 Memberships of the input variable e(t)

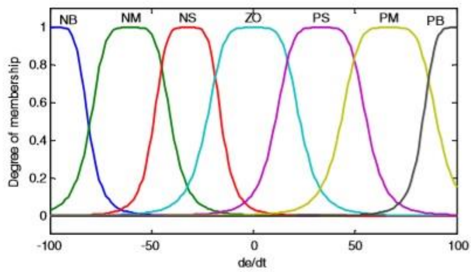

Fig.11 Memberships of the input variable de(t)/dt

The output of the fuzzy logic is the parameters of classical PID controller Kp, Ki and Kd and have same degrees {ZE, VS, MS, ME, MB, VB, VL}. Fig 7 show the truth of Kp is {0, 6}, for Ki and Kd {0,3}

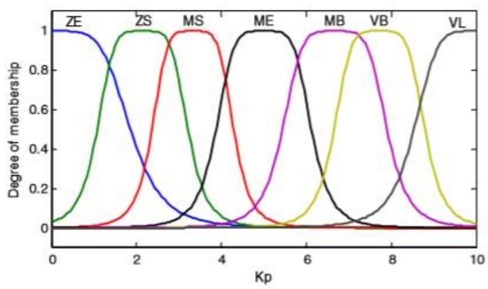

Fig.12 Memberships of the output variable Kp

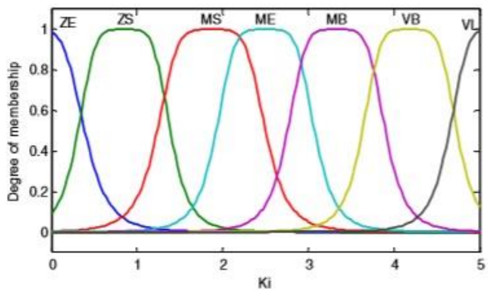

Fig.13 Memberships of the output variable Ki

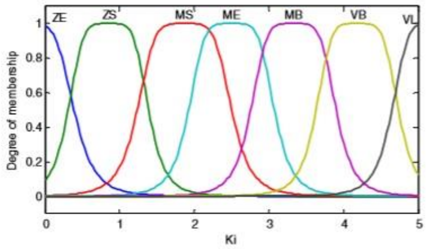

Fig.14 Memberships of the output variable Kd

The PID-Fuzzy logic speed controller is used to improve the dynamic response and reduce the steady state error

III. SIMULATION RESULTS

The complete simulink cicuit of our system is shown in Fig 15. And the Fuzzy logic based mppt ckt in simulink is given in Fig.16

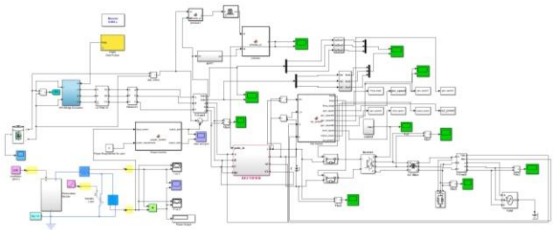

Fig.15 Simulink Model of Proposed System

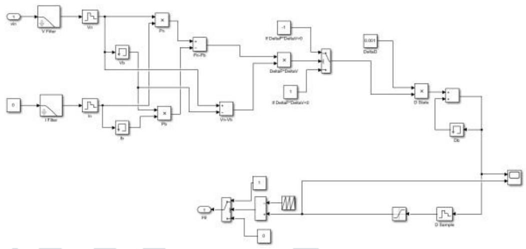

Fig.16 Simulink Model of Fuzzy PID MPPT

A power controller is designed to keep track of generated power and required power so when generated power is more than required, the excess of power is given to grid.
Combined power of battery and pv is given to mppt which is based on fuzzy pid control. The ouput of this pid block is given to inverter through a rectifier. The inverter pulses are are generated and controlled by VSI control.
Given below are the voltage and power waveforms of simulation

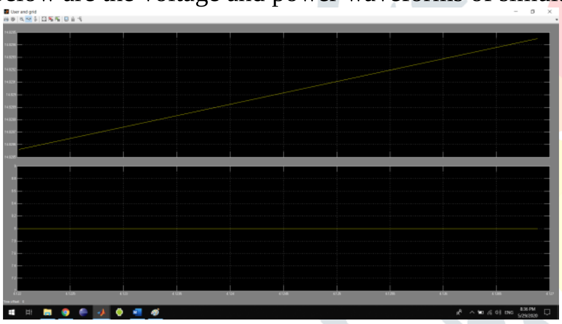

Fig.17 Power given to User and Grid

Fig.18 Output of PID controller block

The flat line is constant pv output given for local need. And the excess of generation, shown by increasing line is fed to grid.

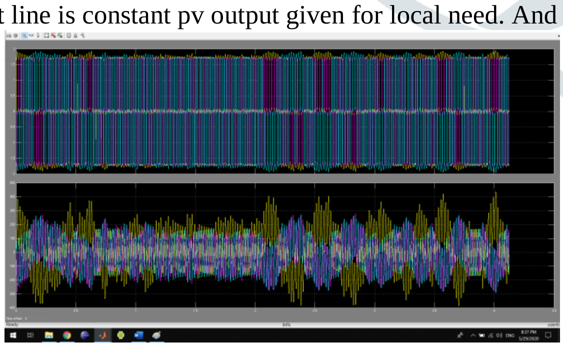

Fig.19 Power flowing through the system

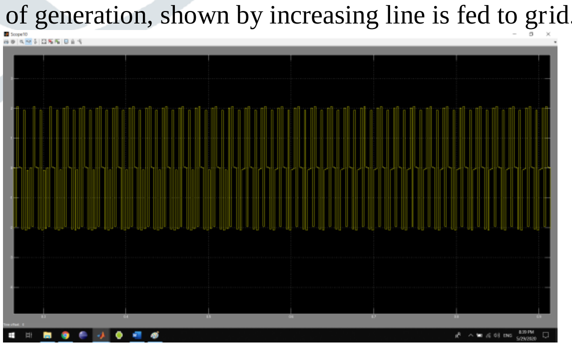

Fig.20 Controlled voltage output

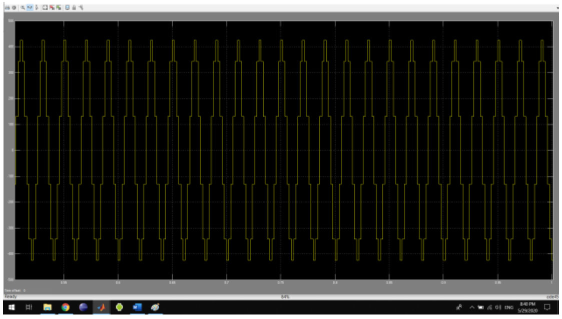

Fig.21 Grid phase voltage

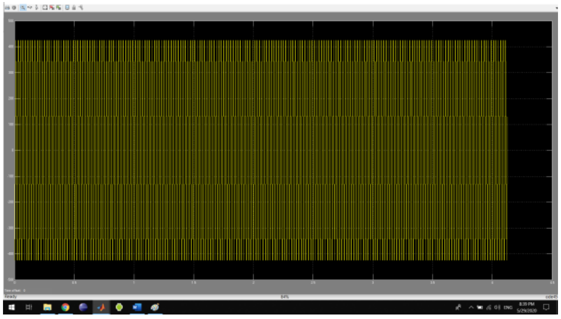

Fig.22 Grid line voltage

IV. CONCLUSION

A complete power system based module has been analysed and simulated in MATLAB/ SIMULINK software program. From the above simulation results we can say that the system gives controlled output voltage and current as per the load demand. Fuzzy PID controller stabilizes and control the current and voltage of PV. FLC can provide an efficient order for nonlinear systems because they offer additional flexibility. This system can be implemented in real and will be very beneficial from farmers point of view. The future scope of the proposed system is simulating this system taking real time data such as farmers power requirement and the amount of power need to be generated. We can also add a EHV charging station and calculate the revenue period.

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