Enhancing Renewable Energy Capture with Fuzzy Logic MPPT Control in PV and Wind Power Systems

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Abstract. There are many natural resources available in nature to produce power like solar, wind, bio-gas and hydel etc. By producing power through these resources, we can decrease the burden to the other power generation units. In this project we are using the application based on the hybrid power systems like (SWHPS). It includes solar radiation, solar panels, turbine, permanent magnet synchronous generator (PMSG), controller, converter and finally inverter. In this photovoltaic method the algorithm used is (P&O) for both power systems as a control logic for increasing the power generated using the method called maximum power point tracking system (MPPT). In this project we will show the total survey of power controller is done by P&O algorithm for both hybrid power systems, the MPPT controller is executed through Fuzzy Logic Controller (FLC) by both renewable sources in hybrid power systems. MPPT controlled boost converter is common for both power generation units. The voltage and current are the common inputs for the hybrid power systems but the wind generation unit has the extra input known as speed related to the PMSG device. The SWHPS with the Fuzzy Logic Control based MPPT exhibits for having a greater and quick run when related with the other controllers. In this the presentation of the various implementations (solar, wind) of MPPT controller are explored through this project are shown in Matrix laboratory application through simulation. Simulated outputs are in the load voltage, load current and load power of SWHPS.

1 Introduction

Non-conventional sources are giving importance as energy resources like fossil fuels prices differ continuously. Non-conventional energy resources are the vast producers which cannot deplete forever. When more than one resource is available to supply power efficiently to the consumers, the different sources can be employed for better usage to the consumers. Through this paper, two sources are taken as PV and Wind energy systems [1]. These resources give best way to gain the defendable and pollution free power generation. The exhaustion of non-renewable energy sources doesn’t make over the development for

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the hybrid grid connections. The recent method to stabilize the consumer order is by adding the RES to the unit. The significant characteristics of hybrid power system include stability, reliability, and running efficiency. This system allows overcoming the drawbacks of both the generating stations because their operation purely depends on the critical variations of weather conditions. The hybrid power system in electricity generation is the best method for gaining more reliability and less economical than the individual energy sources. In this paper for inexhaustible sources mainly the wind energy conversion system using the PMSG is the trending method for electricity generation. By installing the layered panel PMSG for converter for direct driving of PMSG for getting low wind speeds through gearbox. The gearbox adds the additional weight, core losses, and maintenance. This PMSG has no losses rotor; total losses are cramped at field winding of the stator core. In this gear loss establishment of wind power unit shows a systematic and authentic wind generation system. All alone a single solar panel can generate energy up to 2 to 3 watts. The solar panel is designed by using the two-diode method. In this the PV cells are connected in such a way that it forms as solar panel or module and this panels are arranged as same as the solar cells to form as solar array to generate the required energy. Hence, a PV module contains irradiance of arrays, MPPT, booster rectifiers and wind unit consist same with inclusion of turbine and PMSG device. Efficiency and reliability of SWHPS plays a main role in control strategy of the MPPT boost converter, without an actual logic the power units cannot run at MPP [2]. The occurrence of losses will be present when there will be no proper tracking of MPP. The required output power from a hybrid power unit will not get up to the mark if there is no presence of PV and wind energy systems. As the produced output power from the hybrid generation unit will be low with respect to the required operating range, but we can increment the voltage by using the MPPT [3-8]. By using inverter, we can convert the DC to AC power which bought from boost converter. We can increase or decrease the voltage level as per our requirement with the help of transformer. Although, the FLC has the several merits for its ruggedness, easy manufacturing and the circuit is also easy. It has the simple construction because it doesn’t want any awareness about the model; it wants only the info about the working of the prototype. Now a days, maximum controllers are replaced with the FLC’s for faster response and greater reliability.

2 Hybrid power generation module

It contains the three different stages; The generation phase, converting or transmission phase and the consumers phase or distribution phase. With this project, we are describing about the mat lab simulation of the solar and wind power systems. This developed model consists of turbine, PMSG, diode rectifier, boost rectifier, PV array to get the required output with P&O algorithm with MPPT controller [9-12]. The block diagram of developed model is shown in below figure 1
2.1 Modelling of PV modules in MATLAB, SIMULINK

The equivalent circuit diagrams for PV cells are selected by several researches by general mathematical modules are shown below. For fewer amounts of illumination levels, rather using of multi-level single diode module, the two-transistor module operation is flexible and better. The two-transistor analogy of PV cell comprises of photo current (Iph), two currents of transistors such as (Id1) and (Id2), series resistance (Rs), shunt resistance (Rp), photovoltaic current (I orIpv) and the output voltage (V) [13-15]. We use the Kirchhoff current law for obtaining output current.

\[ I_{PV} = I_{PH} - I_{D1} - I_{D2} - I_{SH} \] (1)

Where,

ID1 and ID2 = Diode currents due to diffusion.
Given by (2), (3)

\[ I_{D1} = I_{S1} \left[ \exp \left( \frac{q*V}{N1*k*T} \right) - 1 \right] \] (2)
\[ I_{D2} = I_{S2} \left[ \exp \left( \frac{q*V}{N2*k*T} \right) - 1 \right] \] (3)

Where,

IS1, IS2 = Reverse saturation currents of diode D1, D2.
q = Charge on electron (1.602*10^{-19} C)
V = Cell output voltage
N1, N2 = Quality factors of diode D1, D2

K = Boltzmann constant (1.38*10^{-23})

T = Junction temperature.

The above parameters are used to construct the mathematical module of a photovoltaic cell to copy the recorded/practical PV cell.

We can get this by rephrasing the equations (2), (3), (4), (5).

\[ I_{D1} = I_{S1} \left[ e^{(V + RS \cdot I /N1 \cdot VT)} - 1 \right] \] (4)

\[ I_{D2} = I_{S2} \left[ e^{(V + RS \cdot I /N2 \cdot VT)} - 1 \right] \] (5)

Where,

VT = (NS*k*T/q) known as Thermal voltage with NS as no-of cells connected in the series, and current of shunt resistance is termed as below (6):

\[ I_{SH} = [V+ (RS*IPV) / RP] \] (6)

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**2.2 Wind power system (turbine) and PMSG modelling**

- Turbine’s power output (mechanical)
- \( \lambda = \text{Rotor speed ratio} \)
- \( \theta = \text{pitch} \)
- \( \rho = \text{density} \)

Fig. 3. Designing of PV power system using MPPT control
The equation-based modelling of the wind power system and PMSG in matrix laboratory/simulation is performed by (8), (10). PMSG parameters are taken into consideration from (17).

Fig 4. Designing of wind power system using MPPT control

Above figure shows the MPPT implementation of wind energy unit using P&O algorithm. The various inputs for PMSG are current, voltage and speed. The voltage and various speeds of the turbine are used to calculate the current. The duty cycle is measured from the range of errors and measured current. Wind system operation at the MPP is controlled by the duty cycle [16-18]. The implementation of fuzzy controller using P&O algorithm is done by selecting a certain suitable like errors and change in the errors. All these are considered with photovoltaic input currents and voltages and the output is generated using duty cycle (19). The fuzzy logic control of P&O algorithm has some rules and they are given as;

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2.3 Implementation of control logic of MPPT

For the PV and wind-based power generation boost converters are controlled by the MPPT. The voltage and current are used as the input signals for the PV power system and speed of
the PMSG is considered as the additional input for the wind power system. The algorithm used for both the power system for MPPT controller is P&O algorithm. The PV panel gives current and voltage as the inputs for the MPPT [19]. Control logic uses the inputs and determines the duty cycle for the required amount of output voltage. The MPPT helps for continuous tracing of the power generation by the use of control logic and helps to reach the required value. For wind power generation system also the MPPT is implemented with the same algorithm. Error or change in error is used to determine or calculate the duty cycle of the thyristor or switch which presents in the boost converter for controlling the generation of the power at the MPPT.

**Fig.5.** Boost converter for MPPT controller for P&O algorithm.

### 3 Simulation Diagram and Results

**Fig.6.** Simulation diagram
Fig. 7. Solar panel irradiation

Fig. 8. Wind turbine speed
Fig. 9. Grid output voltage
4 Conclusion

In this paper, the wind and PV generation modules with relevant boost converters and MPPT controller along with FLC are used for Mat lab/simulation. This new method (FLC) is used to compare with the conventional MPPT methods. Every module is examined with various disturbances for both solar radiation and photovoltaic temperature. During different environmental conditions, the suggested techniques show efficient results in the simulation. The proposed model with FLC will show greater results with high reliability, faster in response, flexible, and easy to understand when differentiated with the non-renewable energy sources. When both the methods are compared with their power tracking efficiencies, the developed model has a greater impact than the conventional methods.

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