MODELLING AND SIMULATION OF A HYBRID GREEN SOURCE GENERATION WITH MPPT CONTROL FOR A STANDALONE POWER SYSTEM

DEEPIKA.S[1], SATHISHKUMAR.R[2]
[1]Post Graduate Scholar, Department of EEE, Anna University, Regional Centre-Madurai, India
Email: deepikasankar06@gmail.com
[2]Faculty, Department of EEE, Anna University, Regional Centre-Madurai, India
Email: rskgct@gmail.com

Abstract: *The depleting fossil fuels reserves and increasing concern towards global warming have created the need to surge for the alternative power generation resource. Renewable energy resources like Wind, Solar, biogas, biomass and fuel cells are gaining eminence nowadays, whereas they are no/ low pollutant, more energy efficient and also they serve as a promising solution for recent year's energy crisis. This paper proposes an Hybrid Wind/Solar/Fuel cell (FC) alternative energy system for Stand-alone applications. Wind and PV are the primary power resources of the system, and an FC is used as a backup. Due to the Intermittent Nature of Solar and Wind, Maximum Power Point Tracking (MPPT) is used to extract maximum available power from the Wind and Solar. The Standard Perturbs and Observes method of MPPT with boost converter is used for both PV and Wind generation system. The novelty in MPPT control is achieved by simulink model rather than embedded MATLAB function module. An overall power management strategy of the proposed system is to manage power flows among the different energy sources and the storage unit in the system. For the proposed system, using MATLAB/Simulink a simulation model has been developed.*

Keywords: *Hybrid Energy system, Renewable Sources, MPPT, P&O method, Power Management.*

1. INTRODUCTION

The constantly increasing consumption of energy, the exhaustible nature of fossil fuel and its ever increasing cost and global environment worsening have created interest in green power generation systems. A hybrid renewable energy system is the combination of two or more energy sources, usually Solar and Wind power. The Leading advantage of Hybrid system is reliability enhancement of the system. Also, battery size can be reduced as the Solar and Wind Energy sources are complementary in nature. The Wind and Solar energy power generation growth has exceeded the most optimistic estimation. The suitable alternative energy resources is growing more intensively in order to reduce the dependence on fossil fuels [2],[3].

FC's also showing great potential to be future source because of its merits and quick progress in FC technologies. i.e. Fuel cells have high efficiency, high reliability, low/no carbon emissions due to the limited number of moving parts and longer life than batteries. Hence this paper proposed a standalone hybrid system which consisting of Wind, Solar and Fuel cell as an alternative energy system [1],[5].

To take considerable advantage of renewable energy, the primary resources of the system are Wind and Solar, and for back-up, FC with Power Deficit Controller is used. To extract maximum available power from PV module and wind under varying operating conditions Maximum Power Point Tracking algorithm is used [4],[6].

In Solar conversion system, MPPT is achieved with the DC to DC converter which operates PV module at its maximum power point by using the Standard P&O (Perturb and Observe) Algorithm. Similarly, in Wind Energy conversion system proposed P&O method is used to extract peak power from wind mill.

2. SYSTEM CONFIGURATION

2.1. Simplified Block Diagram

The Fig.1 shows a simplified diagram of a Hybrid stand-alone DG system comprising PV, WT and FC. The power available from PV and WT feeds the load, and when there is power deficit, the FC-power deficit controller combination turns the hydrogen into electric power and serves the load demand.

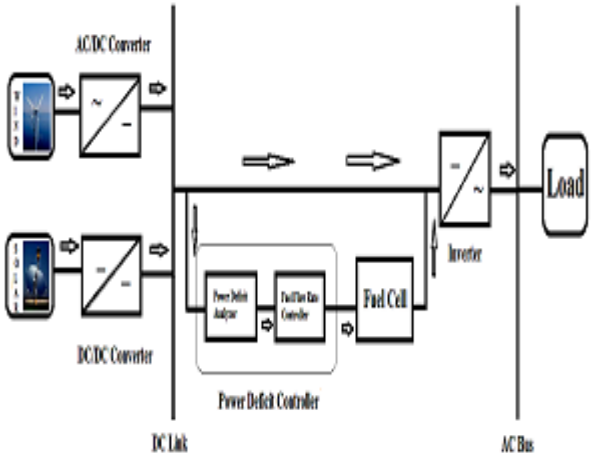

Fig.1: Simplified Block diagram Representation

2.2. Photovoltaic Conversion System

Solar cells are semiconductor devices which coverts solar radiation (sun light) into a direct current. When the surface of the PV cell strikes by sunlight, will yield electric field which provide momentum and stimulates electrons resulting flow of current when the cell is connected to an Electric Load. The physical block of PV array is the solar cell, which is basically an P-N junction semiconductor which converts the light energy directly into Electricity. The Structure of an solar cell and its equivalent circuit is shown below.

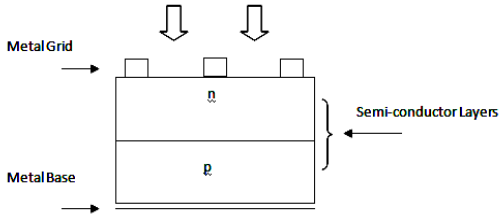

Fig.2: Physical Structure of Solar Cell

A current source parallel with a diode consists the Equivalent circuit of a solar cell as shown below.

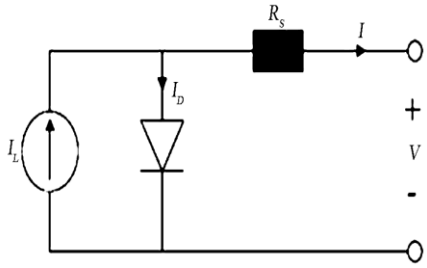

Fig.3: Equivalent circuit of Solar Cell

The output power of PV panels using a set of separate vertical and horizontal components of the solar irradiation data is calculated based on the following conventional model :

$$P_{PV} = \frac{G}{1000} \times P_{PV,rated} \times \eta_{PV,conv} \quad (1)$$

where,

$\hat{G}$ is perpendicular irradiation at the surface of an Pv array (W/m^2), $P_{PV,rated}$is rated power of each PV array at Ĝ=1000 W/m^2, and $\eta_{PV,conv}$ is the efficiency of the PV with Maximum Power Point Tracking (MPPT), connected to it.

2.3. Wind Conversion System

Wind is simply air in motion. Wind Power is converted into Electricity using Wind Turbine-Electric Generator set. The production of Electricity by Wind Energy depends on the velocity of wind acting on the wind turbine. This variable speed wind turbine is self-regulating with a permanent magnet alternator. Wind Energy Conversion systems produce electrical energy by harnessing the Kinetic energy. Like the other renewable energy resources, wind energy is clean and safe.

Power Extraction:

The power from the wind is given as

$$P = 1/2\rho AV^3 \quad (2)$$

Where,
P= power output in watts.
ρ= air density in kg/m^3
A= swept area of blade in m^2
V= Wind speed in m/sec
Since ρ and A are constants for wind mills, the power output varies proportional to the cube of speed.

2.4. Fuel cell – Power Deficit Controller

2.4.1. Fuel cell:

Fuel cells are known to be Electrochemical device which produce electrons by chemical reaction. Proton Exchange membrane is the most common type Fuel cell used in small and large scale power system applications which has reliable performance under intermittent supply. This type of fuel cell is commercially available for stationary generation, industrial scale capacities and which has dynamic response time of 1 - 3 s. Here, PEMFC stacks were applied to enhance the performance of the hybrid system.

The Figure shown below is the electrical equivalent of fuel cell. E is thermodynamic potential, Ra is the activation resistance and Rint is the fuel cell internal

resistant. The Equivalent circuit of dynamic fuel cell can be modelled by addition of parallel capacitor c as shown below.

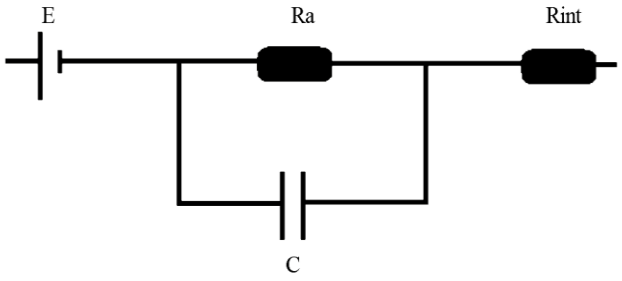

Fig.4: Equivalent Circuit of Fuel cell

A simplified model to compute the output power of the fuel cell is the product of its efficiency and power of the input Hydrogen:

$$P_{FC-inv} = P_{tank-FC} \times \eta_{FC}$$
(3)

The same story as for fuel cell stands true for inverter namely the calculation of power by efficiency:

$$P_{inv-load} = (P_{FC-inv} + P_{ren-inv}) \times \eta_{inv}$$
(4)

Where ηinv is the efficiency of the inverter. For the satisfied working range of the inverter the efficiency should be roughly maintained constant.

2.4.2. Power Deficit controller:

The Controller arbitrarily analyze the solar irradiation level and wind speed level, when there is decrement in any of these parameters it leads to power deficit. Hence the controller analyzes the range of power deficit and decides the fuel flow rate for the PEM-FC stack and supplies fuel to the FC stack to generate electricity to meet the Load demand.

3. MAXIMUM POWER POINT TRACKING (MPPT)

The Maximum Power point Tracking (MPPT) is necessary to draw maximum available power from the PV array/wind mill. The Perturb and observe method is the standard method because of its simplicity and ease of implementation. It is also known as 'Hill Climbing' method. The voltage and current are extracting from the output of PV-array module/Wind generator to find out power. Change in power is calculated by comparing the extracted power with transport delay block. If Power change is positive then enters into the loop to check the voltage condition, if the output is positive after comparison of present voltage and previous voltage then voltage gets Incremented and generate pulse. Else the loop continuous until the voltage is positive.

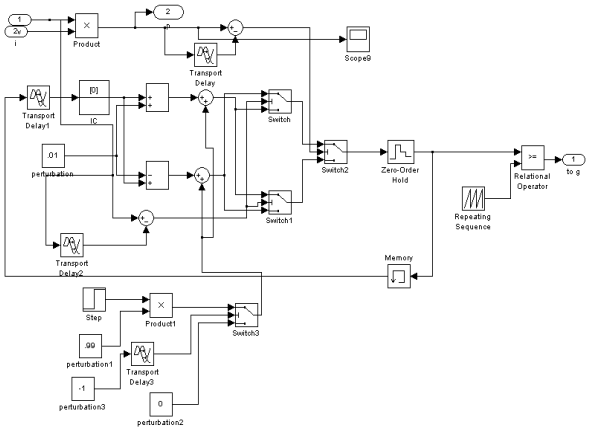

Fig.5 SIMULINK model for MPPT_(P&O method)

3.1.MPPT for Solar

In solar conversion system, PV array is necessary to operate at peak power point at any time to improve its efficiency for satisfactory results. The aim of MPPT is to operate at peak point in spite of change in temperature and solar radiation. Because temperature and solar radiation changes cause the operating point of PV away from the MPP so that efficiency of the system will decline. Here P&O method MPPT with dc-dc converters connected to the PV system with the load. The primary purpose of MPPT control is to regulate the MOSFET's duty cycle in order to kept the PV array on MPP. This algorithm arbitrarily measures the increments/decrements of the voltage and current of the PV array. This method has an advantage of direct array voltage measurement so that requires lower cost where as other methods need solar radiation level and other environmental factors.

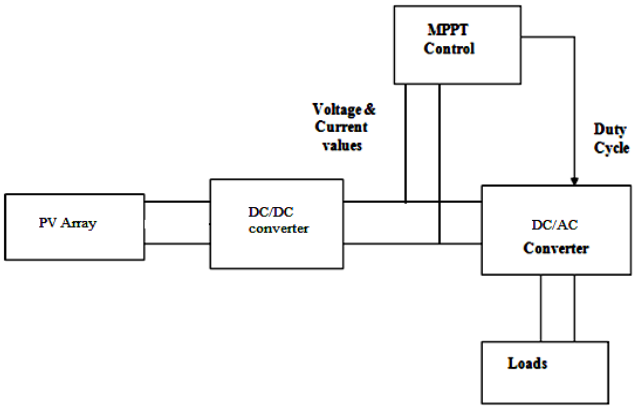

Fig.5: Block Representation of MPPT-Solar

3.2. MPPT for wind

The Wind generator constitutes Wind Turbine coupled with Permanent Magnet Synchronous Generator (PMSG). The three phase diode Rectifier is used for converting AC voltage to DC voltage and then fed to the MOSFET where ratio of the input-output voltage is controlled by a Pulse Width Modulation (PWM) signal from MPPT controller. The P&O algorithm measures the generated voltage and current values arbitrarily measured taken as inputs of the MPPT controller and the duty cycle of the MOSFET changes proportionally with inputs increment/decrement. i.e. Increase in duty cycle results increase in power output and the direction of perturbation signals same as previous cycle and as contradiction change in duty cycle produces a decrease in power, then the direction of perturbation signal is reversed.

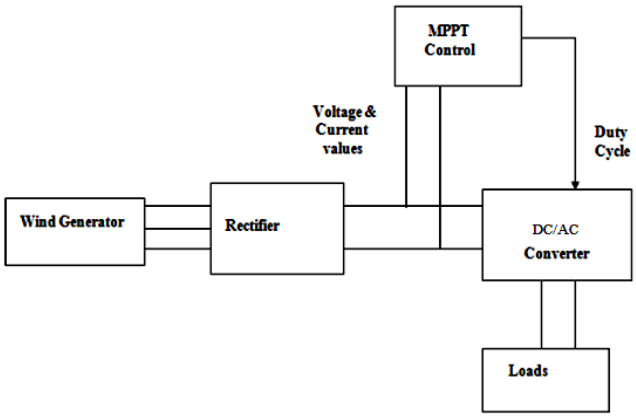

Fig.6: Block Representation of MPPT-Wind

4. SIMULATION RESULTS

For the proposed Hybrid Wind/Solar/FC-Power deficit controller energy system, a test bed simulation has been developed using MATLAB/Simulink. In order to validate the system performance, the simulation case studies have been carried out with ambient solar Irradiation and wind Velocity.

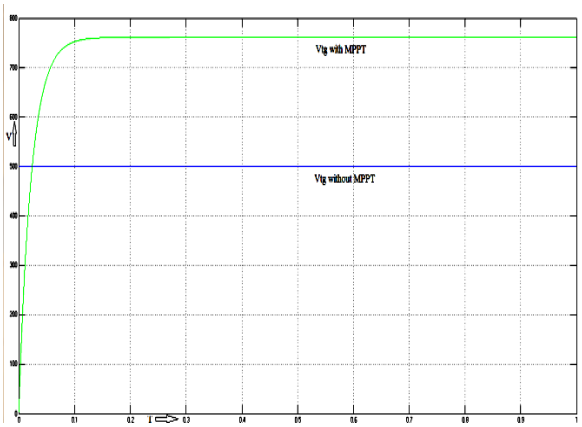

Fig.7: Solar Energy with and without MPPT

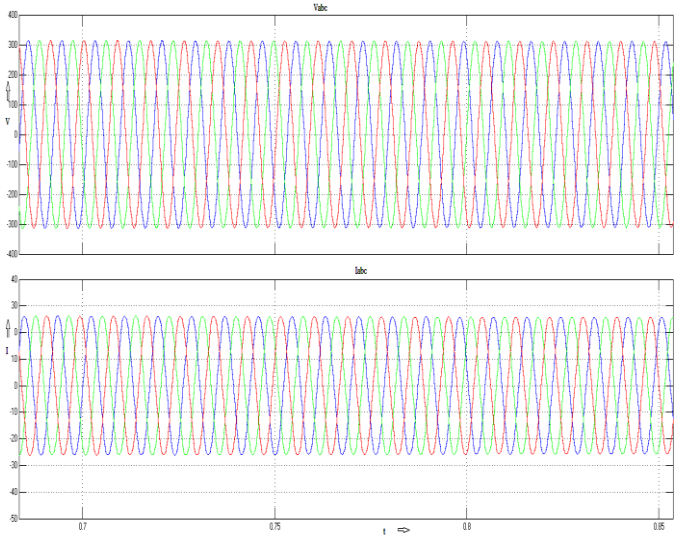

Fig.8: Wind Generator-PMSG Output Power

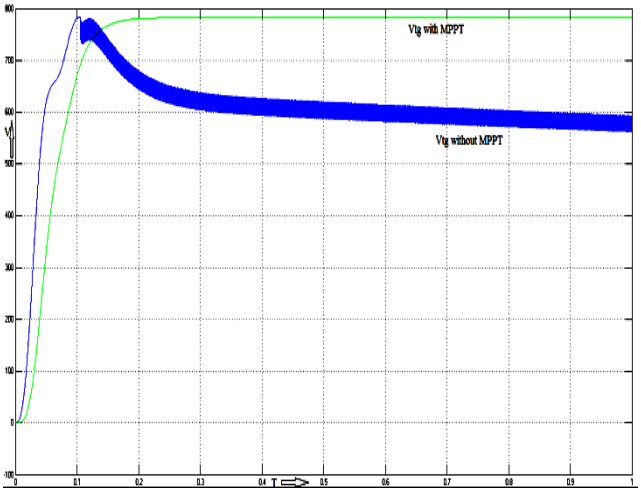

Fig.9: Wind Energy with and without MPPT

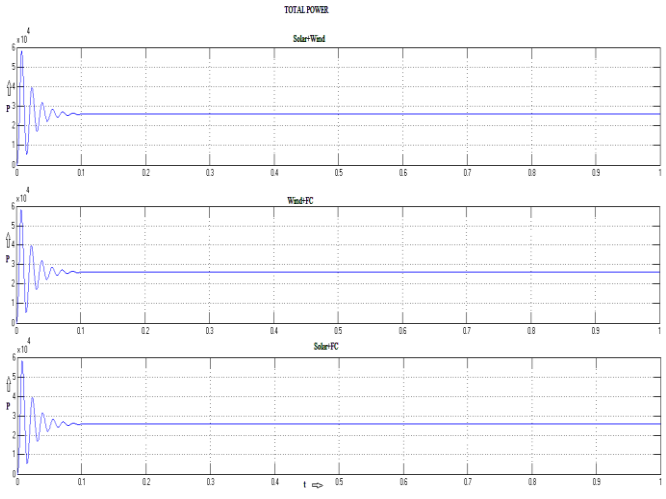

Fig.10: DC Output Power Waveforms of Hybrid Energy System with different energy Resource combination

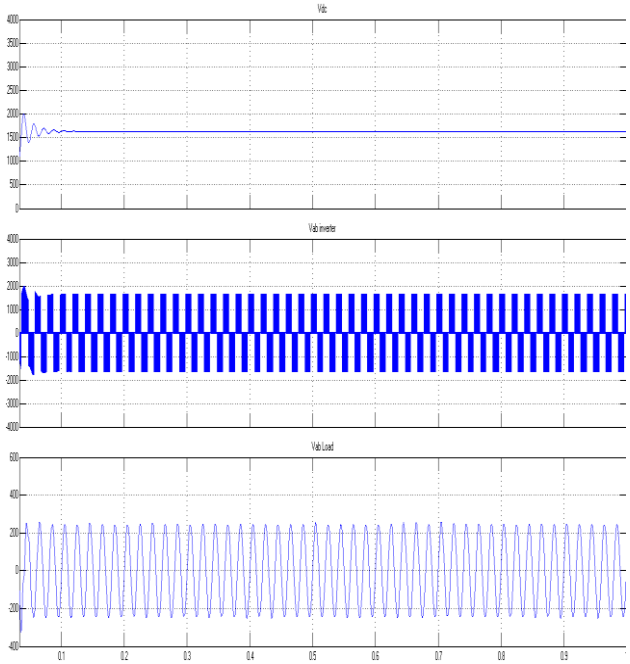

Fig.11: Inverter Output and AC Output power Waveforms of Hybrid Energy System

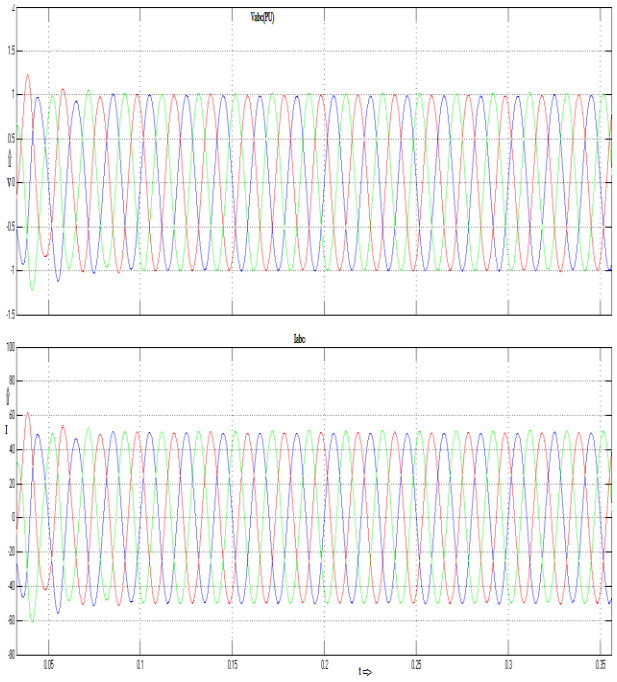

Fig.12: Three Phase Current and Voltage Waveform

5. OVER-ALL POWER MANAGEMENT STRATEGY

Power Flow Management Strategy of the system is according to the following rules:

1) If the wind and solar generations equal the load demand, then the total power generated by renewable sources alone is injected to the load. Hence, the Power balancing equation can be given as:

$$P_{Load} = P_{Wind} + P_{PV}, P_{sys} = 0 \quad (5)$$

2) If load demand exceeds the power generated due to unavailability of sufficient wind and solar source, Power Deficit occurs; the fuel cell will come into action. Hence, the Power balancing equation can be given as:

$$P_{Load} = P_{Wind}/P_{PV} + P_{FC}, \; P_{sys} < 0 \quad (6)$$

6. CONCLUSION

Renewable energy resources like Wind, Solar, biomass, biogas and fuel cells are gaining eminence nowadays, as they are reduce pollution, more energy efficient and also they serve as a promising solution to the recent year's toughest energy crisis. A complete model simulating the proposed Hybrid wind, solar and fuel cell generation system is done using MATLAB/Simulink. The MPPT controller has been developed for both the wind and solar energy resources. The simulation results showed satisfactory performance of the hybrid system.

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