DEVELOPMENT OF HYBIRD PHOTOVOLTAIC-WIND GENERATION SYSTEM

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ABSTRACT
Recent development of small-scale energy technologies and global increase in the energy demand has made the renewable energy systems more popular. Renewable energy sources such as the sun, wind etc offers clean and abundant energy depending on weather conditions. Hybridizing solar and wind power sources provide a realistic form of power generation. This paper outlines the design of a hybrid power system consisting of solar photovoltaic (PV) power system, wind power system and battery storage. A control strategies for hybrid wind/photovoltaic energy system is proposed. The wind and PV are used as main energy sources, while the battery is used as back-up energy source. The paper presents the state of the art of stand-alone hybrid solar and wind systems. The modeling of hybrid system is developed in MATLAB- SIMULINK.

General Terms
Renewable Energy System, Hybrid System, Photovoltaic System, Wind System.

Keywords
Hybrid renewable energy, Photovoltaic, Wind energy, Stand-alone.

1. INTRODUCTION
In the past few decades, because of severe depletion of traditional energy resources and environment concerns, the renewable energy resources have become more important worldwide [1]. The critical condition of industrial fuels has led to steady improvement in the growth of renewable energy sources. Unlike fossil and nuclear energy sources, the renewable energy sources such as solar, wind, hydropower, ocean, biomass etc do not cause pollution. Out of all these renewable sources solar and wind energy are the world's fastest evolving energy resources because of their many advantages like pollutant free, low cost, easy availability and very less or zero emission of pollutant gases. The main drawback of solar and wind energy system is it's unpredictable nature and dependence on seasonal weather conditions [2]. Combining the two sources of solar and wind can provide better reliability and their hybrid system becomes more economical to run since the weakness of one system can be complemented by the strength of the other one.

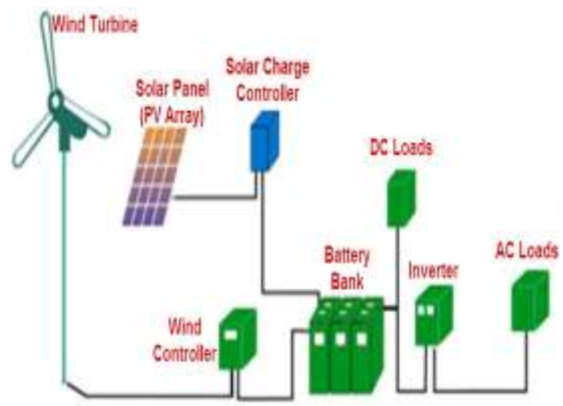

Fig.1 Block Diagram of Proposed Work

The integration of hybrid solar and wind power system can reduce the total lifecycle cost and the size of energy storage needed to standalone power supplies in many situations, while at the same time the combination of energy sources provide a more reliable supply of electricity.

This paper presents the modeling and simulation of standalone Hybrid Photovoltaic-Wind generation system using MATLAB/SIMULINK. It includes the design of PV panel with equation and includes the equation that forms the wind turbine. The two systems are combined to operate individually and simultaneously. Finally the simulated result of the hybrid system is presented.

2. MODELING OF POWER SOURCES

2.1 Modeling of PV Cell
The photovoltaic system converts sunlight directly to electricity without having any destructive effect on our environment. The

basic segment of PV array is PV cell, which is just a simple p-n junction device. A PV array consists of a large number of PV cells in series and parallel connections. It is the combination of many PV modules. A solar cell can be modeled by a current source and an diode which is inverted is connected in parallel to it. It has its allowable series and parallel resistance [3].

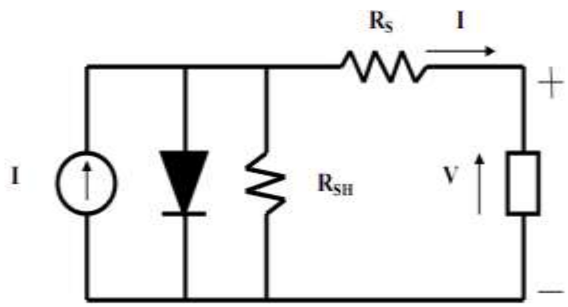

Fig.2 Equivalent circuit of a PV cell

The output current from the PV array is

$$I = I_{sc} - I_d \qquad (1)$$

$$I_d = I_o(e^{\wedge}qV_d / kT - 1) \qquad (2)$$

where,

Io = reverse saturation current of the diode,

q = electron charge,

V_d = voltage across the diode,

k = Boltzmann constant (1.38 * 10 19 J/K) and

T = junction temperature in Kelvin (K).

From equ. 1 and equ. 2

$$I = I_{sc} - I_o(e^{\wedge}qV_d / kT - 1) \qquad (3)$$

By suitable approximations,

$$I = I_{sc} - I_o(e^{\wedge}q((V + IR_s)/nkT) - 1) \qquad (4)$$

where,

I = photovoltaic cell current,

V = PV cell voltage,

T = temperature (in Kelvin) and

n = diode ideality factor.

2.2 Modeling of Wind Turbines

Wind energy is an environment friendly and endless source. Therefore, For future demand a wind energy generation system is one of the best sources of alternative energy.

A wind turbine converts kinetic energy of air i.e. wind power into mechanical power i.e. rotating motion of the turbine that can be used directly to run the machine or generator. The magnitude of this converted mechanical energy depends on the air density and the wind velocity. The wind turbine model is based on the study of the steady-state power characteristics of the turbine. Power captured by wind turbine blade is a concomitant of the blade shape, the pitch angle, speed of rotation, radius of the rotor. The wind power (Pm) that is developed by the turbine is given by the equation:

$$P_m = \frac{1}{2}\rho A v^3 C_p(\lambda, \beta) \qquad (5)$$

Where,

P_m: Mechanical output power of the turbine(W)

CP = performance coefficient of turbine

ρ = air density (kg/m3)

A = area of turbine blades (m3)

v = wind velocity (m/sec)

λ = tip speed ratio

β = blade pitch angle (deg).

The pitch angle, β, refers to the angle in which the turbine blades are aligned with respect to its longitudinal axis.

The coefficient CP is the fraction of kinetic energy which is converted by wind turbine into mechanical energy. It is related to the tip speed ratio (λ).

The term λ is the tip-speed ratio, given by the equation:

$$\lambda = \frac{R\omega_b}{v_w} \qquad (6)$$

where ,

R = turbine radius

ω_b = angular rotational speed

3. CONTROL STRATEGY OF HYBRID PHOTOVOLTAIC/WIND SYSTEM

The control strategy has an important role in system operation. A proper control system increases the power availability, system efficiency, battery life and the amount of power generation. It also decreases the number of deficit hours, the engine operating hours and the amount of dumped power.

The electric generation hybrid systems (EGHS) capable to satisfy the power demand depend on the atmospheric conditions. The operation of the generation subsystems is managed through the supervisor control algorithm. For the design of the supervisor, it was decided that the Solar subsystem would be the main generator, while the wind generator subsystem would be complementary. This choice is suggested by the design already made based upon the monthly averages annual site rating. However, the supervisor applications extend to considering the wind subsystem as the main generator and the photovoltaic subsystem would be complementary.

The three possible modes of generation are determined by the energy balance between the total demand and the total generation (wind and solar).

We can have three cases:

Case 1

This mode corresponds to the periods where solar power is itself sufficient for supplying the load demand. However, the PV generator must provide the total power while the wind subsystem is supposed to be stopped and the batteries are charging. This situation is maintained so that the power required by the load does not exceed the maximum PV power. Beyond such a limit, the supervisor switches in Case 2 and activates the wind generator in the generation system. In this case, the objective of the photovoltaic system is under power control according to this reference:

$$P_{ref1\_s} = P_{required} = V_{batt.}(I_{load} + I_{batt.}) \qquad (7)$$

where,

I_{load} = the load current,

$I_{batt.}$ = the battery current, and

$P_{required}$ = the total required power

Case 2

In this case, the solar subsystem is set to track a power reference and the wind system generates the maximum power. This one is the power being required to complete the power produced by the photovoltaic generator at the same time supplying the total power load. It should be noted that in cases 1 and 2, the battery bank are not used to supply power to the load, instead they become a part of the power required. Once the maximum production limit of the hybrid system is exceeded by any power demand, as the system switches in the Case 3. while in cases 2 and 3, the PV system will produce maximum power at MPPT operation. Different algorithms can be used to extract the maximum power .

The reference power is given by:

$$P_{ref2\_s} = P_{pv}^{opt} = P_{s}^{opt} = V_{pv}^{opt}.I_{pv}^{opt} \qquad (8)$$

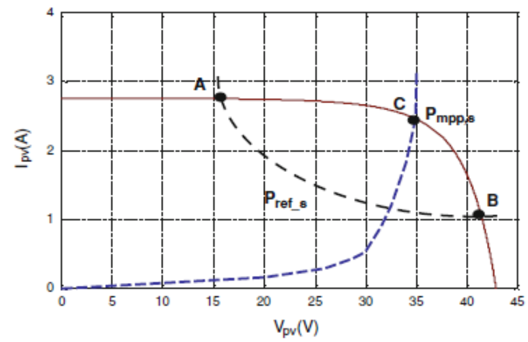

Fig. 3 Characteristics of PV panel and power reference.

When the solar power is insufficient to supply the total power required than wind system starts its operation.

The wind power reference is given by:

$$P_{ref1\_s} = P_{required} - P_{s}^{opt} = V_{batt} \cdot (I_{load} + I_{batt} + I_{s}) \qquad \text{... (9)}$$

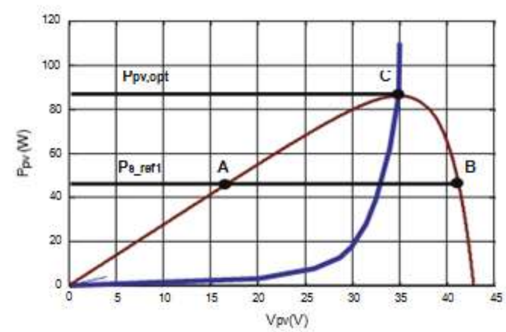

Fig. 4 Characteristic of PV power generation

Case 3

In this case, both generation subsystems (solar and wind) set to operate at their maximum energy conversion points. In addition, to supply the load demand, the battery bank are discharged or charged. At discharge, Case 3 is maintained as long as the available energy levels of the battery bank is sufficient to complete the load demand, after that, the load must be disconnected to charge the batteries. The wind system produces MPPT, the reference power is given by:

$$P_{ref2\_w} = P_{w}^{opt} = K_{opt} \cdot \Omega_{opt}^{3} \qquad (10)$$

K_{opt} ,a coefficient which depends on the ratio of tip speed and optimal power coefficient.

In Fig. 5 the intersection of $P_w(\Omega)$ characteristic with reference $P_{ref2\_w}(\Omega)$ (point C') which corresponds to the maximum power point for a particular value of wind speed. As for the operation of photovoltaic system, we remark that two operating points can develop the same reference power (point A' and B').

Operation on the right side of the point of maximum power requires a system of power control. The operating point (A') would be the most appropriate. The reference angular velocity which corresponds to the operating MPPT is given by:

$$\Omega_{ref} = \Omega_{opt} = 3\sqrt{\frac{P_{ref\,2\_w}}{K_{opt}}} \tag{11}$$

Then the supervisor decides the case (1 or 2/3) by comparing the measured mechanical speed with the reference speed.

$$P_{ref\,1\_s} = P_{required} = V_{batt.}(I_{load} + I_{batt.})$$

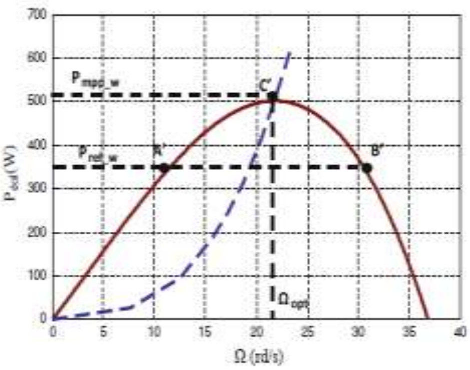

Fig. 5 Characteristic of $P_w(X)$ with photovoltaic power Reference P_{ref_pv} produced

4. SIMULATION RESULTS

4.1 Simulation results of PV module

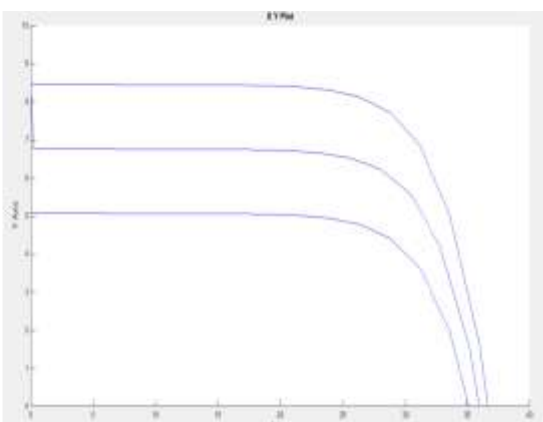

Fig. 6 V-I curve of PV panel

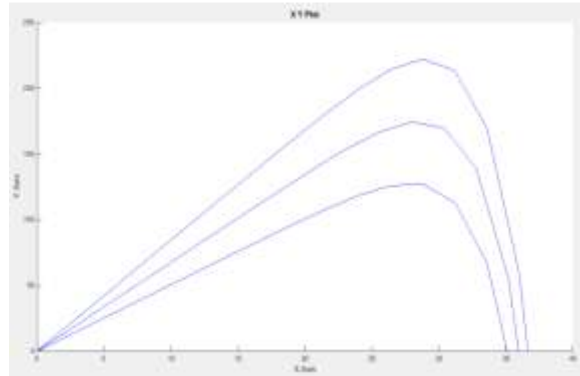

Fig. 7 P-V curve of PV Panel

4.2 Simulation results of Wind energy system

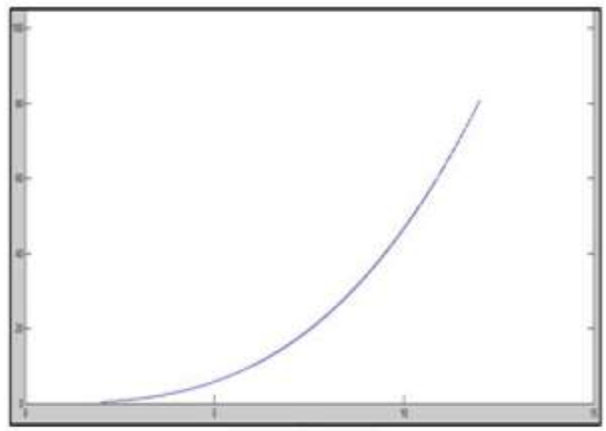

Fig. 8 Wind Power-Speed Curve

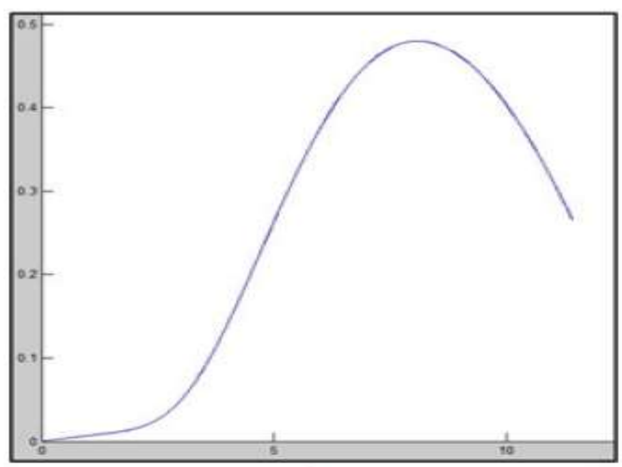

Fig. 9 Power Coefficient (C_p)- tip speed ratio (λ) curve

4.3 Simulation result of hybrid Photovoltaic-wind power plant

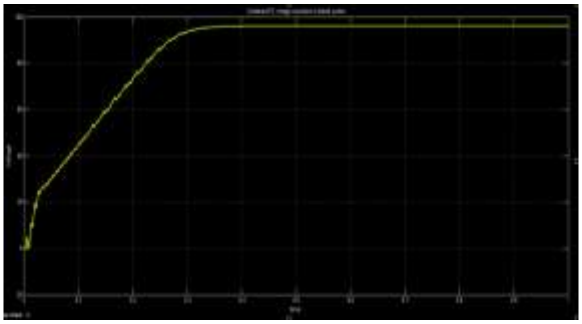

Fig. 10 Output voltage of hybrid photovoltaic-wind system

5. CONCLUSIONS

In these paper, modelling and simulation study of Hybrid PV/Wind system has been carried out in Matlab/simulink. Simulation results show that the hybrid power system can give a reliable power to the loads and it is suitable for stand-alone system. Hybrid generation system of PV and Wind energy system may increase their efficiency by increasing their overall energy output, by reducing energy storage requirement. As compared to individual energy system, hybrid system less costly and more reliable.

6. FUTURE SCOPE

- Maximum Power Point (MPP) can be tracked by using other techniques.
- For more reliable operation and better battery life, battery charge controller can be suitably designed.

7. REFERENCES

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