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Modeling and Simulation of Hybrid Solar-Wind Energy System Using MPPT Algorithm

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ABSTRACT

The contemplated hybrid system enables maximum utilization of freely existing renewable energy sources that's solar and wind energy sources. This system introduces power control strategies of a grid connected solar-wind power generation systems with a versatile power transfer. In this, an adaptive Maximum Power Transfer Tracking algorithm besides the standard perturbs and observations are employed. The system allows usage of two supply sources where loads can be separately supplied or simultaneously supplied depending on the handiness of energy sources. The most determining parameters of mechanical output from wind energy source and the solar energy sources are the turbine rotor speed and the photovoltaic cell operating voltage respectively. Coupled with a wind turbine is a PSMG for the attainability of a conversion system for wind energy and an inverter for converting direct current output from a non-conventional energy into the purposeful alternating current. The solar wind energy systems operate under normal conditions that involve normal wind speed for the case of wind energy and normal room temperature for photovoltaic energy sources.
Key words: MPPT, Photovoltaic, Wind, Power control, PSMG.

INTRODUCTION

Electric power systems are amongst the capital investment components of a contemporary economy [1, 2, 3, 4, 5]. Electric power systems involve four main parts which includes Power Generation, Power Transmission, Voltage Transformation and Power Consumption [1, 6, 7, 8]. Its normally difficult to construct transmission lines and transformation systems in most remote areas due to their nature [9, 10]. Also, many are looking at sustainable energy alternatives in awake to protect the planet for future generations as worry over global warming and the depletion of fossil fuel supplies grows [11, 12]. Above all photovoltaic, wind, and hydro power have the greatest potential to satisfy our energy needs. Even while wind energy is capable of producing vast amounts of power, it is incredibly unpredictable and may appear one instant and disappear the next [13, 14]. Similar to this, solar energy is there all day long, but the amount of solar irradiation varies due to the strength of the sunlight and the unpredictability of the shadows cast by clouds, animals, and other objects [15]. Both wind and photovoltaic systems have the inherent flaw of being intermittent, which renders them unstable. The system's power transfer efficiency and dependability can be considerably increased by merging these two sporadic sources and using maximum power point tracking (MPPT) algorithms [7, 8, 9]. One of the most recent developments in power electronics is the merging of renewable energy sources and energy storage devices [2]. In order to maintain or increase the reliability and quality of the power supply, new operational strategies for distributed generators and renewable energy sources are needed. Since integrated monitoring and control and consistency in controller structure are more convenient than a common ac type, combining multiple renewable resources via a common dc bus of a power converter has become typical [10,11,12]. Analysis is done on the dynamic performance of a wind and solar system. A model of a wind turbine system was created and contrasted with an actual system. The majority of applications are for standalone operation, with load balancing as the primary control goal. A few grid-connected systems show the grid as merely a backup option to use when the supply from renewable sources is insufficient. They were initially intended to support local load requirements with a chance of a temporary loss of power supply. However, a hybrid system that injects electricity more steadily or has the ability to regulate its power flexibly is preferable from the standpoint of utility. Users also like a system that offers a variety of power transfer alternatives since it improves system management and functioning [3]. Such a hybrid system's control techniques ought to be very dissimilar from those of conventional systems. In this paper, a grid-connected wind-Solar-battery hybrid system with flexible power transfer is dynamically modeled and controlled. In contrast to conventional systems, the hybrid system takes into account the grid's ability to dispatch its power injection. The hybrid system has three operating modes: dispatch operation, averaging operation, and normal operation without battery utilization [2].

Two modified techniques that is a modified hysteresis control approach for a battery charger/discharger and a power averaging technique utilizing a low-pass filter are used to successfully accomplish such modes of operation. The hybrid system's idea, operation, and supervisory control are described. In the control of wind turbines and PV arrays, conventional maximum power tracking techniques are used. Power System Computer Aided Design/Electromagnetic Transients Program for DC (PSCAD/EMTDC), power-system transient-analysis software, served as the foundation for dynamic modeling and simulations. The program was built using Dommel's method, which was created especially for simulating high-voltage direct current systems and is effective for simulating transients in power systems that are controlled by power electronics [4].

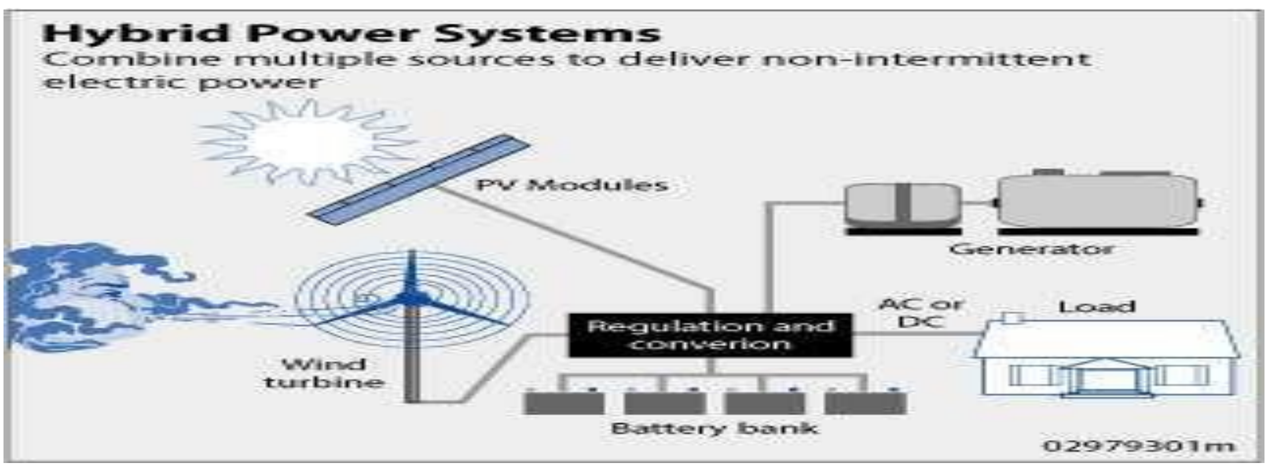

Figure 1: General Hybrid System [5]

Problem Statement

Due to several differences of Solar-Wind resources in different places, the solar-wind hybrid system design should base on the special location situation.

Purpose of the study

To model and simulate a hybrid Solar-Wind Energy System Using Maximum Power Point Tracking Algorithm

Specific Objectives

To design different schemes of a Hybrid System (Solar and Wind Energy)

To simulate the optimized schemes of Hybrid Energy systems to analyse the power supply quality

To increase the efficiency of the System

Research Questions

How to design different alternative schemes of the hybrid energy system?

What are the optimized techniques of the hybrid energy system & which is the best technique?

How to improve efficiency of the system?

Scope of the study

This hybrid system is modelled for 30MW Nakasongola Military Barracks Solar power plant in Central Uganda

Significance of the study

In a hybrid energy system, wind and solar power proportions impact the reliability and economy of the system since solar and wind resources vary from an area to another. It is very crucial to optimize and simulate the system in order to construct a solar wind hybrid system that can steadily supply power and cost effective [6].

This study will help the government and investors realize the feasibility, power supply quality, Capital cost and operational cost of the hybrid system in Uganda that will help them in decision making towards investment plans.

METHODOLOGY

Simulation

Simulation is accomplished by Simulink an environment with multi domain simulation and its model-based design for embedded systems. Simulink provides a graphical interface and also has customized set of block libraries which help in designing, simulating, implementing and testing various systems which vary with time like video processing, image processing, signal processing and in communication controls.

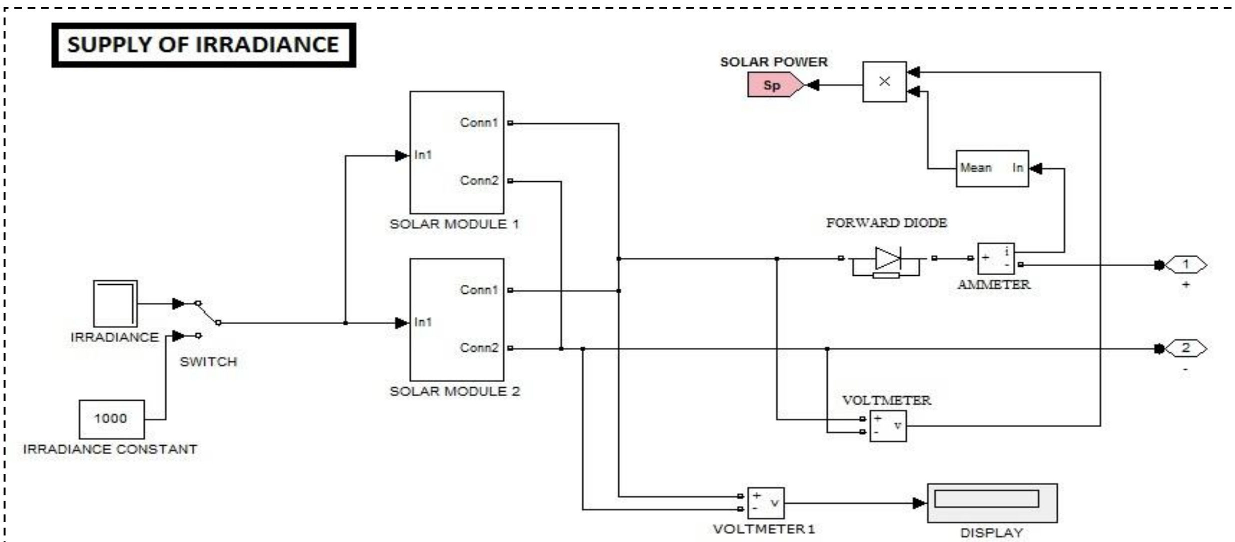

Figure 2: simulation model showing the utilization of irradiance and solar modules

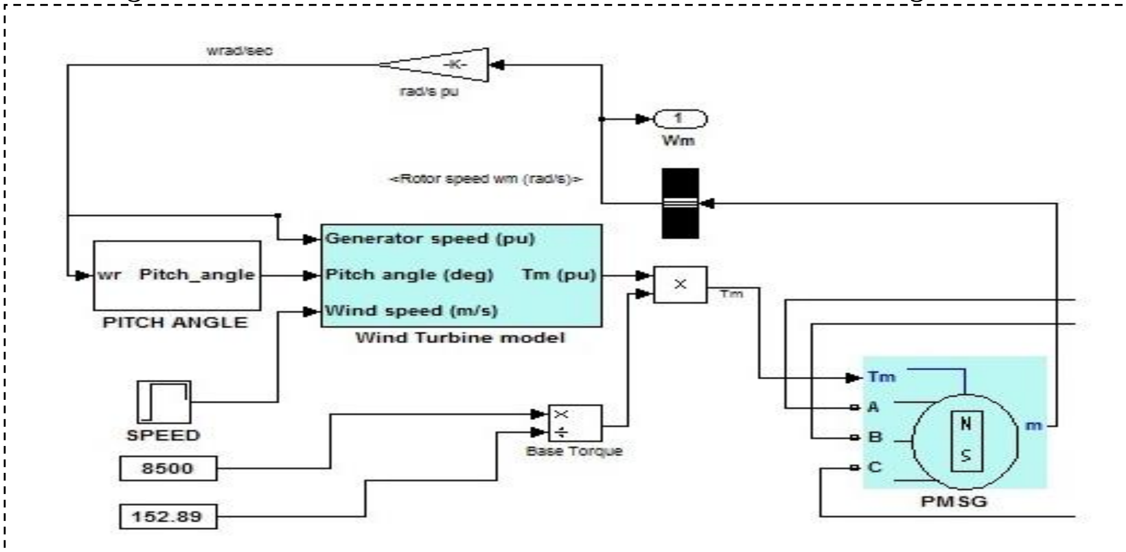

Figure 3: Wind Turbine linked with Synchronous Generator

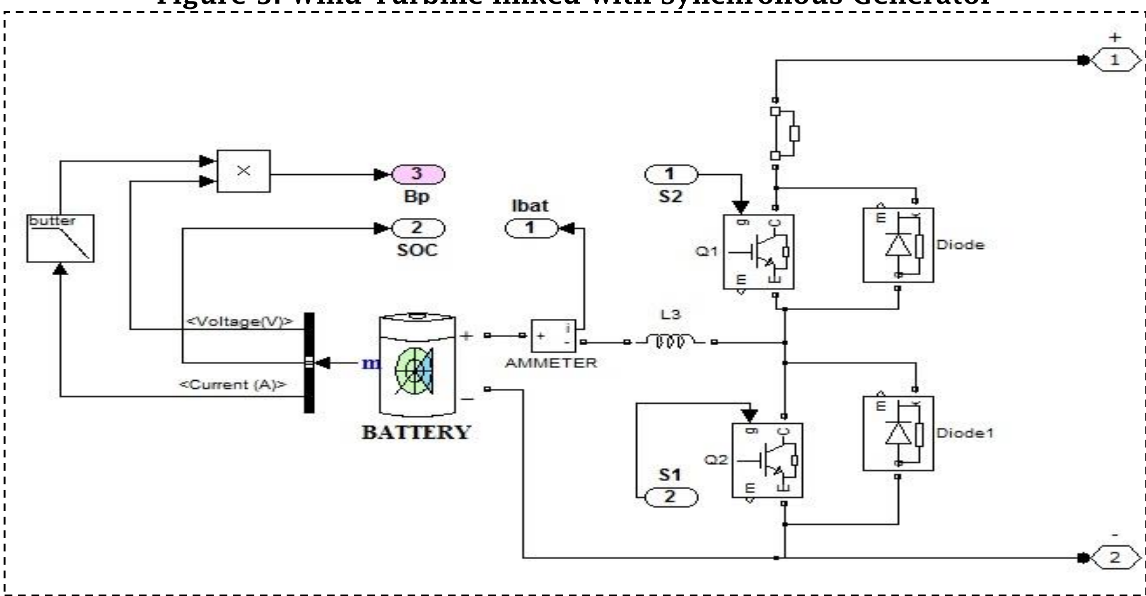

Figure 4: Battery Operation features sufficient supply to load

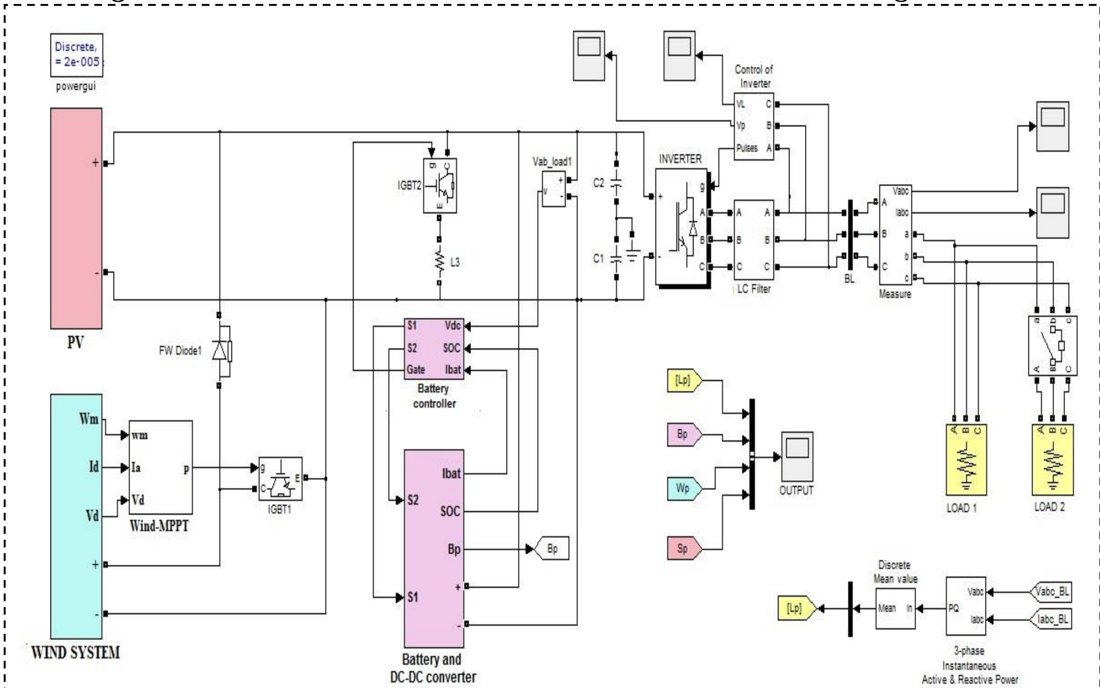

Figure 5: Composite Simulation Model of Proposed Hybrid System

RESULTS ANALYSIS AND DISCUSSION

Simulink software gives displays and scopes which help in visualizing the system. Results can also be analysed by building customizable displays using MATLAB visualization and GUI development tools.

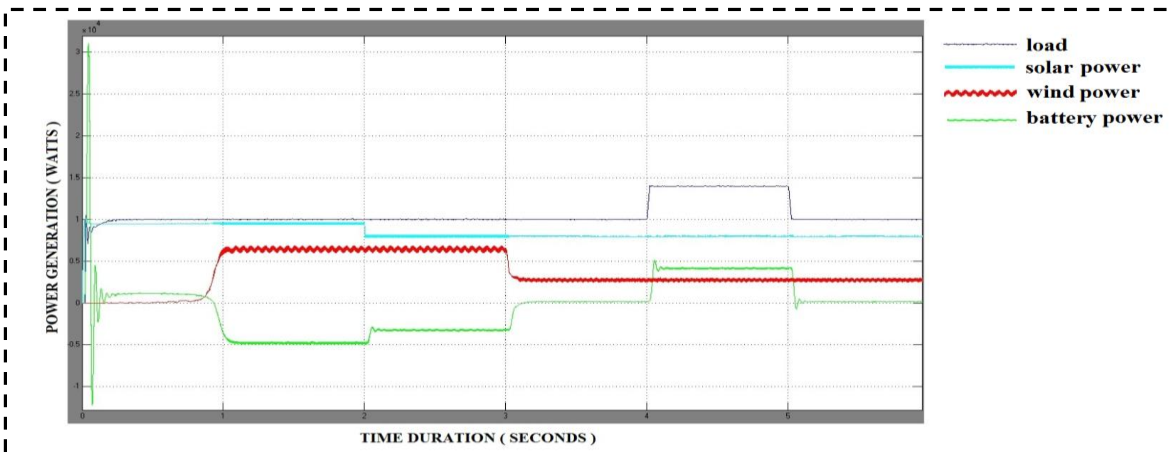

Figure 6: Load Sharing Action Performed by the Hybrid Energy in Polycrystalline Solar Panel TSP 215

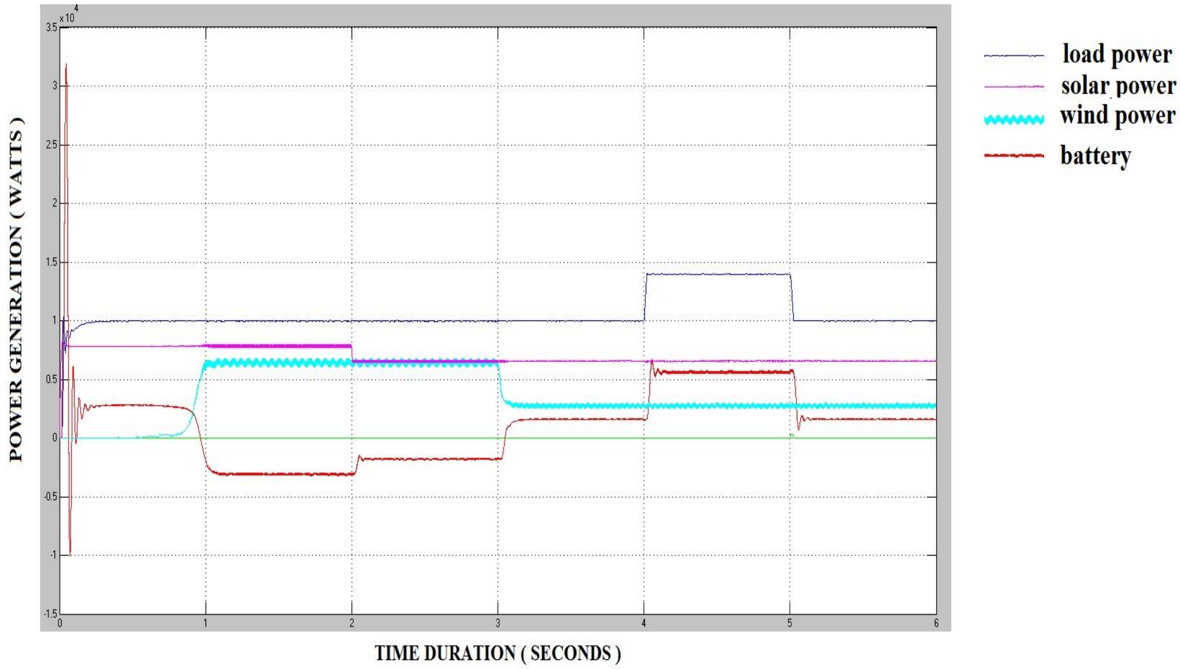

Figure 7: Load Sharing Action Performed by the Hybrid Energy in BIPV Double Glass Solar Panel TSBM 180

Table 1: Load Sharing Between Solar & Wind Systems Supported By Battery

Time (S)	Solar $*10^4$	Wind$*10^4$	Battery Power $*10^4$	Battery Action	Load $*10^4$	Remarks
0-1	0.92	0(0-0.8)	+0.08	Supplying	1	G < L
	0.92	0.03(0.8)	+0.05			
1-2	0.94	0.56	-0.05	Charging	1	G < L
2-3	0.78	0.56	-3.4	Charging	1	G < L
3-4	0.78	0.2	+0.02	Supplying	1	G < L
4-5	0.78	0.2	+4.2	Supplying	1.4	G < L
5-6	0.78	0.2	+0.02	Supplying	1	G < L

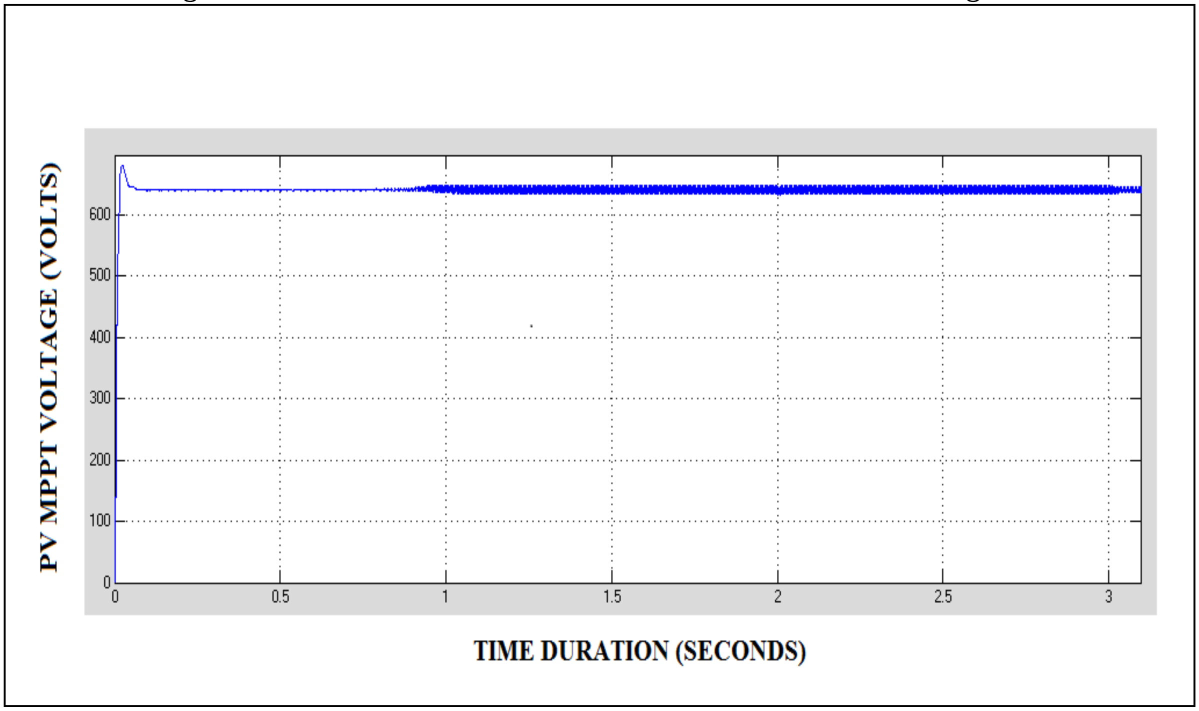

Figure 8: Phase Voltage observed at the PV array

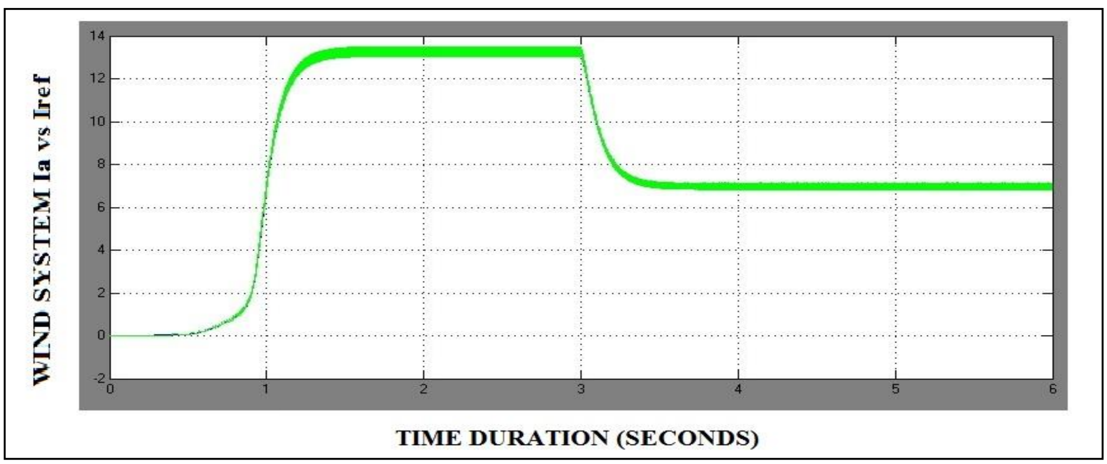

Figure 9: The relative variation curve of Actual Current (Ia) and Reference Current (Iref)

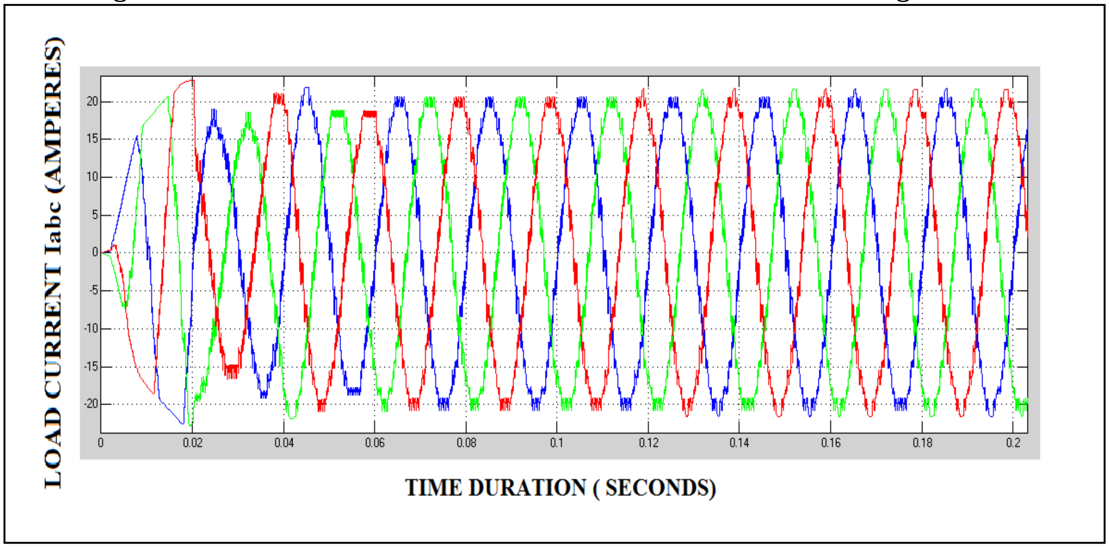

Figure 10: The load current supplied to the load is sinusoidal in nature as depicted in the simulation

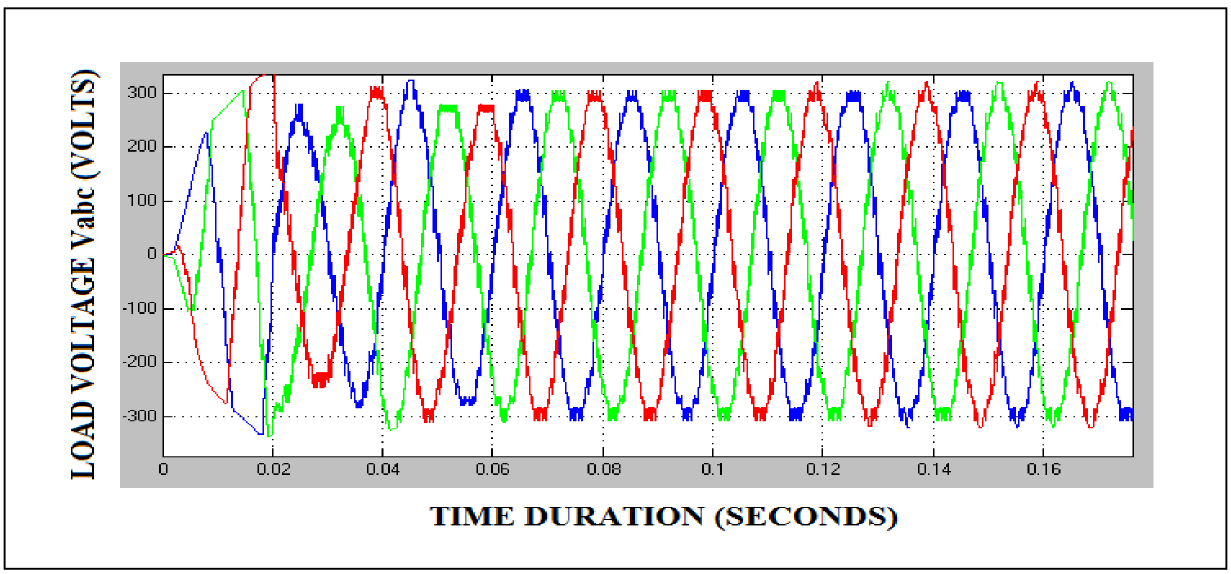

Figure 11: Three Phase Voltage Supplied to the Load by the Inverter

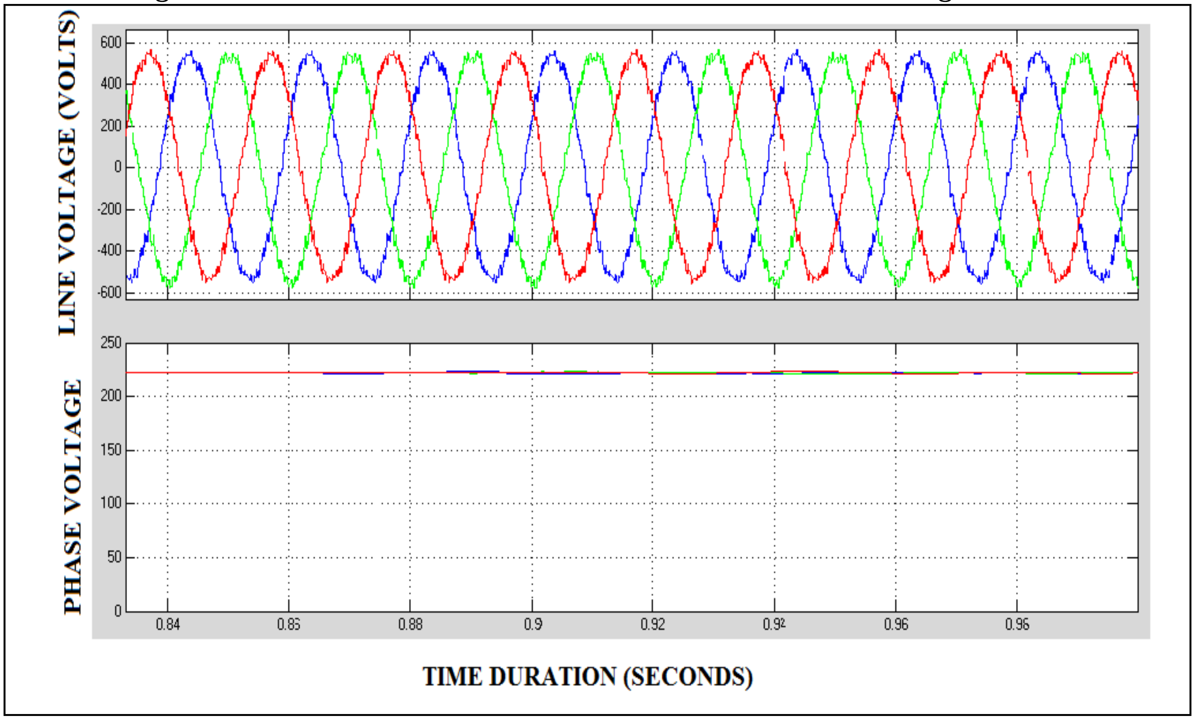

Figure 12: AC Line Voltage and Phase Voltage Given by the Inverter

Table 2: Life Cycle of Hybrid System

Time(S)	Characteristics
0-1	Photovoltaic energy at full irradiance Batteries partially supply for the load Wind Turbines tend towards base speed of 12m/s after a period of 0.5 seconds Load is at 10kW
1-2	Wind achieves 5.6kW Batteries store 5Kw
2-3	Photovoltaic energy reduced by 15% Batteries store 3.5Kw
3-4	Speed of the wind reduces to 9m/s Batteries partially supply for the load
4-5	Load increased by 40% Batteries are responsible for increased load demand
5-6	Load demand settles to the previous point

Yielded values for the photovoltaic panel
Open Circuit Voltage (V_{oc}) = 36.60V
Max. Power Current(I_{MP}) = 30.3V
Short Circuit Current (I_{oc}) = 8.01A
Number of cells in a ROW = 11
Number of cells in (2*1) = photovoltaic Array = 11*2=22 Cells
% Error in accomplishing Max. Power point Tracker = 4%
Max. Power point Tracker Voltage = $666 - (666 * .04) = 640$
The preferred Direct Current link =640
Max. Power from a single Photovoltaic $\boldsymbol{V_{MP}}$*$\boldsymbol{I_{MP}}$ =30.3*7.10=215.13W
Max. Power from a single ROW =11*215.13 = 2366.43W = 2.4kW
Max. Power delivered by a single solar module = (2366.43V+2366.43) =4732.86W =4.7kW
Total Power from the two modules = 4732.86*2 = 9465.7W=9.5kW
Max. Irradiance = 1000

Max. Power at Max. Irradiance =9.5kW

After 2 seconds, % irradiance reduced by 15% to 85%.

Solar power cut down = 9.5-(9.5*0.15) = 8.1Kw

Yielded Values from wind Energy System

$$N = \frac{120f}{P}$$

Where;

N= Revolutions per minute (rpm)

P= Number of poles = 4 Poles

f= Output frequency of Permanent Synchronous Generator (PMSG)

$$N = \frac{120*50}{4} = 1500 \text{ rpm}$$

Converting 1500rpm into radians per second

1500Rpm= 1500*2Ω/60 = 157 rad/s

Nominal Mech. Output Power of the wind turbine = 8.5kW

Power = $\tau \times \omega$

Where;

τ= Base torque

ω=Angular Velocity

$$Base\ Torque(\tau) = \frac{Mechanical\ output\ Power\ (PMech)}{Angular\ Velocity}$$

=8500/157=54.15J

Working Performance of various photovoltaic panels is represented through simulated results. Differences in the output are to altered current and voltage ratings. Delivered current and Voltage ratings depend on the physical conditions prevailing in its surroundings and on its physical characteristics.

Simulated Graphs

Photovoltaic energy drops its irradiance by 15% from 2 seconds.

10kW is the load demanded to fulfil throughout the time frame except at 4 to 5 seconds when it increases to 14kW.

Initially wind turbines rotating at 5m/s except to the base speed of 12m/s after 0.5s where its rotating reduced by 25% of its base speed.

From the graph below, all the above characteristics are clearly observed.

The Photovoltaic Array's Maximum voltage is around 640V. The deciding factor of the maximum voltage is explained by the varying irradiance as shown by the following curve.

Table 3: Major Landmarks of Proposed Hybrid System

Time (S)	Wind Energy	Solar Energy	Battery	Load
0-1		Speed tends to the base speed		
1-2			Significant Charging	
2-3	Irradiance drop	Speed falls		
3-4				
4-5			Mainstay load sharing	Additional load is attached
5-6				

CONCLUSION

In this thesis an inverter was used for converting solar systems and wind systems output into alternating current power output. The load demand was met by the combination of wind energy system, Photovoltaic energy systems and Batteries. The circuit breakers were used for providing a connection to an additional load of 5kW in a stipulated period of time.

In order to provide maximum output power to meet load demand under all operating conditions, the hybrid was controlled. Both the simultaneous operation of wind and solar systems, singly operation of wind system and singly operation photovoltaic system were supported by the battery

RECOMMENDATIONS

In order to dispose excess power, dump loads can be used optimum modelling of essential parameters can be applied to control the losses incurred in the initial stages of operation of wind turbines Other Different methods of Maximum Power Point Trackers can be implemented and compared. To distribute the generated power, distribution transformers can be added to system.

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