Mitigation of Uncertainties in Hybrid Renewable Energy Systems

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***Abstract*— Electricity is very important facility for the human being. All the convectional energy resource is changing day by day. So it is necessary to shift from convectional to non-convectional energy resources. Although solar and wind energy are two of the most viable renewable sources. Little research has been done on operating both energy sources along the side one another in order to take the advantage of their complementary characters. In this content autonomous photovoltaic and wind hybrid energy systems have been found to be more economically viable alternative to full fill the energy demands of numerous isolated consumers world side. In this article, an optimal design of a hybrid solar-wind energy plant is developed with different ideas of the hybrid system configuration with appropriate exercising of power with respect to source, load and battery. This article also observes and identify the different hybrid renewable system and then identify the uncertainties caused by it and overcome that uncertainties.**

Keywords*— *Hybrid Energy Storage Systems, Solar energy, Wind Energy, Power & Energy Management, Boost converter.

I. INTRODUCTION

In the initial stage of power energy system development, the electricity is supplied to the users in a type of bulk electric transmission system. Due to the technology of power system is improved, the traditional type of power system operating pattern seems to occur some weak points in the field of flexibleness and securities. Besides that, fossil fuel price is fluctuating due to the global economic and limited resource; it found that producing electricity with conventional fossil fuel will lead to the environment pollution. In order to overcome all these issues, the hybrid solar wind turbine system based on renewable energy such as solar and wind is taken into account as the alternative method to produce and supply electricity power energy to the users. Solar and wind can be categorized an intermittent source of energy since it is not continuous supply and does not meet electricity load demand in some time [1]. For these two types of renewable energy, wind energy is the more affected source if compared to solar energy due to its inconstancy. Similarly, these two unpredictable energy sources standalone system will produce fluctuated output energy and thus cannot ensure the minimum level of power continuity required by the load. Solar energy system, photovoltaic (PV) cells are electronic devices that are based on semiconductor technology and can produce an electric current directly from sunlight. The best silicon PV modules currently commercially available have an efficiency of over 18%, and it is expected that in about 10 year time module efficiencies may raise to 25%. The PV system also depends on the weather conditions and only can operate during day-time [2].

Wind power is basically electricity produced by a generator, which is driven by a turbine according to flowing air aerodynamics, and is one of the fastest growing renewable energy technologies around the world. A hybrid energy system is defined as the component combination of two or more types of power generation system [3]. For this research, solar energy system is integrated with wind turbine system to form a hybrid renewable energy system.

Since the power output of these renewable energy is ultimately depends on climatic conditions such as temperature, solar irradiance, wind speed and etc. The instability of the system output is compensated by adding a suitable energy storage system to the hybrid energy system. The power autonomy is greatly relied on the perfect balance exist between power demand and generated power [4].

The benefits of utilizing renewable energy sources such as hybrid solar wind turbine systems are increased the reliability of the hybrid energy system because it is based on more than one electricity generation source. Besides that, it is a free from the pollution and environmental friendly system, since it does not use any fossil fuel to drive gas turbine for generator. The solar energy also becomes one of the most promising alternatives for conventional energy sources and has been increasingly used to generate electric power from sunshine. Moreover, the hybrid solar wind energy system is suitable to use in remote areas with inaccessible to utility grid [5]. However, there is also disadvantage of using hybrid systems such as in most cases the system is over sized because it contains different types of power generation system.

Nowadays energy storage is strongly needed to allow grid safety and stability due to the wide penetration of renewable plants. In this scenario, the hybridization of different storage technologies can be a techno economic solution useful to overcome these issues and promote their diffusion. Hybridization allows multi-operation modes of the Energy Storage System (ESS), merging the positive features of base technologies and extending their application ranges [5]-[10]. Project provides a dynamic analysis of a Hybrid Energy Storage System (HESS) consisting of a capacitor and a battery pack coupled to a PV generation plant and a residential load [6]. A dynamic model of the overall micro grid was developed implementing the HESS preliminary sizing and a suitable management algorithm. The instantaneous behaviour of each component was evaluated [7]. A brief summary of the micro grid performance at different weather and load conditions was provided together with a characterization of the impact of power fluctuations on the battery current and on the power exchange with the grid.

II. Literature Survey

There are so many hybrid researches are carried out on the solar and wind power generation. The utilization of renewable energy required system. The literature carried out with categorization of the different system stand alone as follows:

Stand Alone Solar PV System

Abhaya Swarup et al. (2014) developed a model for energy management of PV based energy system [1]. This model has been mainly proposed to raise the public awareness and education levels of solar systems in an interesting and entertaining way. The results indicate that the problems with PV systems were not due to PV array and instead it was due to the performance of the battery units.

Vivek Kapil et al. (2014) have developed an artificial neural network model for designing PV systems for remote areas and presented the influence of various parameters on the design of PV systems [3]. The results of artificial neural network model showed a variation of 5% as compared to other models with more reliability and accuracy. The application of solar power is varied and the scope of PV systems being employed even in domestic applications appears to be bright.

Bhattacharaya et al. (2012) developed a simplified design approach and economic appraisal of a solar PV system. In this model, the PV array and battery bank sizes for a standalone PV system were estimated [4]. Also a cost comparison of the standalone PV system with a PV diesel hybrid system was presented. The results indicate that the hybrid systems were cost effective than standalone systems for a given location.

Hamid Marafia et al. (2008) studied the feasibility of PV technology for power generation and presented comparative economic analysis of power generation with a conventional gas turbine [6]. The results indicate that the solar PV systems are not economical as compared with a conventional gas turbine. However, it was concluded that PV systems could become economical when the system cost reduces to below $2.50 per peak Watt with conversion efficiency above 20%.

Usha Bajpai et al. (2007) developed a model to optimize the size of PV panel and battery in a standalone PV powered system. Optimization of PV system was done based on the cell area, efficiency, and cell power and array inclination [8]. Hence this type of standalone PV power system can be more reliable, viable and acceptable.

Standalone Wind Energy Conversion Systems

Aydogan Ozdamar et al. (2008) have analyzed and presented a case study on wind energy utilization in a house in Izmir, Turkey [9]. The developed model determines the number of batteries needed for continuous energy supply, for each wind turbine taking into account of the economic aspects. It was found that the wind battery hybrid system was not economical in the areas of low wind potential.

Kanat A. Baigarin et al. (2006) have discussed about the potential of wind energy resources available in central Asia [10]. The equations used for determining the distribution of wind energy output, energy density, energy cost and efficiency have been discussed in detail.

Suresh H. et al. (2007) have developed a model to investigate the optimum sitting of wind turbine generators based on site and wind turbine type. The methodology of analysis was based on the accurate assessment of wind power potential of various sites [11]. The analytical computation of annual and monthly capacity factors has been carried out by using the weibull statistical model employing cubic mean cube root of wind speeds. A judicious choice of potential sites and wind turbine generator systems can be made using the model proposed.

Hybrid Solar PV and Wind Energy Systems

Bhave A.G et al. (2012) studied the techno economic feasibility of installing solar PV wind hybrid system [13]. This system uses electrical storage by lead acid battery and auxiliary power from AC mains. The result from the above study showed that 80% of the energy demand was satisfied by the solar PV wind hybrid system.

Habib M.A. et al. (2013) have developed a model for optimizing the size of a hybrid photovoltaic wind energy system. The procedure was applied for the sizing of solar wind hybrid system designed to produce a constant load of 5 kW in the Dhahran area, Saudi Arabia [14]. The analysis indicates that a hybrid system power output can be optimized to suit specific applications with variable or constant power loads.

Francois Giraud et al. (2013) analyzed a model for design of wind–PV system with battery storage for grid connected rooftop system. The system was designed to meet a typical load demand for a given loss of power supply probability [15]. The various parameters like system reliability, power quality, loss of supply and effects of the randomness of the wind and the solar radiation on systems design have been studied. The results showed that the wind and solar systems were complementary to each other and resulted in improved reliability of the system.

Rajesh Karki (2014) developed a simulation method for photovoltaic and wind energy utilization in small isolated power systems based on reliability/cost implications [16]. This simulation method provides objective indicators to help system planners decide upon appropriate installation sites, operating polices selection of energy types, sizes and mixes in capability expansion. In this model, cost and reliability are the main parameters to be considered as it has a significant impact on the design.

Power Management of Hybrid PV-Fuel Cell Power Systems

PV solar energy systems are widely used as an important alternative energy source. To overcome the problem of intermittent power generation, PV power systems may be integrated with other power sources.

Fuel cells are an attractive option because of high efficiency, modularity and fuel flexibility; however, one main week point is their slow dynamics. On the other hand, current technology batteries by themselves are usually insufficient to provide the long term energy that the increasing loads require

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 01, January-2021

[26]. Hybrid systems composed of fuel cells and batteries can be integrated with PV power systems to provide uninterrupted high quality power. The goal of this study is to design an effective power management system for a PV/fuel cell/battery hybrid power system so that the combination can be used as a reliable power source. The structure of the hybrid power system is described, and control strategies for power management of the hybrid power system are discussed.

Power Management of A Hybrid PV And Ultra Capacitor For Stand-Alone And Grid Connected Applications

The integration of PV, fuel cell and energy storage systems for reliable power generation. In this system fuel cell is used as main power source and power from PV whenever available is harvested completely with storage system compensating for power fluctuations. This topology has high efficiency, modularity and fuel flexibility. The sources in this hybrid system complement each other very well against environmental variations and load variations. Of the many storage systems the use of super capacitor gives advantage of absorbing and contributing to power transients quickly and efficiently [26]-[28]. The main objective of this study is to design an effective power management system for PV/fuel cell/storage hybrid system thus to give high quality reliable power. Maximum Power Point Tracking (MPPT) for PV system is used for maximum power extraction. Finally the structure of hybrid system with control strategies for power management is discussed. Power management strategy for a standalone PV or battery hybrid system is investigated in this project. A pair of DC/DC converters is used to interface a PV array and a lead acid battery bank to a common DC link. The presented control strategy manages the power flow between the converters and the load in order to maintain the power balance in the system and enable the battery to support the PV array when the available PV power is insufficient to meet the load [15].

III. HYBRID ENERGY STORAGE SYSTEMS

This gives an overview of the innovative field of Hybrid Energy Storage Systems (HESS). An HESS is characterized by a beneficial coupling of two or more energy storage technologies with supplementary operating characteristics. It briefly discusses typical HESS applications; energy storage coupling architectures; basic energy management concepts and a principle approach for the power flow decomposition based on peak shaving and double low pass filtering. Four HESS configurations, suitable for the application in decentralized PV systems: a) power to heat/battery, b) power to heat/battery/hydrogen, c) super capacitor/battery and d) battery are briefly discussed.

Storage Specification

The global problems of a rapidly rising CO_2 concentration in the atmosphere, the greenhouse effect and the related severe changes in world surface temperature and world climate have to be addressed and solved quickly. One important part of the solution will be a fast transition from the antiquated fossil based energy system to a sustainable, 100%-renewable energy system. Therefore, a further and fast dissemination of PV and wind power is required. PV and wind power fluctuations on an hourly, daily and annual time scale can be handled, employing a variety of flexibility technologies, such as demand side management, grid extension or energy storage [1]. A number of storage technologies based on electrical, mechanical, chemical and thermal energy storage principles are available with quite different technical parameters and operating characteristics. At this point, the utilization of the HESS approach, integrating storage technologies with supplementary operating characteristics, can be very beneficial.

Table 1.Comparison of Different Energy Storage Technologies

	supercap	SMES	flywheel	lead-acid	lithium-ion	NaS	redox-flow	hydrogen	pumped hydro	CAES
energy density in Wh/l	2-10	0,5-10	80-200	50-100	200-350	150-250	20-70	750/250bar 2400/liquid	0,27-1,5	3-6
installation costs in €/kW	150-200	high	300	150-200	150-200	150-200	1000-1500	1500-2000	500-1000	700-1000
installation costs in €/kWh	10000-20000	high	1000	100-250	300-800	500-700	300-500	0,3-0,6	5-20	40-80
reaction time	<10ms	1-10ms	>10ms	3-5ms	3-5ms	3-5ms	>1s	10min	>3min	3-10min
self-discharge rate	up to 25% in first 48h	10-15 %/day	5-15 %/h	0,1-0,4 %/day	5 %/month	10 %/day	0,1-0,4 %/day	0,003-0,03 %/day	0,005-0,02 %/day	0,5-1 %/day
cycle life-time	>1Mill.	>1Mill.	>1Mill.	500-2000	2000-7000	5000-10000	>10000	>5000		
life-time in years	15	20	15	5-15	5-20	15-20	10-15	20	80	ca. 25
system efficiency in %	77-83	80-90	80-95	70-75	80-85	68-75	70-80	34-40	75-82	60-70
short-term (<1min)	XXX	XXX	XXX		X		X			
mid-term (>1min,<2d)			X	XXX	XXX	XX	XX	X	XX	XX
long-term (>2d)				X		X	XX	XXX	XXX	XX

Advantages

Main advantages of a HESS are:

A) Reduction of total investment costs compared to a single storage system (due to a decoupling of energy and power, ES2 only has to cover average power demand)

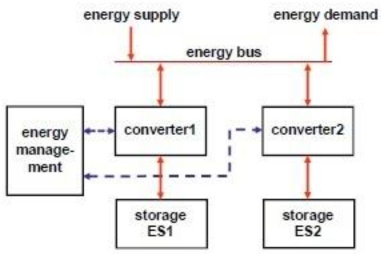

Fig.1. Basic Structure of A HESS.

B) Increase of total system efficiency (due to operation of ES2 at optimized, high efficiency operating points and reduction of dynamic losses of ES2)

C) Increase of storage and system lifetime (optimized operation and reduction of dynamic stress of ES2)

Overview of HESS Applications

Results of a literature review indicate quite a number of promising HESS applications

i).HESS in hybrid and fuel cell powered electric vehicles (super capacitors/battery HESS [7] or battery/fuel cell HESS [10]),

ii).HESS applications in renewable autonomous energy supply systems mainly based on a battery/hydrogen combination [12], [16]

iii).Grid connected HESS on a household [17], district or regional level (e.g. lithium ion/redox flow battery application for the island Pell worm [18])
iv).HESS for large scale wind and PV power management [19]
v).Other specific HESS configurations, e.g. SMES/battery HESS [21], CAES/battery HESS [22] and battery HESS [23]

Moreover, power to heat will enable HESS to perform peak shaving and hereby significantly reduce the stress for the other storage components and for the public grid. Optimizing design, control and energy management strategies for HESS at the interface between electricity, heat and gas sector will play an important role and will unfold significant potentials for further improvements of cost, efficiency and lifetime of renewable energy systems.

Energy Storage Coupling Architectures in HESS

There are different ways for the coupling of the energy storages in a HESS. A simple approach is the direct DC coupling of two storages. Main advantage is the simplicity and cost effectiveness. Main disadvantage is the lack of possibilities for power flow control and energy management and a resulting ineffective utilization of the storages.

The second energy storage coupling architecture in a HESS is via one bidirectional DC/DC converter. The converter can either be connected to the high-power or to the high energy storage. In the latter case the high energy storage can be protected against peak power and fast load fluctuations. The DC/DC converter then operates in current controlled mode.

A drawback of this solution is the fluctuation of the DC bus voltage, which is identical to the voltage of the high power storage. The third and most promising coupling architecture consists of two DC/DC converters. Here the parallel converter topology is very common. The additional DC/DC converter associated with the high power storage is in charge of the voltage regulation of the DC bus. It helps to operate the high power storage in a broader voltage band, and hereby the available storage capacity is better utilized. Besides the parallel converter topology also a serial, cascade type of converter topology is possible, which is generally more expensive and more difficult to be controlled. Disadvantages of the two converter coupling architecture are higher complexity and slightly higher costs.

Control and Energy Management Concepts for HESS

An intelligent control and optimizing management of the power flow distribution is essential for a good operation of any HESS.

The main feature of optimization based approaches is the minimization of a cost function. Optimization based approaches can be distinguished into global and real time algorithms. Frequency decoupling is well suited for real time

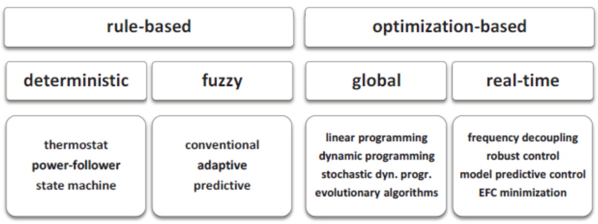

Fig. 2. Control and Energy Management Concepts for HESS.

applications. It is usually accomplished by a simple low pass filter or by advanced filter concepts based on wavelet or Fourier transform. This algorithm divides the control and optimization problem into three layers the primary control of bus voltage and fuel cell current, the secondary control to limit fuel cell operating range and power gradient and to perform battery charge and load following control, and the system control to optimally adjust the secondary control parameters aiming for the minimization of H_2 consumption and dynamic fuel cell stress parameter.

HESS design/sizing and energy management optimization problems are usually strongly interdependent. Therefore, intelligent HESS design algorithms take into account both, component sizes and energy management parameters.

A particle swarm optimization algorithm was successfully employed demonstrating good convergence, fast computation speed and an excellent handling of the complex, nonlinear optimization problem [35].

Implementation on Hybrid Renewable Energy System

Hybrid renewable energy systems (HRES) are becoming more commonplace, are well developed and well defined today. A critical component of the HRES system is the ESS. Most ESS are designed for a single function, whereas the emerging requirements for HRES storage systems are to perform multiple functions. The hybrid energy storage system provides an elegant solution to the problem.

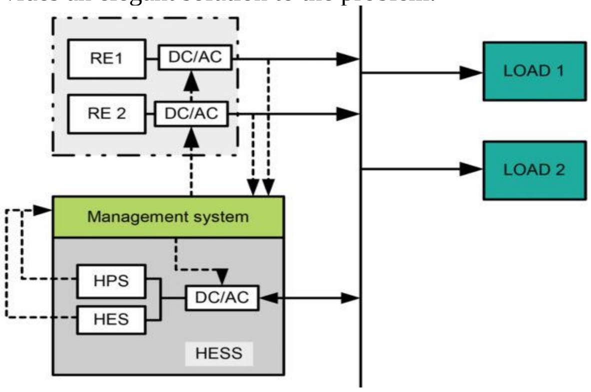

Fig.3. HRES System Using HESS.

The concept of the HESS realizes on the fact that heterogeneous ESS technologies have complementary characteristics in terms of power and energy density, life cycle, response rate, and other characteristics. A HESS is characterized by a beneficial coupling of two or more energy storage technologies with complementary or supplementary operating characteristics. In a typical HESS one storage unit is dedicated to cover high power demand, such as transients and fast load fluctuations and therefore is characterized by a fast response time, high efficiency and high cycle lifetime. The other storage will be the high energy storage with a low self-discharge rate and lower energy specific installation costs. It is beneficial to hybridize ESS technologies in the way that synergize the functional advantages of two or more heterogeneous existing ESS technologies.

IV.SIMULATION OF EXISTING SYSTEM

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 01, January-2021

programming in an easy to use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include:

1. Math and computation
2. Algorithm development
3. Modeling, simulation, and prototyping
4. Data analysis, exploration, and visualization
5. Scientific and engineering graphics.

BIDIRECTIONAL DC-DC CONVERTER

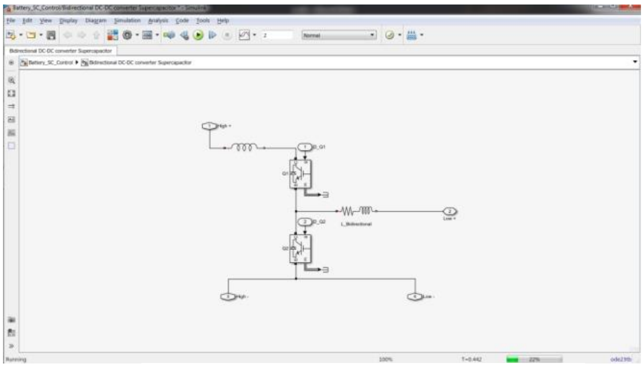

Fig 4. Subsystem of DC/DC Bidirectional converter

Bidirectional DC/DC converter shown in Fig 5.1 is used as a key device for interfacing the storage devices between source and load in renewable energy system for continuous flow of power because the output of the renewable energy system fluctuates due to change in weather conditions.

MAXIMUM POWER POINT TRACKING (MPPT)

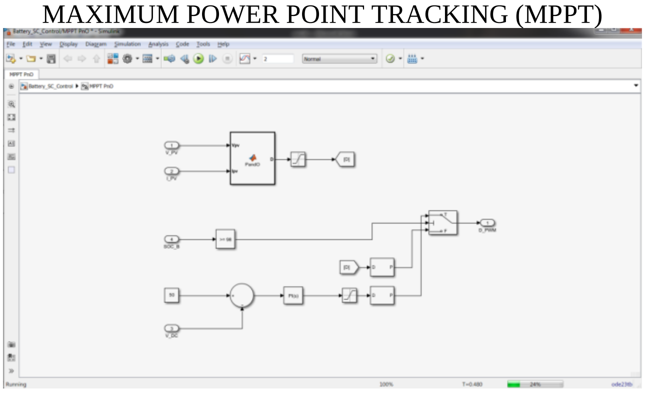

Fig 5.MATLAB Subsystem Representing P&O Algorithm

The major principle of MPPT is to extract the maximum available power from PV module by making them operate at the most efficient voltage (maximum power point).
MPPT checks output of PV module, compares it to battery voltage then fixes what is the best power that PV module can produce to charge the battery and converts it to the best voltage to get maximum current into battery. It can also supply power to a DC load, which is connected directly to the battery.

BOOST CONVERTER

A boost converter (step-up converter) shown in Fig 5.3 is a DC/DC power converter that steps up voltage from its input to its output. It is a class of switched-mode power supply containing at least two semiconductors and at least one energy storage element: a capacitor, inductor, or the two in combination. The switch used is IGBT switch.

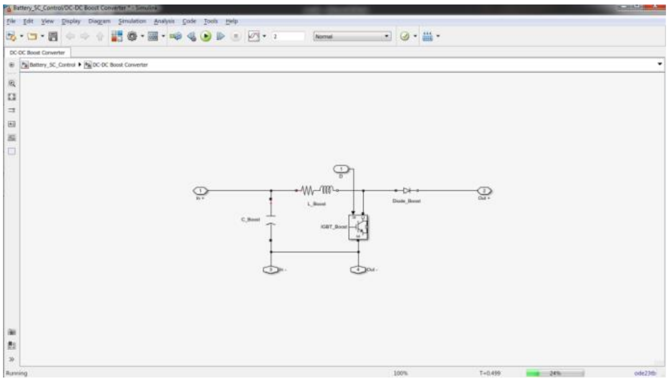

Fig 5.3 MATLAB Subsystem Representing DC/DC Boost converter

BATTERY SUPER CAPACITOR CONTROL UNIT:

The super capacitor shown in Fig 5.4, is electrically known as the electrochemical capacitor because it stores electrical charge in the electric double layer of a surface electrolyte interface. This interface is primarily a high surface area carbon.

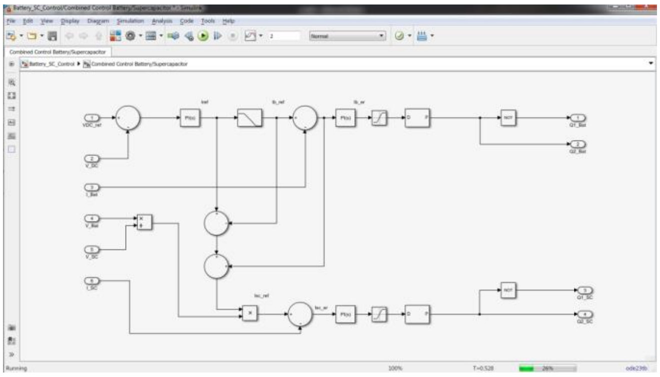

Fig 5.4 MATLAB Subsystem Representing Super capacitor

EXTENSION WIND SYSTEM

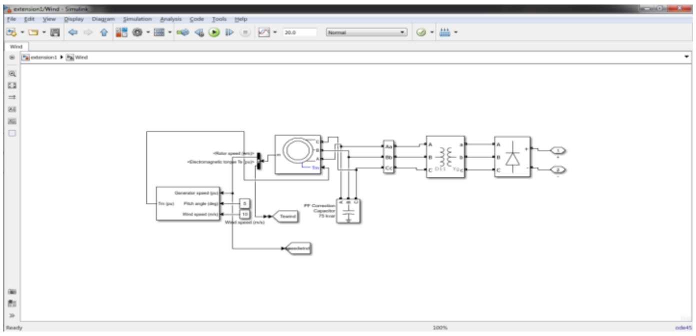

Fig 5.5 MATLAB Subsystem Representing Wind System

PV ARRAY RESPONSE

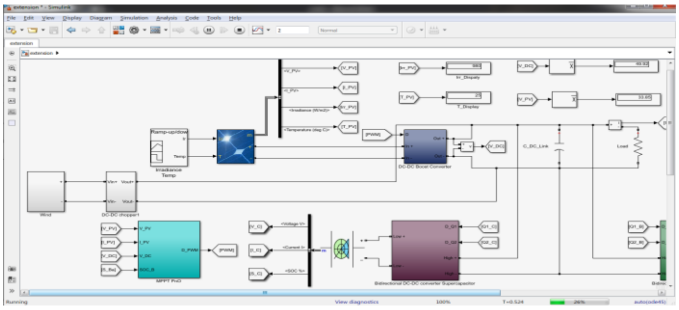

Fig 6 MATLAB Subsystem Representing PV Array System

SIMULATION RESULTS OF SYSTEM

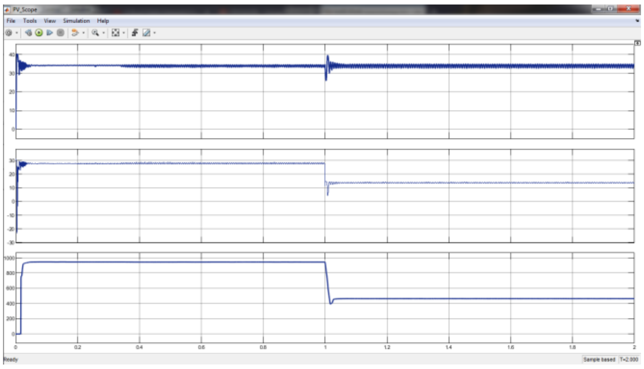

Fig 5.7: a) Voltage, b) Current and c) Power Response for PV array system.

In Fig 5.7, voltage, current and power response of PV modules was represented as mode of irradiance change variation was observed in this phenomenon and effect of load is also observed with simple harmonics declares no pure DC outcome.

In figure 5.8, voltage, current, storage and power response of Super capacitor modules was represented as mode of charge and discharge variation was observed in this phenomenon and effect of load is also observed.

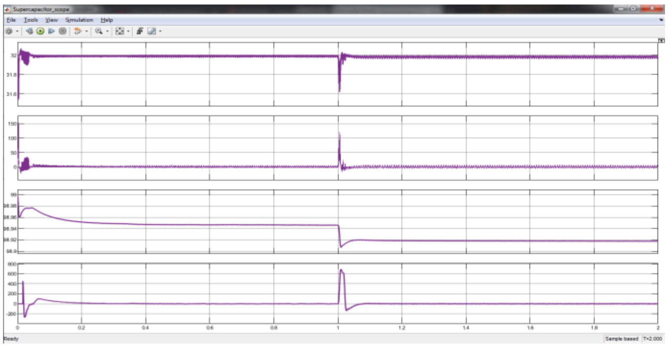

Fig 5.8: a) Voltage, b) Current and c) Storage Response and d)Power response for Super Capacitor Array System.

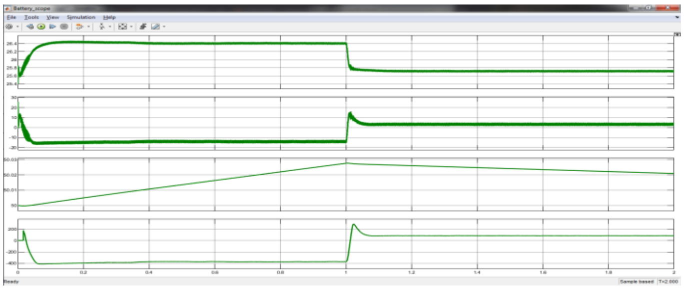

Fig 5.9: a) Voltage, b) current and c) Storage response and d) Power response for Battery array system

In Fig5.9, voltage, current, storage and power response of battery modules was represented as mode of charge and discharge variation was observed in this phenomenon and effect of load is also observed.

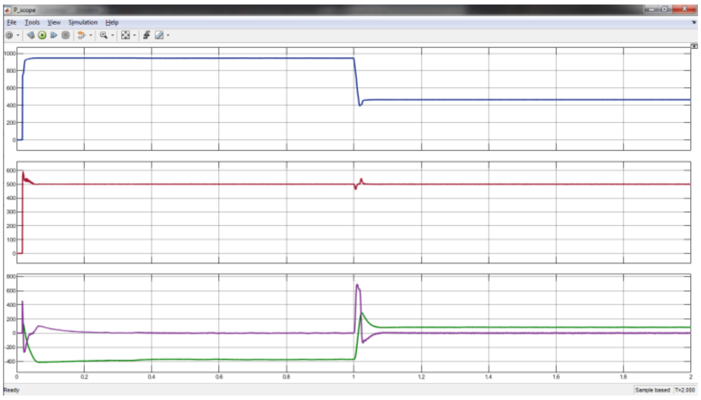

Fig 5.10: a) Power at PV module, b) Power at Load and c) Power at both storage units for hybrid storage system.

In fig 5.10, power response at PV array, power response at load and power response of Super capacitor with battery modules was represented

V. CONCLUSION

The utilization of renewable resources is greatly demanding in the world. The world facing the problem of global scarcity of electricity and pollution can be easily overcome with renewable energies. The presented research work is based on the different researches on the utilization of the natural resources like solar and wind and combination of both the sources. Hybrid power generation is the solution to compensate the upcoming demand. In this project an optimal design of a hybrid solar wind energy plant is developed with different ideas of the hybrid system configuration with appropriate exercising of power with respect to source, load and battery. A new algorithm is introduced for improving the energy management and storage of power. By using this algorithm we can do the management of power as per our requirement and can optimize usage of appropriate source. This project also observes and identify the different hybrid renewable system and then identify the uncertainties caused by it and overcome the same. Factors like power management, storage and optimization of source are taken considered and implemented as a major source in project. In this project load is identified at different conditions and proposes the power source at different values which are necessary to satisfy the different conditions required by the load. Using an existing computer model of hybrid systems or creating a new one allows an extensive research on their work under different conditions and configurations and facilitates their design.

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