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Transient Stability and Cost Analysis of a System with Distributed Generation and Energy Storage Devices

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Abstract- Renewable energy integration focusses on incorporating renewable energy, distributed generation, energy storage, thermally activated technologies and demand response into the electric distribution and transmission system. . Energy Storage plays a key role in enabling a low-carbon electricity system. Energy storage can supply more flexibility and balancing the grid, providing a backup to intermittent renewable energy. It can improve the management of distribution networks, reducing cost and improving efficiency. Electrical power system is always subjected to different loading conditions. The load variation gives negative impact on the entire power system parameters. The assessment of transient stability is an essential requirement for the security of electrical power system This paper presents the simulation results of a transient stability and economic analysis with battery backup and ultra capacitor in grid connected operation

Index Terms- renewable energy, battery backup, ultra capacitor energy storage, transient stability and economic analysis.

I. INTRODUCTION

Renewable energy is generally defined as energy that comes from resources which are naturally replenished on a human timescale such as sunlight, wind, rain, tides, waves and geothermal heat. Renewable energy replaces conventional fuels in four distinct area i) electricity generation ii) hot water/space heating, motor fuels and rural (off-grid) service areas. Rapid development of renewable energy and energy efficiency is resulting in significant energy security, climate change mitigation and economic benefits.

In international public opinion surveys there is a strong support for promoting renewable sources such as solar panel and wind power. In recent years the development of alternative energy sources have become a global priority giving rise to intensive research about less environmentally polluting renewable source[1]. The installation of smaller and distributive power plants have been made possible due to changes in both the power system concept and the economy of scale.

A micro grid can be defined as a combination of loads and micro sources that provides electric power to a local area [2]. Many commercial pv systems works as a current source in grid connected mode [3]. The operation of micro grid offers distinct advantages to customers and utilities (i.e) improved energy efficiency, reduced environmental impact and greater reliability.
Energy storage improves the efficiency and reliability of electric supply system by reducing the requirements for spinning reserves to meet power demands, making better use of efficient base load generation and allowing greater use of intermittent renewable energy technologies. Energy storage can help to increase the energy security, reduce the environmental impact of electricity generation, transmission and consumption and broaden the diversification opportunities for utilities by adding more generation options to their port folios. Eg: Distributed power and renewable energy.

Super capacitors are also known as electro chemical capacitors or ultra capacitors. They have characteristics of both batteries and capacitors and could be used by utilities to regulate power quality. Battery systems allow utilities or utility customers to store electrical energy for dispatch at a times when its use is more economical strategic (or) efficient. It uses lead - acid batteries. Low maintance have been developed for distributed power application.

II. SYSTEM CONFIGURATION

The block diagram of the system is shown in figure 2.1.

A. *PRINCIPLE OF OPERATION OF PV SYSTEM*

Sunlight is composed of photons or particles of solar energy, photons comprises of various amounts of energy of different wavelengths of the solar spectrum. When enough sunlight is absorbed by the material, electrons are dislodged from the materials atoms.

When electrons leave their position holes are formed. The performance of a photo voltaic array is dependent upon sunlight. Climatic conditions have a significant effect on the amount of solar energy received by an array and in turn its performance. Current technology photo voltaic modules are about 10% efficient in converting sunlight. The characteristic and equivalent circuit of PV array is shown in figure 2.2 and 2.3 respectively.

B. PRINCIPLE OF OPERATION OF WIND SYSTEM

Wind is simply defined as moving air. When the earth heats up from sunrays it releases wind, this is a balanced reaction meant to cool the earth. The sun heat is felt more on dry land than on the sea. The air expands and easily reaches maximum high altitudes, then cool air drops down and moves as wind. Wind energy is generated by converting kinetic energy through friction process into useful forms such as electricity and mechanical energy. These two energy sources are put in to use by humans to achieve various purposes. In the past, people constructed wind mills to generate energy meant for grinding rains. They also constructed mechanical wind pumps to be uses to pump large amounts of water into the farms.

C. SINGLE PHASE INVERTER

A current controlled H-bridge single phase inverter is been chosen [4]. It is fed from a dc source in which I-V curve of a PV panel has been programmed to emulate an array of 12 series connected PV panels. It enables the voltage to be applied across the load in either direction.

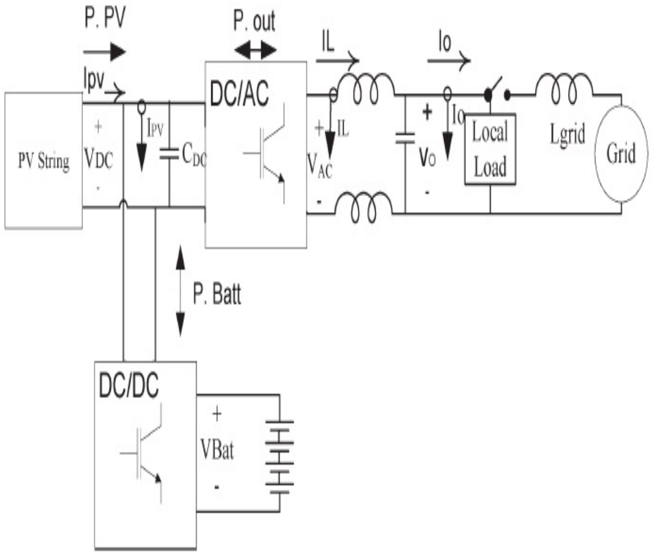

Fig-2.1: Block Diagram of PV system under study

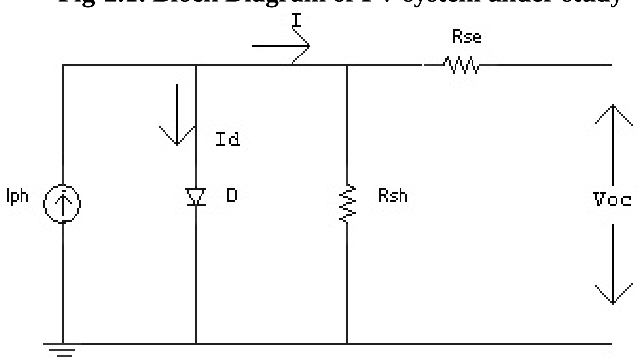

Fig-2.2: Characteristic of PV array

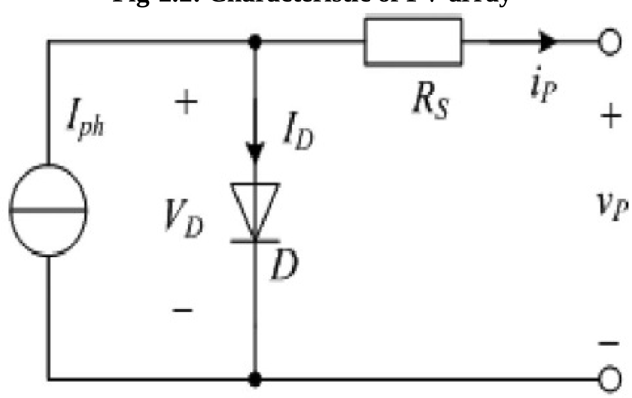

Fig-2.3: Equivalent circuit of PV array

D. DC-DC CONVERTER

DC- DC converter regulates the output voltage. It performs multiple functions such as a battery charge regulator and a boost converter to deliver energy from the battery to inverter [3]. It offers to increase the voltage from a partially lowered battery voltage thereby saving space instead of using multiple batteries to accomplish the same thing.

III. ENERGY MANAGEMENT

Electric utilities are faced with many challenges imposed by today's smart grid. High penetration of bulk renewable demand response options, coupled with increased operating and maintenance costs, security contribute to the needs of today's advanced Energy Management System (EMS). It has its origin in the need for electronic utility companies to operate their generation as economically as possible. EMS own and operates the generation, transmission and the distribution the economic dispatch and scheduling of generation usually done to minimize the total operating cost of generation.

IV. ENERGY STORAGE DEVICES

A. BATTERY

It is an electrochemical device that stores energy and then supplies it as electricity to a load circuit. They are typically organized in strings and can be connected in series or parallel or a combination of both, to provide the operating voltage and current. It impact the overall reliability of the battery solution. Battery system are treated as short term to medium term sources of stored energy capable of supporting a critical load for minutes or hours. Battery systems can be the primary source of back up power, but they usually support the load until an alternate source of power is available. The data regarding battery is explained in the table1.

Batteries usually provide 5-15mins of backup power. The extended battery run time allows for both humans and softwares to perform emergency procedures.

B. ULTRA CAPACITOR

A capacitor is an electric circuit element used to store an electrical charge temporarily. In general, it consists of two metallic plates separated and insulated from each other by a non -conductive material such as glass (or) porcelain.

An ultra capacitor is a double layer electro chemical capacitor that can store thousands of times more energy than a common capacitor. It shares characteristics with both batteries and conventional capacitors and has an energy density (ratio of energy output to its weight) approaching 20% of a battery. In other words , a battery would have to be 80% heavier thanthe ultra capacitor in order to produce the equivalent energy output. It could be a suitable battery replacement in situations where a long run time is not required. It is highly reliable energy storage system that would require little or no maintenance.

Table-1: BATTERY CONFIGURATION

Sl. No	**Parameters**	**Range**
1	Environmental Impact	Consider less toxic
2	Discharge/Recharge rate	Fast
3	Current Cost	High

4	Broad field performance history	Less than 5 years
5	Operating temperature range	-40°C to 60°C
6	Life expectancy range	6-20 years

Ultra capacitor still in an emerging phase of development are very promising power bridging technology for short backup applications such as fuel start up. They are used primarily for peak load sharing due to very fast charge and discharge cycles. Large ultra capacitors with energy densities over 29KWh/m^3 are still under development. The data regarding ultra capacitor is briefed in table2.

Table- 2: ULTRA CAPACITOR CONFIGURATION

Sl. No	Parameters	Range
1	Temperature performance	Low and its capable of delivering energy down to -40°C with minimal effect on efficiency
2	Low equivalent series resistance	Less than 1Ω
3	Charge rate	36.8% of full charge
4	Discharge rate	63.2% of full charge
5	Current charging and discharge rate	High
6	Energy density	10% of conventional batteries
7	Power density	10 to 100 times greater
8	Maximum Voltage	2.7V or less
9	Typical time constant	1 second
10	Efficiency	>90%
11	Operating temperature range	-40° to 70°C
12	Life time	10 to 20 years
13	Charge/discharge rate	500000 to 1000000 cycles

V. SIMULATION RESULTS

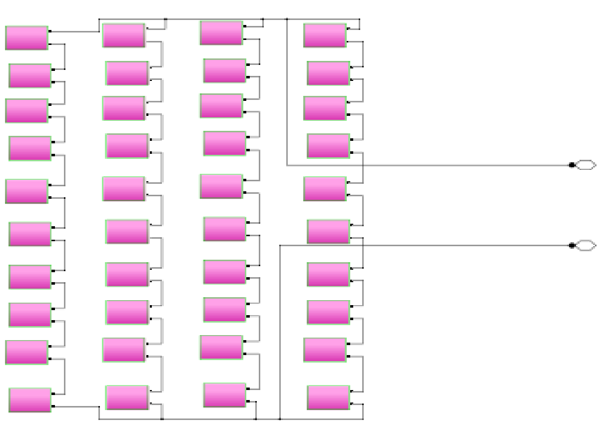

Fig-5.1: Subsystem of PV array

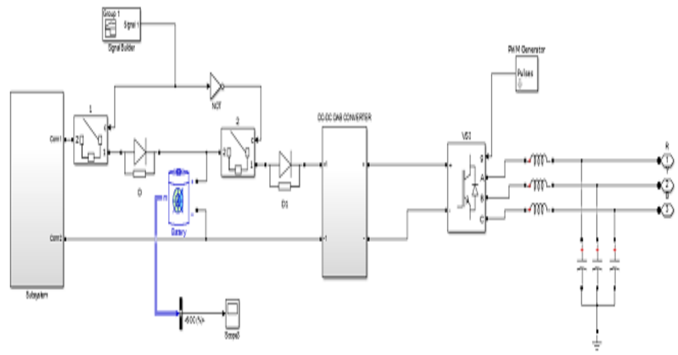

Fig-5.2: Modelling of battery in test system

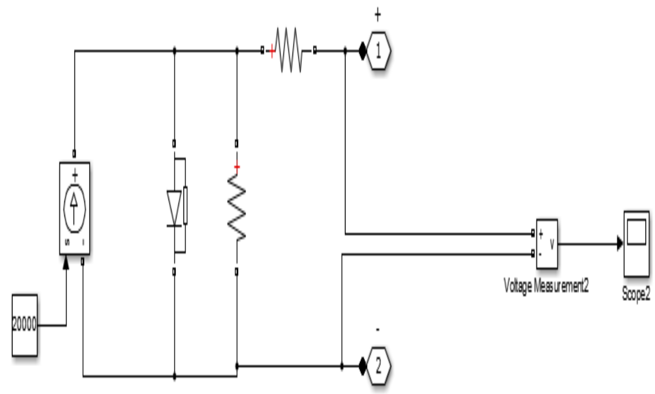

Fig-5.3: Subsystem representing equivalent circuit of PV array

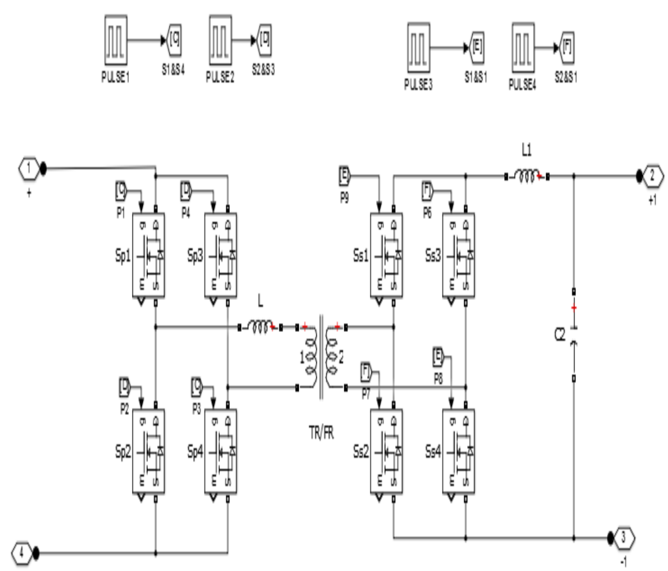

Fig-5.4: DAB converter Subsystem

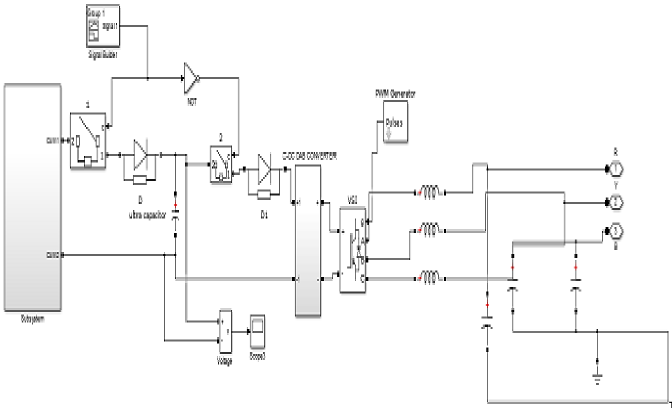

Fig-5.5: Modelling of ultra-capacitor in test system

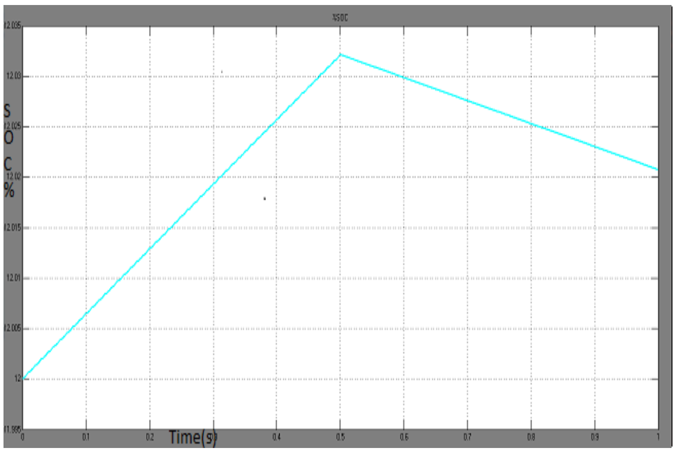

Fig-5.6: State of Charging of Ultra capacitor in a test system

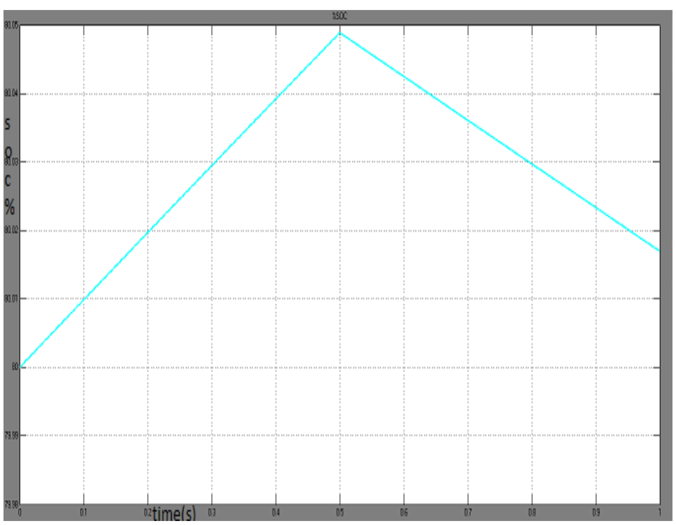

Fig-5.7: State of Charging of Battery in a test system

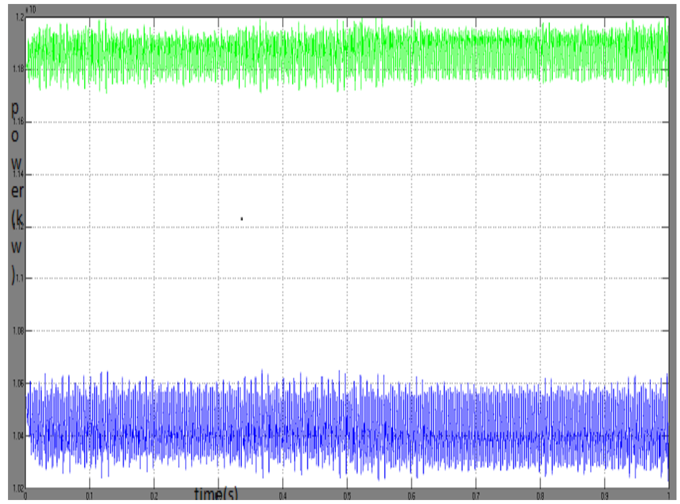

Fig-5.8: Active and reactive power of an ultra-capacitor connected test system

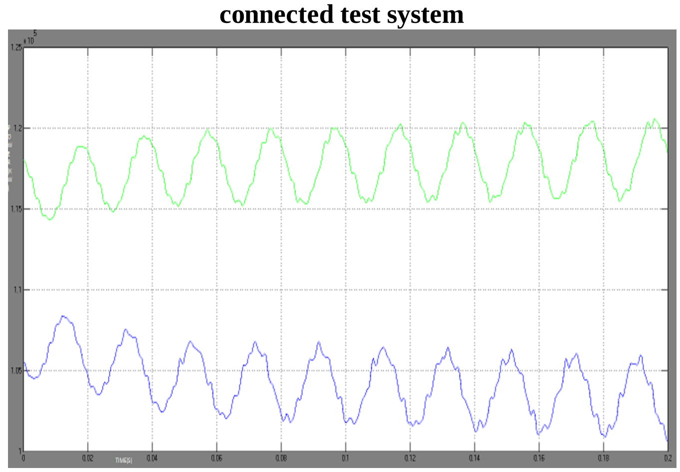

Fig-5.9: Active and Reactive power of a test system in steady state

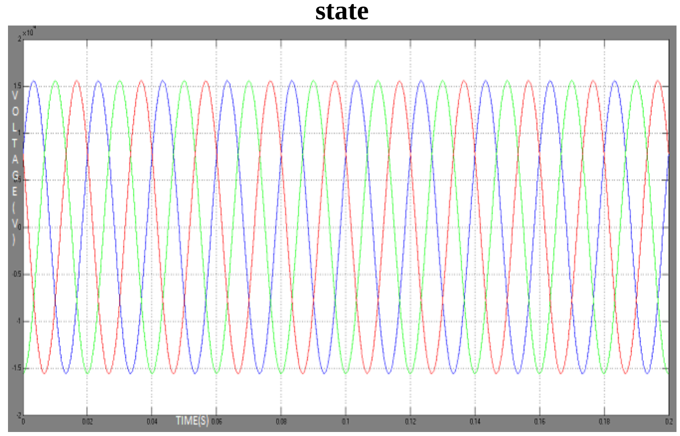

Fig-5.10: Output voltage of test system in steady state

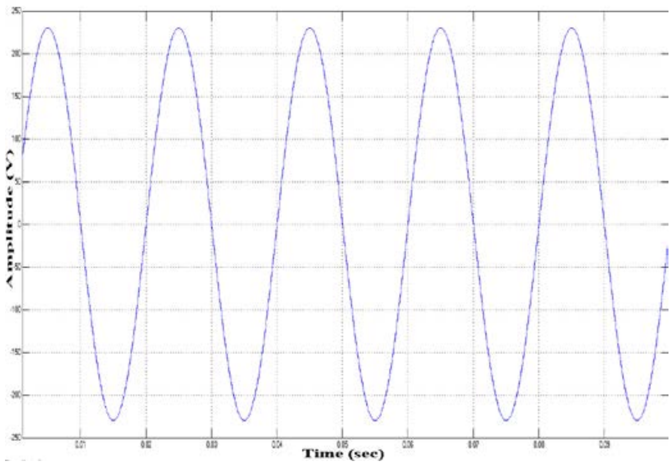

Fig.5.11: Output of Battery connected Closed PV System

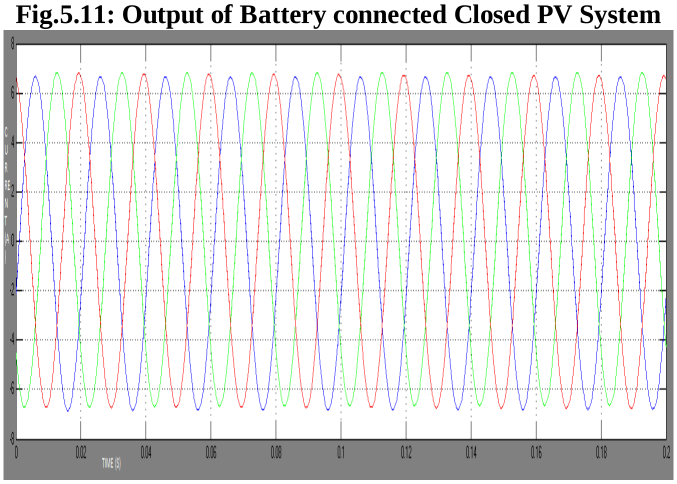

Fig.5.12: Output current of test system in steady state

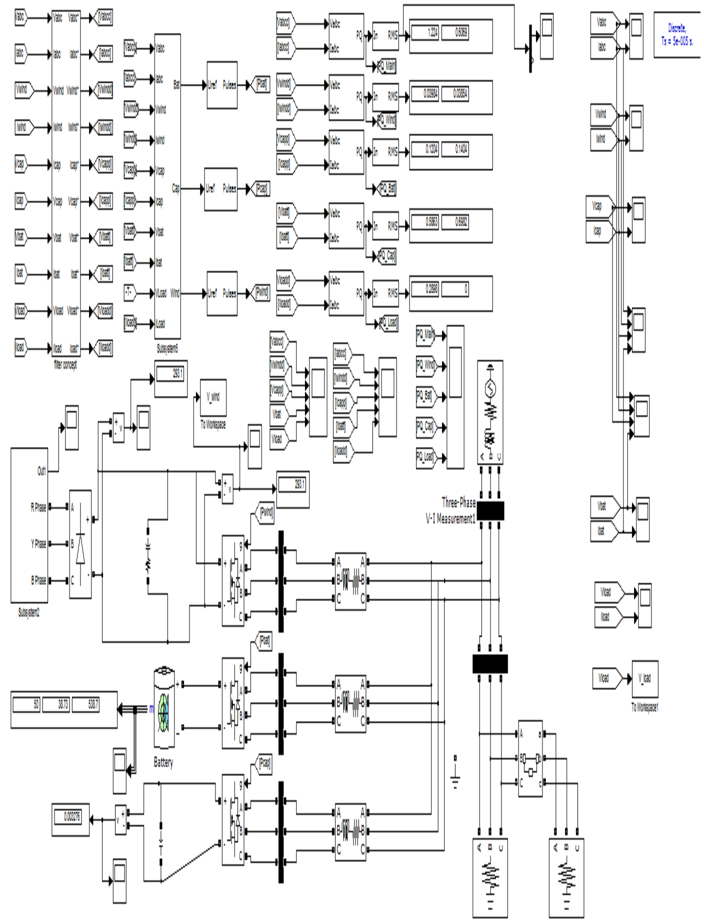

Fig-5.13: Simulink model of hybrid grid connected sytem

VI. TRANSIENT STABILITY ANALYSIS

Transient Stability involves the study of the power system following a major disturbance. The objective of the transient stability study is to ascertain whether the load returns to a steady value following the clearance of the disturbance. The ability of a power system to maintain stability under continuous small disturbances is investigated under the name of Dynamic Stability (also known as small-signal stability). These small disturbances occur due random fluctuations in loads and generation levels. In an interconnected power system, these random variations can lead catastrophic failure.

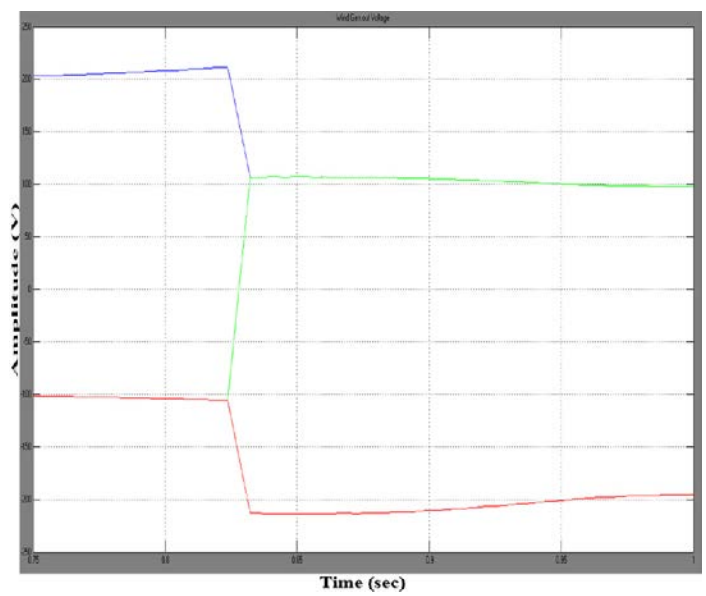

Fig.6.1: Wind generated output voltage

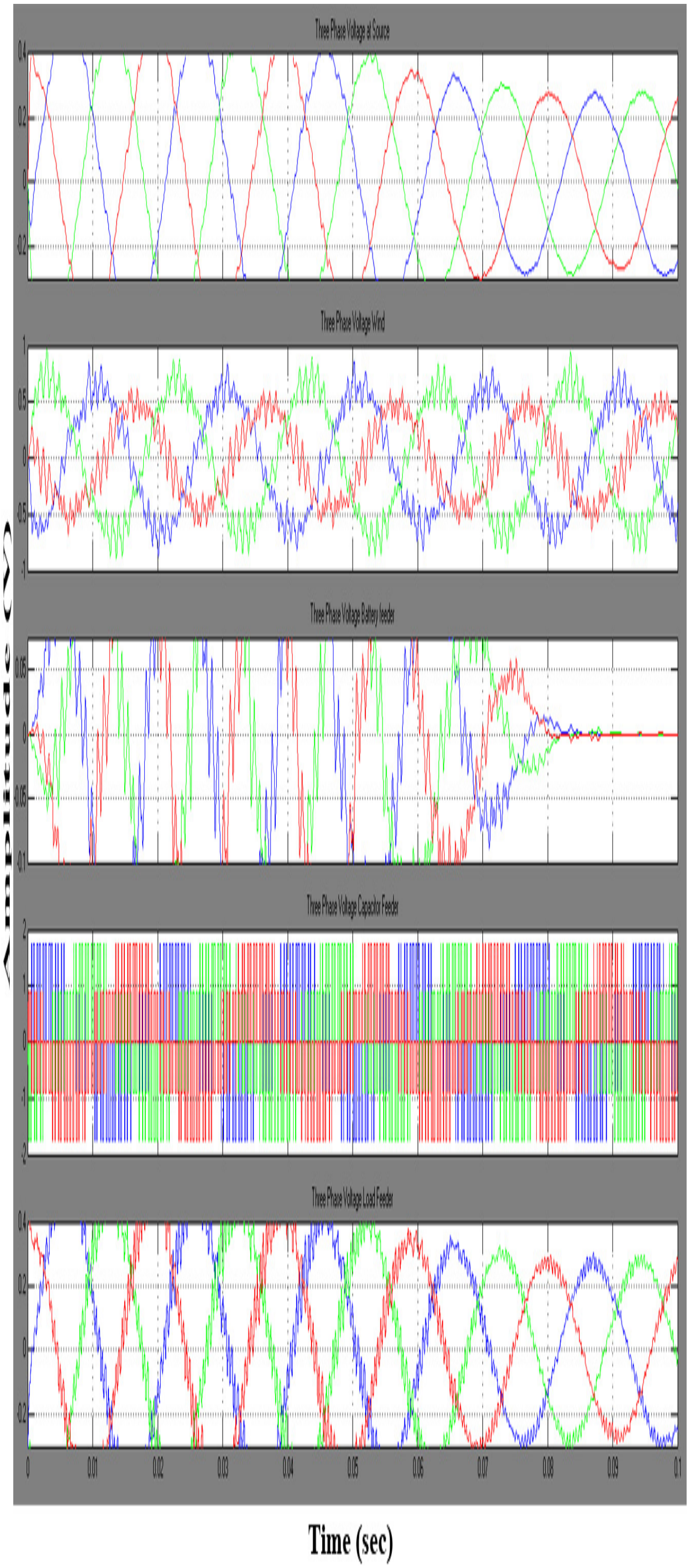

Fig-6.2: Three phase amplitudes of source, battery and capacitor feeder, load feeder, wind.

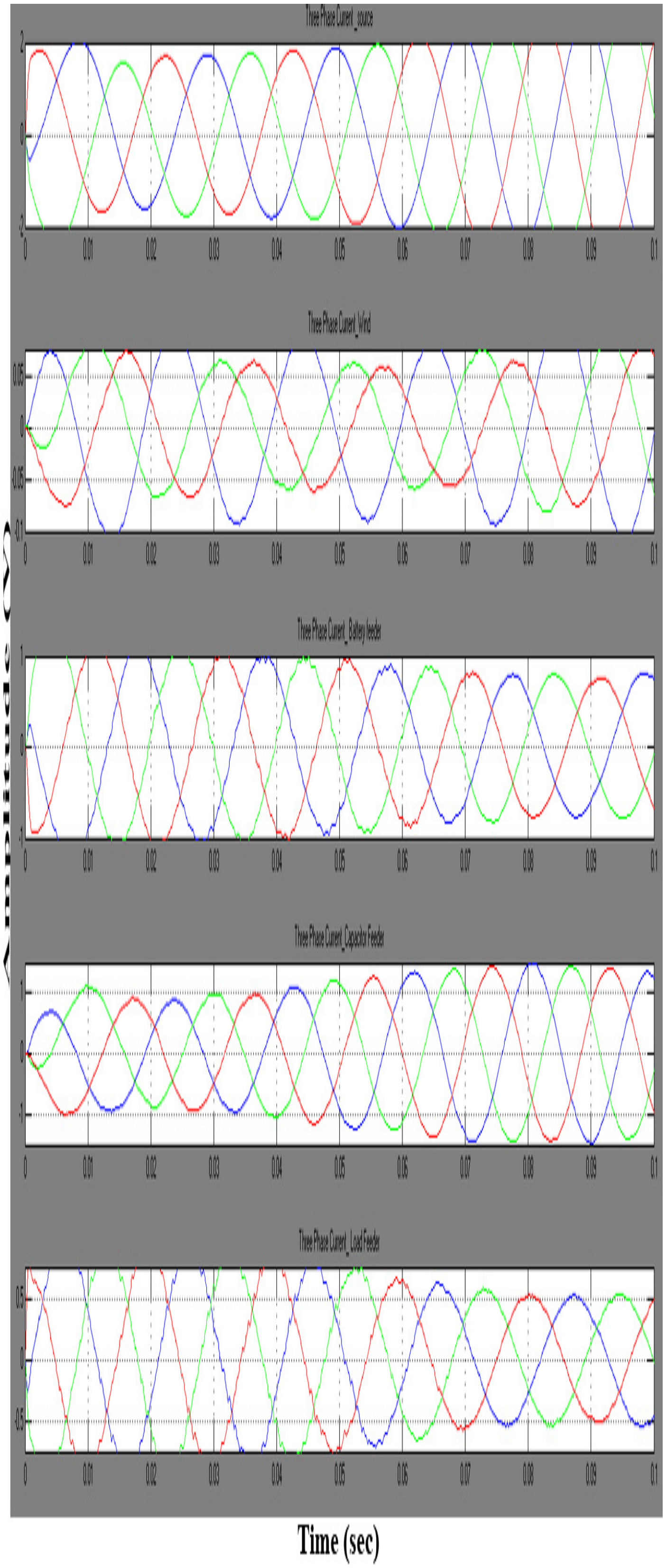

Fig-6.3: Three phase currents of source, battery and capacitor feeder, load feeder, wind.

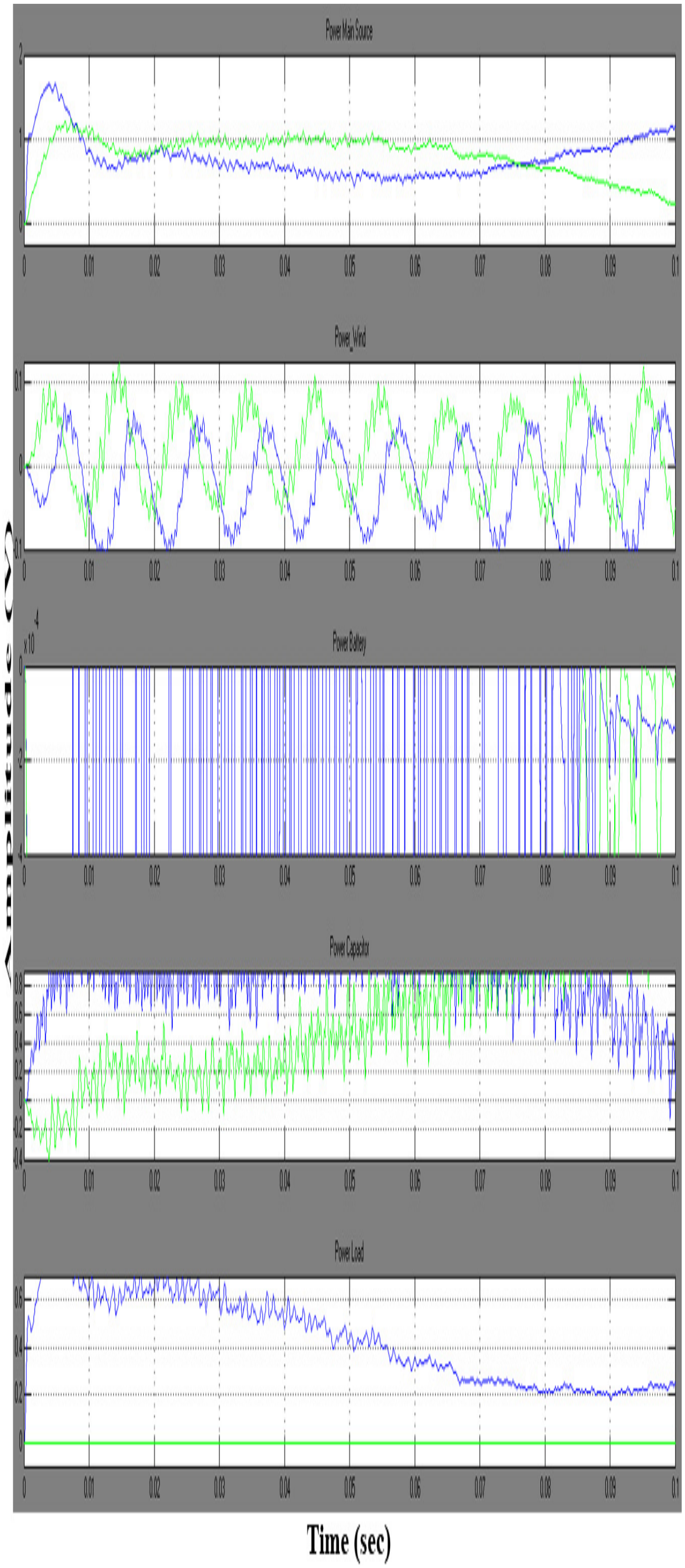

Fig-6.4: Three phase power of source, battery and capacitor feeder, load feeder, wind.

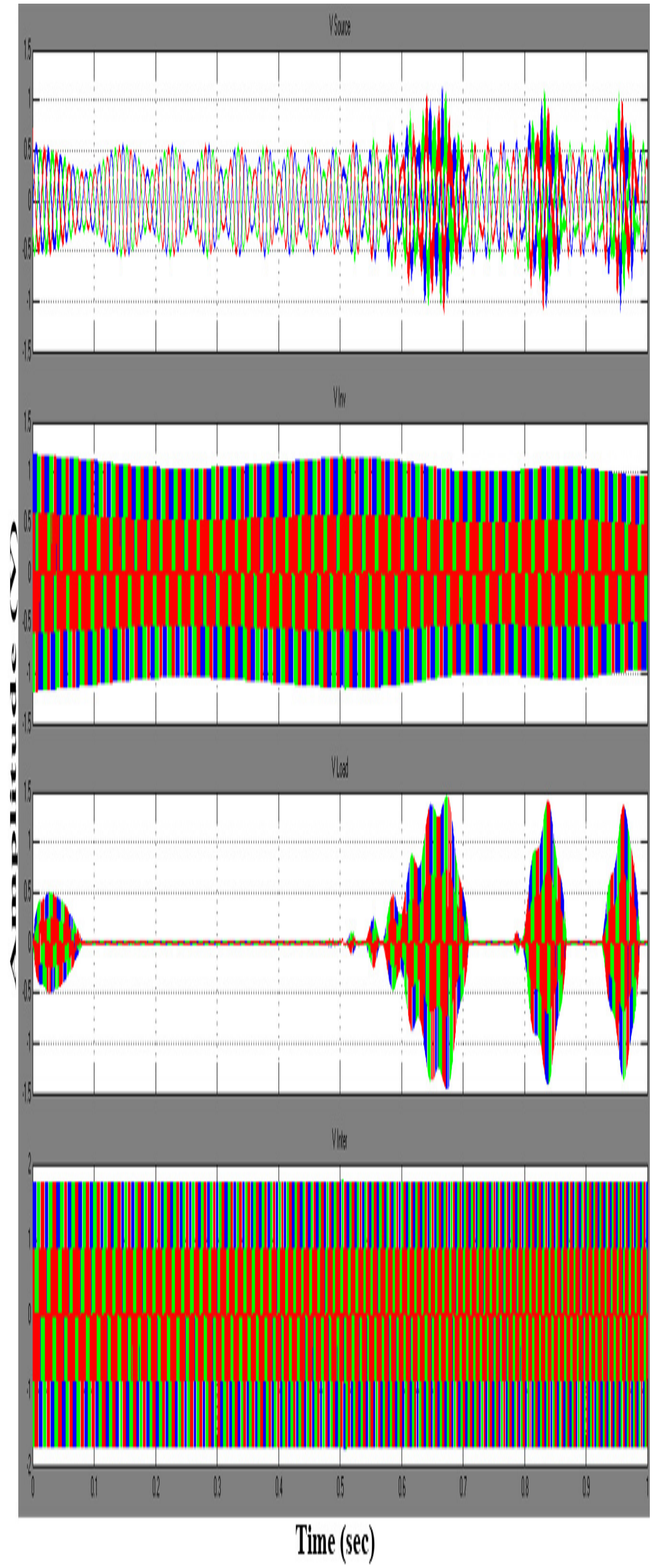

Fig.6.5: Transient stability analysis of a hybrid system

VII. ECONOMIC ANALYSIS

Consider a battery of 12V and 100A-h capacity. For a 14 bus system, 14 nodes are present and hence 20 batteries are required and they are connected in series at a cost of 6000 each. In the same way consider an ultra-capacitor connected 5 in series at a cost of 2500 each. Hence the total cost for these energy storage devices comes upto 20 lakhs. In a substation there are various equipment's like power transformer, switch gear, insulators, generator, windmill, protection device, measurement device, switch yard etc.. Hence the cost of per equipment per annum comes upto 30 lakhs including its maintenance. By the usage of these energy storage devices we can reduce the damaging amount. The benefit comes upto 20-30%.

VIII. CONCLUSION

The landscape of alternative energy storage is gaining more recognition. Despite the growth of alternative technologies, the view over the next few years is that batteries will still remain the principle resource for energy storage in the data center. The result analysis suggests that energy storage devices in the system along with distributed generators can improve the transient stability of the system. An economic study for the cost with energy storage devices was analyzed. The main operational aspects of the system were verified by means of simulation results.

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