Power System Stability and LVRT Capability Enhancement of Grid Connected Hybrid System with UPFC and Energy Storage System

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Abstract: ***The present day power system network is having more and more renewable energy resources(RES) included into it, day by day. PV-Wind hybrid power generation systems are promising energy sources, because they are able to generate electric power in remote areas and complement the demand of conventional electrical power systems. But the intermittent nature of these sources adversely affects the power system stability. During the initial stage of introducing PV, Wind systems to the electrical energy market, they were allowed to be disconnecting from the grid during fault events in the grid side to avoid any possible damages. Currently, the developed grid codes require them to ride-through intermittent fault conditions to remain connected and support the grid under such events. This will assure sustainable power delivery to the grid during faults and abnormal operating situations. A cost effective approach to improve the Fault Ride Through(FRT) capability of the existing PV-Wind hybrid systems is by connecting fexible ac transmission system (FACTS) device to the Point of Common Coupling(PCC). Among all the FACTS devices, UPFC performs this operation well. By controlling the UPFC as a virtual inductor can lead to increase the voltage at the PCC during the fault clearing while all other devices can only recover voltage after fault clearing at the PCC. The back-up energy supply system incorporated with UPFC is providing a complete control of real and reactive power at the same time and hence is competent to improve the performance of an electrical power system. Thus the backup energy supply unit integrated is superconducting magnetic energy storage (SMES), because, SMES based UPFC is much better in terms of transient stability and lvrt capability improvement, maintaining constant DC bus voltage.***

Keywords: Renewable Energy Sources, Power System Stability, Low Voltage Ride Through Capability, Unified Power Flow Controller, Super Conducting Magnetic Energy Storage

1. Introduction

In the light of researches so far, by the year 2020, around 20% of the total energy will be generated from renewable energy. Among the various renewable energy sources available, Wind and solar power are omnipresent, of free access and friendly with the environment. Nowadays, the combined use of these renewable energy sources is more attractive, promising and are able to generate electric power in remote areas and complement the demand of conventional electrical power systems. Among the major drawbacks of this type of generation are the intermittent nature of the sources, and its impact on the power system stability. Thus the grid operators require that these kind of generation must contribute with the stability of the power system. In this sense, operators of transmission systems define minimum requirements for the connection of new generation plants to the grid, i.e., a grid code. It is required that the generation plants should have Low Voltage Ride through (LVRT) capability according to the grid code (e.g. the IEEE 1547a-2014 Standard).

A cost effective approach to improve the Fault Ride Through(FRT) capability isby connecting flexible ac transmission system (FACTS) device to the PCC. Unified Power Flow Controller(UPFC) with Superconducting magnetic energy storage(SMES) system forms a better solution for improving the power system stability and LVRT capability of the Grid connected PV-Wind hybrid system.

2. Grid Connected PV-Wind Hybrid System with UPFC-SMES Unit

Efficient generation and use of clean electricity is critical for any nations future.An alternative to fossil-fired power plants is the use of renewable electricity generating technologies. A lot of improvements have been seen in the field of renewable energy generation. The advantages of renewable electricity are many, including reduced environmental impact, potential for lower costs and reduced dependence on imported fuels. However, some forms of renewable electricity, notably wind and solar, can aggravate the operational challenge of meeting electricity demand, though wind and solar energy are the readily available and easy to implement renewable energy sources of energy. The output of wind and solar plants varies with the resource (the wind and the sun, respectively). Hybrid PV-Wind system is more promising source of energy as compared to individual PV system or Wind system.

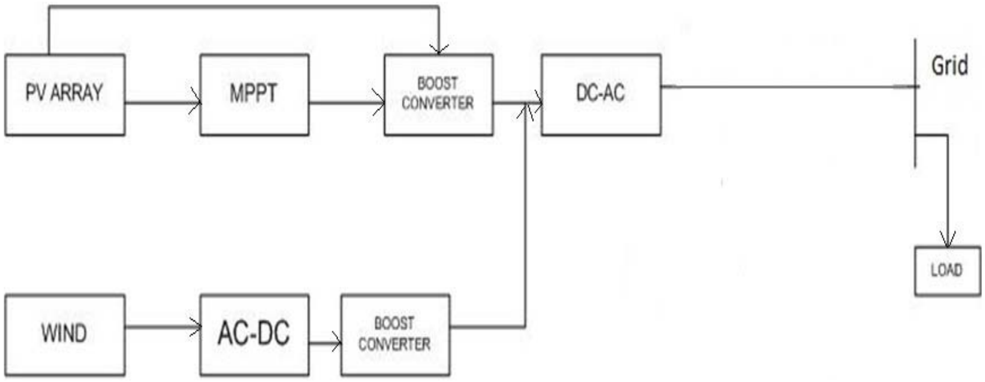

Figure 1: Grid Connected PV-Wind Hybrid System

Among the major drawbacks of this type of generation are the intermittent nature of the sources (the solar radiation and the wind) and its impact on the power system stability. Also, as per grid code (e.g. the IEEE 1547a-2014 Standard) it is required that the generation plants should have L ow Voltage Ride Through (LVRT) capability to remain connected and support the grid under faulty events. This will assure sustainable power delivery to the grid duringfaults and abnormal operating situations. Thus the major focus regarding grid connected hybrid PV-Wind system is drawn towards the power system stability and LVRT capability enhancement.

A cost effective approach to improve the FRT capability and power system stability of the existing hybrid system is by connecting flexible ac transmission system(FACTS) device to the PCC. The UPFC is one of the most potential FACTS devices for power flow control. It can provide independent and simultaneous control of both real and reactive power flow.

3. Unifed Power Flow Controller (UPFC)

UPFC is a fast and flexible, new Flexible Alternating Current Transmission(FACTS) power flow controller, which can be used to control the power flow in transmission line by controlling the impedance, voltage magnitude and phase angle. This new FACTS device is a combination of two old FACTS devices: the STATCOM and the SSSC. Both STATCOM and SSSC are coupled through DC link to allow the continuous flow of real power between the series output terminal of SSSC and shunt output terminal of STATCOM. SSSC injects voltage in series with the line. STATCOM injects current at a point it is connected to the line.

The basic components of UPFC are two Voltage Source Inverter (VSI) sharing a common DC storage capacitor and are connected to the transmission line through two coupling transformers. One VSI connected to transmission line in shunt through a shunt transformer, while the other one is connected to transmission line in series through series transformer. The series inverter is controlled to inject a symmetrical three phase voltage system of controllable magnitude and phase angle in series with the line to control active and reactive power flows onthe transmission line. So, this inverter will exchange active and reactive power with the line. The reactive power is electronically provided by the series inverter, and the active power is transmitted to the dc terminals. The shunt inverter is operatedin such a way as to demand this dc terminal power (positive or negative) from the line keeping the voltage across the storage capacitor Vdc constant. So, the net real power absorbed from the line by the UPFC is equal only to the losses of the inverters and their transformers. The remaining capacity of the shunt inverter can be used to exchange reactive power with the line so as to provide a voltage regulation at the connection point.

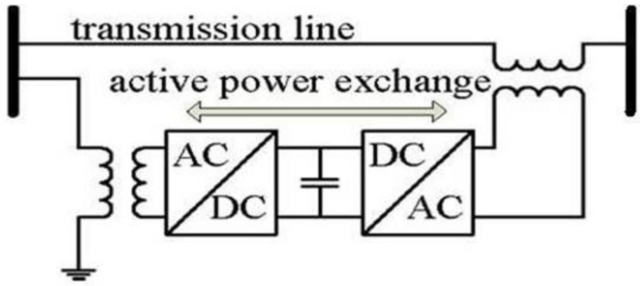

Figure 2: UPFC

A UPFC can respond rapidly to transients and assist in maintaining transient anddynamic stability. However DC link capacitor energy storage is unable to supply controllable active power for an extensive duration due to its inadequate energy storage. This DC link capacitor cannot compensate converter losses for the period of large transients. Though the DC link capacitor energy storage is limited to a defnite value, the backup energy storage systems have been introduced to store more energy. This backup energy storage system is used to improve the dynamic performance of power systems with sustained action in which it can help the power grid. SMES unit forms the better choice for Energy Storage Systems(ESS).

4. Superconducting Magnetic Energy Storage (SMES) Unit

The addition of energy storage allows the UPFC to inject and/or absorb activeand reactive power simultaneously, providing additional benefits and improvements in the system. Superconducting Magnetic Energy Storage(SMES) unit has the rewards of rapid responses, minimum energy loss during the conversion high energy density and high efficiency evaluated with other backup energy storage systems.

An SMES device is a dc current device that stores energy in the magnetic field. The dc current flowing through a superconducting wire in a large magnet creates the magnetic field. Since energy is stored as circulating current, energy can be drawn from an SMES unit with almost instantaneous response with energy stored or delivered over periods ranging from a fraction of a second to several hours. An SMES unit consists of a large superconducting coil at the cryogenic temperature. This temperature is maintained by a cryostat or dewar that contains helium or nitrogen liquid vessels. A bypass switch is used to reduce energy losses when the coil is on standby. And it also serves other purposes such as bypassing dc coil current if utility tie is lost, removing converter from service, orprotecting the coil if cooling is lost.

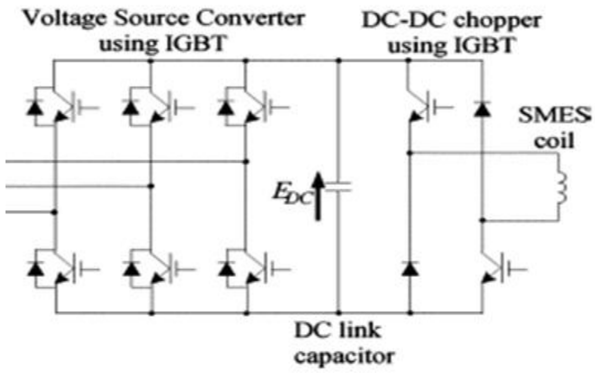

Figure 3: SMES Unit

Hence, UPFC with the SMES integrated system operates as the best solution for improving the power system stability and LVRT capability.

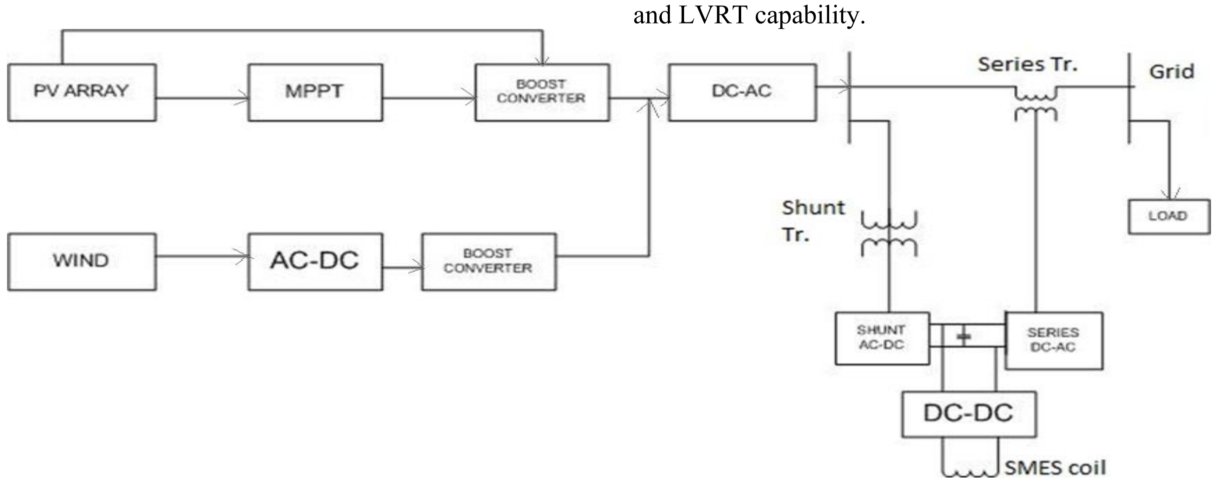

Figure 4: Grid Connected PV-Wind Hybrid System With UPFC-SMES Unit

5. Simulation Results

The system here under consideration, Grid Connected PV-Wind Hybrid System with UPFC-SMES Unit, was simulated using MATLAB Simulink.

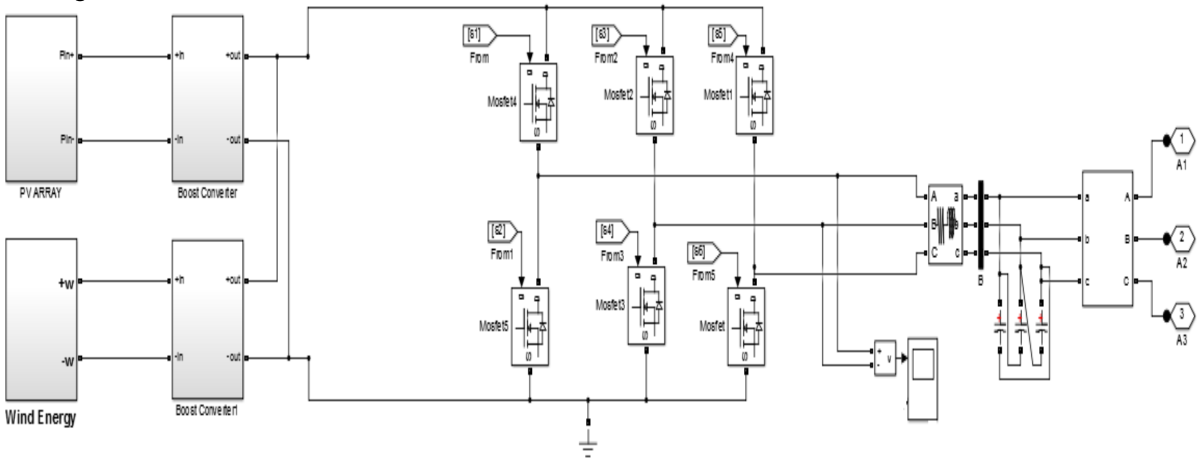

Figure 5: Distribution Generation System

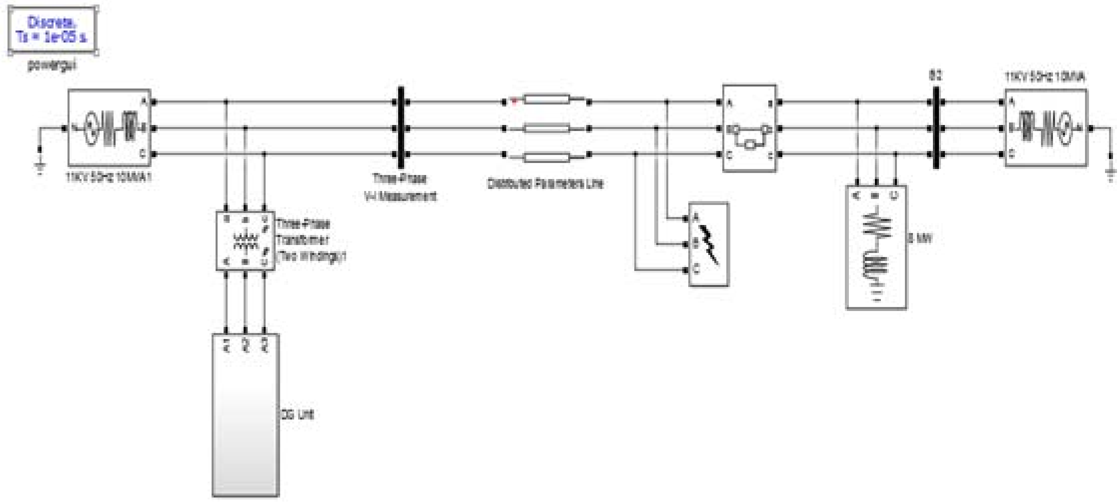

Figure 6: System without UPFC

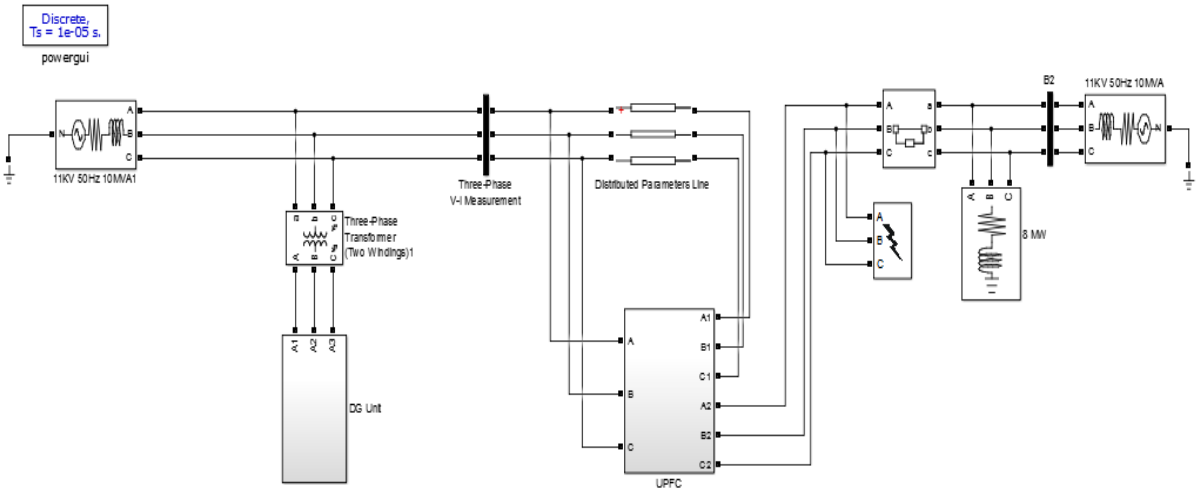

Figure 7: System with UPFC

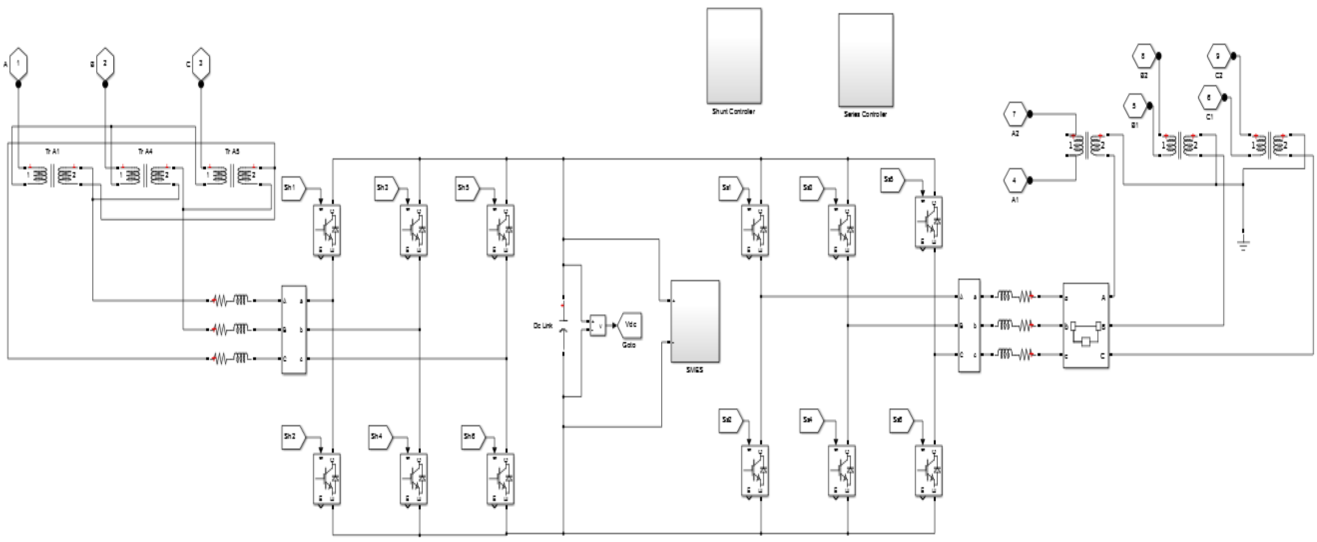

Figure 8: UPFC

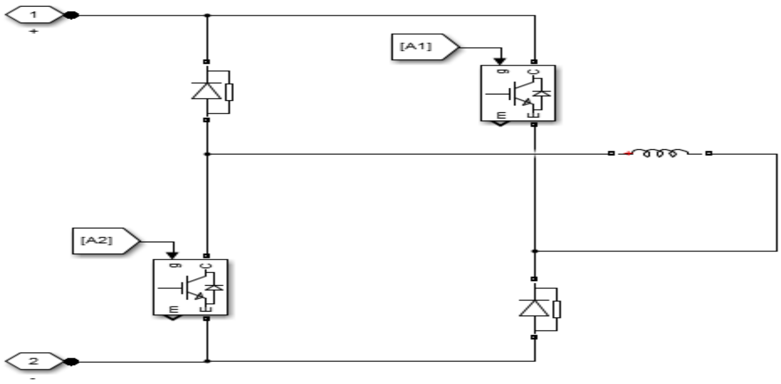

Figure 9: Superconducting Magnetic Energy Storage Unit

The following results were obtained to validate the considered system.

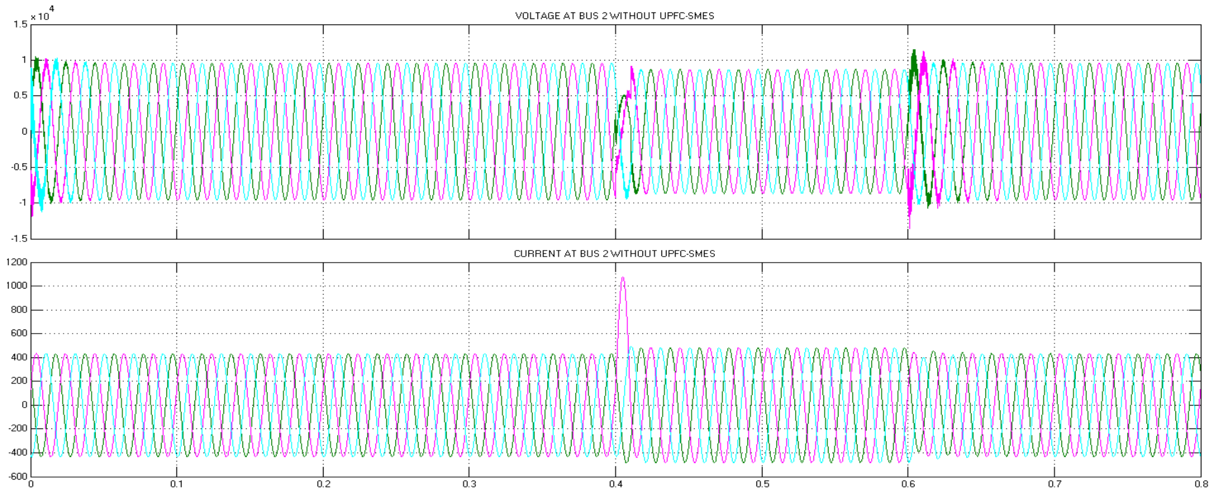

Figure 10: Voltage and Current At Bus 2 Without Upfc

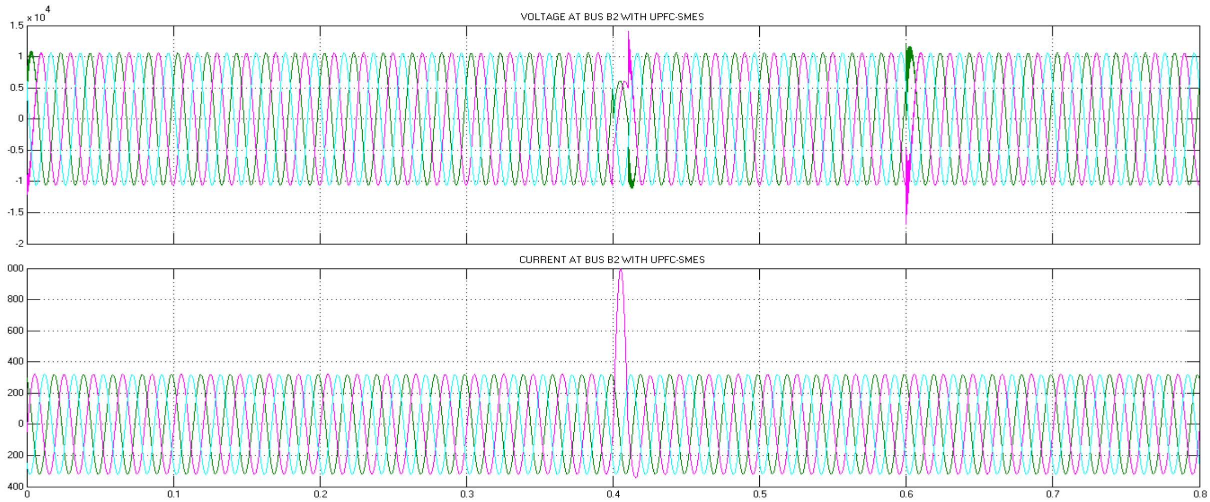

Figure 11: Voltage and Current At Bus 2 WithUpfc

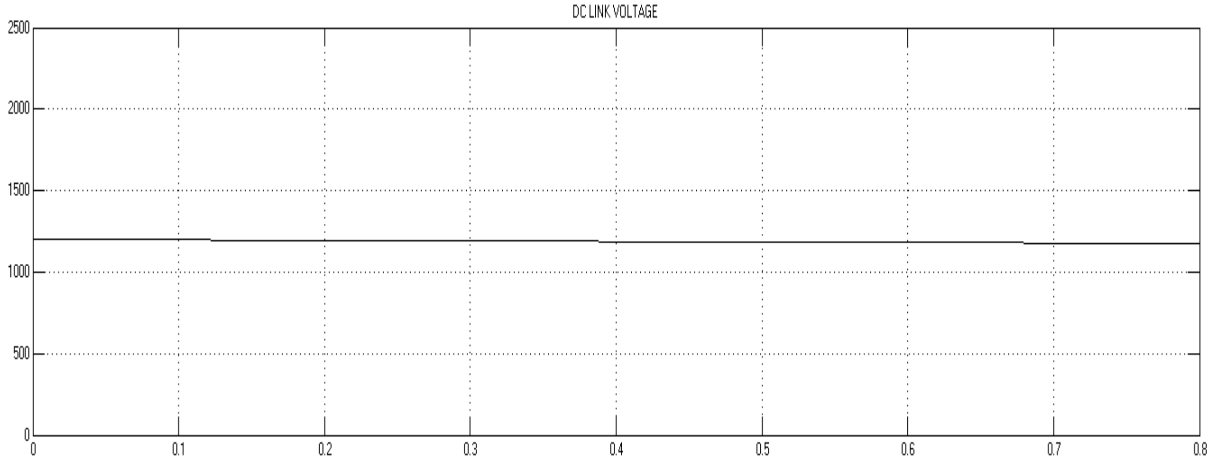

Figure 12: DC Link Voltage

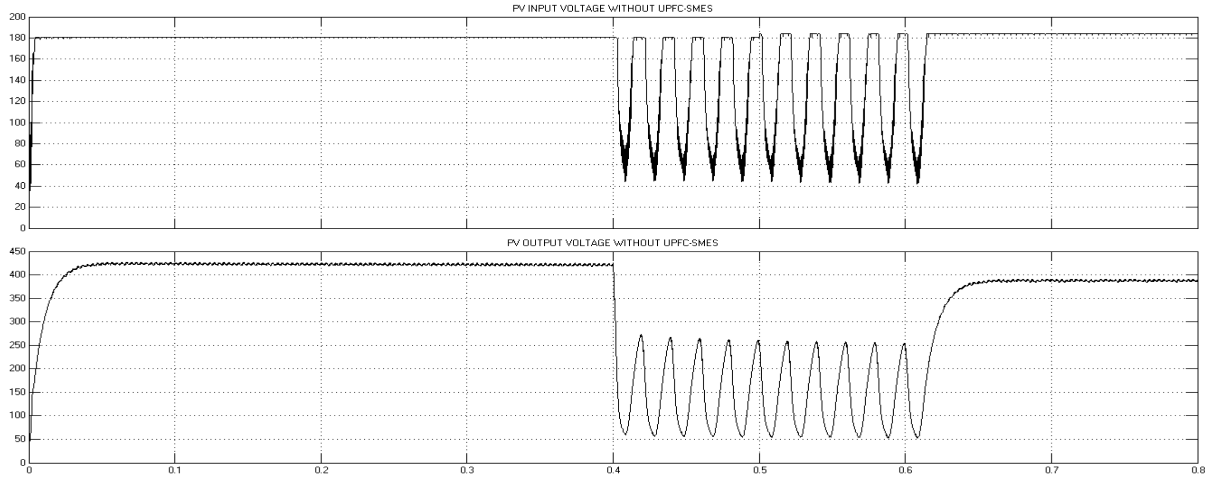

Figure 13: PV Voltages WithoutUpfc

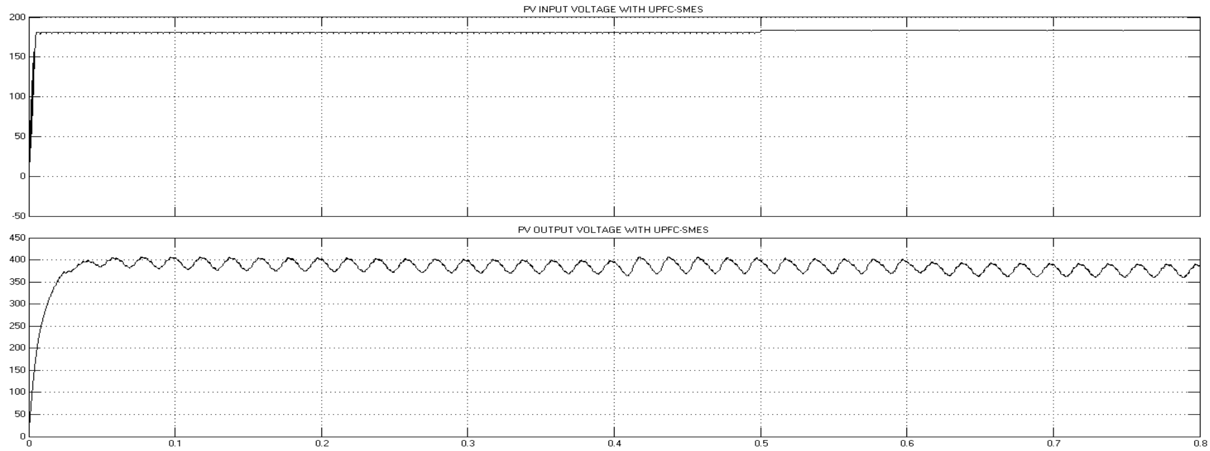

Figure 14: PV Voltages WithUpfc

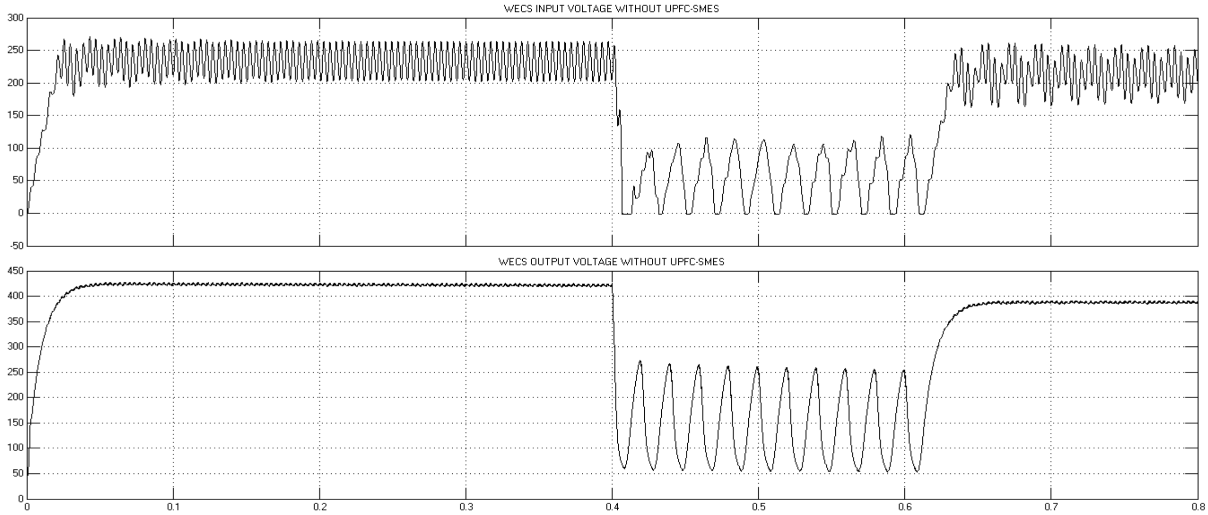

Figure 15: WECS Voltages without Upfc

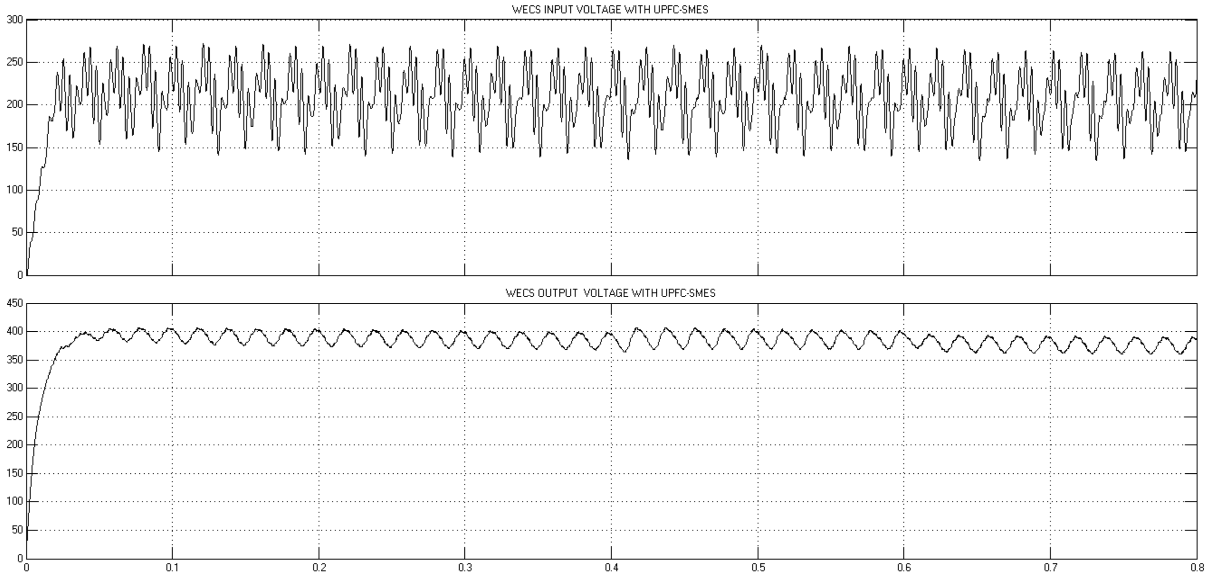

Figure 16: WECSVoltages With Upfc

6. Conclusion

The relevance of hybrid PV-Wind renewable energy system is studied. There were power system stability issues regarding the intermittent nature of these renewable energy systems. Also, as per the renewed grid code(IEEE 1547a-2014), this hybrid system has to ride-through intermittent fault conditions to remain connected and support the grid under such events. This will assure sustainable power delivery to the grid during faults and abnormal operating situations. A cost effective approach is to use FACTS devices for Power system stability and LVRT capability enhancement. UPFC forms a better choice as it is capable of increasing the voltage at the PCC during the fault clearing. As the DC link capacitor energy storage is limited to a definite value, the backup energy storage systems have been introduced to store more energy. SMES is the backup energy storage system integrated to UPFC as it performs well in transient stability and lvrt capability improvement, maintaining constant DC bus voltage, in a grid connected pv-wind hybrid system. Relevant results were obtained to validate the considered system in improving system stability and lvrt capability.

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