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UPFC INTEGRATED WITH BATTERY ENERGY STORAGE SYSTEMS FOR STABILITY IMPROVEMENT

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ABSTRACT

In Electrical Power network, consumer loads are time to time variation in existing transmission system. Loads will not constant means, power quality issues there such as voltage have been flickering and deviations in power supply which make some of the electronic equipments and domestic devices highly sensitive to it . Unified Power Flow Controller (UPFC) is most promising new technologies among the many FACTS devices which can improve the power system operation and power quality problems. To avoid such problems need to find out devices that can provide a backup during the time of voltage sags and such deviations. UPFC joined with batteries through dc-dc chopper have been introduced to improve their ability to exchange real power. The active power injected into the DC-bus is controlled by varying the duty cycle of the switches in the dc-dc chopper while the battery is discharging.

Keywords: FACTS, UPFC, Energy storage system, Battery, Stability, DC-DC chopper.

Contribution/ Originality

Energy storage devices in power systems can be added to existed FACTS devices to increase their stability of the power system. This paper concentrated in integrating UPFC with battery energy storage system which helps to improving the reliable operation of the power systems.

1. INTRODUCTION

The most important advantage of the UPFC for transient stability improvement is direct through speedy bus voltage, line impedance and phase angle management. Particularly, the UPFC is used to enhance power transfer throughout low-voltage conditions, which usually predominate throughout faults, decreasing the acceleration of native generators [1].

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A UPFC linked in nonparallel and shunt converters with link the DC link capacitor. With the system is capable of expanding transient stability by compensating the imaginary power at the purpose of common affiliation. The final word objective of applying reactive compensation in a transmission line is to extend the contractible power throughout transients. This is frequently accomplished by means of increasing (decreasing) the power transfer capability once the machine angle will increase (decreases). In Figure 1, which shows the one line diagram of a UPFC, if the DC capacitor voltage, V_{DC}, is increased from its par value, the UPFC is overexcited (capacitive mode) and generates reactive power. If the voltage of the DC electrical condenser bank is diminished below the par value, the UPFC is under excited (inductive mode) and absorbs reactive power from the system. This is often fully analogous to increasing or decreasing the sphere voltage of a synchronous compensator [1].

When a huge disturbance occurs or a great amount of load goes out, generators speed up and cause extra kinetic energy to appear in power system. This resultant energy is absorbed into the power system by many solutions such as FACTS devices [2].In view of the fact that energy absorption from power system is inadequate to a certain value of storage. The energy storage systems can be suitable devices to save the extra energy and also decrease the oscillation distribution among the generators and reduce the convertor losses. Energy storage devices in power systems can be added to existed FACTS devices to increase their flexibility in power system stability improvement by satisfying the exchange of active power with power grids [3].

In several analysis papers, it's been shown that associate extent energy storage system (ESS) plays a very important role in grid management. The requirement of storage devices and their utilization in power systems has long been debated. An outline of the various storage technologies, their applications and limitations area unit mentioned in [4-8]. The sooner reviews on storage technology focus completely on lead-acid battery technology. The economic models, their controls, ratings and applications found in United States power systems are mentioned and the potential future applications area unit urged in [4, 5]. In Miller, et al. [6] the utilization of battery energy technology to enhance the power quality and reliability of the power system are mentioned. Number of the reviews administrated recently in [7, 8] discuss regarding the varied storage technologies and counsel that thus far the battery technology is that the most generally used storage device for grid applications. In follow, by integration ESS with UPFC vital enhancements over traditional UPFC performance are realizable. A number of benefits in battery with UPFC technologies are higher energy storage densities, greater cycling capabilities, better reliability, and lower price. This combined system is capable of mitigating of transient stability and voltage fluctuation issues within the grid.

This paper introduces a new proposal, this model is implemented in integrating UPFC with battery energy storage system using MATLAB/Simulink software and computer simulation results under different fault (3-phase to ground fault) clearing times are analyzed for transient stability. Here there are various ways in which the battery with UPFC technologies can help to improving the reliable operation of the power systems. The final results show that the addition of energy storage allows the proposed method to inject and/or absorb active and reactive power at the same time and provides additional benefits and improvements in the system.

2. UNIFIED POWER FLOW CONTROLLER (UPFC)

Unified power flow controller (UPFC) combines series and shunt FACTS device. It consists of a mixture of SSSC in nonparallel and STATCOM in shunt with the line. These two voltage source inverters are connected by a typical DC link capacitor in Fig.1. The series half injects the voltage of governable magnitude within the transmission line to manage the real and reactive power of the power system. The shunt half is employed to take care of the voltage across the DC link capacitor and therefore the bus voltage wherever it's connected by injecting the present of governable magnitude within the system [9].

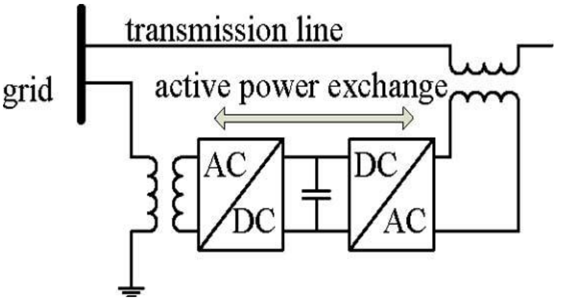

Figure-1.UPFC connection in transmission line

The reactive power is automatically provided by the series electrical converter, and therefore the active power is transmitted to the DC terminals. The shunt electrical converter is operated in such the simplest way on demand this DC terminal power from the line keeping the voltage across the storage electrical condenser V_{DC} constant. The remaining capability of the shunt electrical converter used to exchange reactive power with the line, therefore to supply voltage regulation at a line.

The two VSI will work severally of every different by separating the DC side. Therefore in this case, the shunt electrical converter is working as a STATCOM that generates or absorbs reactive power to control the voltage magnitude at the transmission line. Instead, the series electrical converter is working as SSSC that generates or absorbs reactive power to control the present flow, and thus the power flows on the cable.

3. BATTERY ENERGY STORAGE TECHNOLOGY

The battery energy storage system (BESS) contains primarily of batteries, control and power conditioning system (C-PCS) and remainder of plant. The remainder of the plant is meant to supply smart protection for batteries and C-PCS. The battery and C-PCS technologies are most important BESS elements and every of those technologies are quickly developing. That the contribution state-of-art of every of them has been mentioned severally.

3.1. Batteries

The batteries are manufactured from stacked cells where-in energy is born-again to electricity and the other way around. The required battery voltages in addition as current levels are obtained by the electrically connecting the cells nonparallel and parallel. The batteries are rated in terms of their energy and power capacities. Foremost of the battery types, the power and energy capacities aren't freelance and area unit fastened throughout the battery style. Number of the oppose unnecessary options of a battery are potency, period, operative temperature, depth of discharge (batteries area unit typically not discharged fully and depth of discharge refers to the extent to that they're discharged), self-discharge (some batteries cannot retain their capacity holdup in a very shelf and self-discharge represents the speed of discharge) and energy density.

Currently, essential development goes on with the battery technology. Different kinds of batteries are being developed. The batteries utilized in grid applications as a result extreme deep cycle batteries with energy capability starting from17 to 40MWh and having efficiencies of about70–80%. From the varied battery technologies in Linden [10] some appear to be a lot of appropriate for grid applications and these are mentioned below:

(1) Lead acid: Every cell of a storage battery contains a positive conductor of lead oxide and a negative conductor of sponge lead, separated by micro-porous material and immersed in an aqueous sulfuric acid electrolyte (contained in a plastic case).

(a) Flooded sort: Within the flooded type battery an aqueous sulphuric acid solution is employed. Throughout discharge, the lead oxide on the positive conductor is reduced to guide compound, which reacts with vitriol to make lead sulfate; and therefore the sponge lead on the negative conductor is change to guide ions, that reacts with vitriol to make lead salt. During this manner electricity is generated and through charging this reaction is reversed.

(b) Valve regulated (VRLA) type: the VRLA uses an equivalent basic chemistry technology as flooded lead-acid batteries, except that these batteries are closed with a pressure control valve, in order that they're sealed and the acid solution is immobilized.

(2) Sodium sulphur (NaS): A NaS battery consists of liquefied sulfur at the positive electrode and liquefied sodium at the negative electrode separated by a solid beta alumina ceramic electrolyte. The electrolyte permits solely the positive Sodium ions to travel through it and mix with the sulfur to make Sodium polysulfide. Throughout discharge, positive Sodium ions move in the electrolyte and electrons flow within the external circuit of the battery manufacturing regarding 2V. The battery is unbroken at regarding300°C to permit this method.

(3) Lithium ion (Li ion): The cathode in these batteries may be a lithiated metal oxide and thus the anode is formed of graphitic carbon with a layer structure. The electrolyte is created from Li salts dissolved in organic carbonates. Once the battery is being charged, the Li atoms within the cathode become ions and migrate through the electrolyte toward the carbon anode wherever the mix with external electrons and area unit deposited between carbon layers as Li atoms. This method is reversed throughout discharge.

Some of the most characteristics of flow batteries are: high power, long period, power rating and therefore the energy rating are decoupled, electrolytes may be replaced simply, quick response and may go from charge to discharge modes in regarding 1ms (because most reaction reactions latent period is extremely short), low efficiencies (due to the energy required to flow into the electrolyte and losses thanks to chemical reactions). The system doesn't have any self-discharge, because the electrolytes cannot react once they are hold on severally.

3.2. Integration of Energy Storage Systems with FACTS Devices

An energy storage system (ESS) will play a very important role in grid management and supply essential enhancements over traditional UPFC performance. Battery energy storage systems (BESS) in conjunction with UPFC have recently emerged collectively of the foremost promising near-term storage technologies for power applications [9, 11]. By the addition of associate degree energy storage system to the UPFC, it is potential to manage the active power flow between the UPFC and therefore the point of common coupling (PCC). Thus, the UPFC compensates the reactive power and additionally stores energy within the storage system once the generated power exceeds the power limits that would be injected to battery. Additionally, this response provides promotes management of the power flow at the PCC, by adjusting the direction of power injection, like downwards or upwards.

Recently, a substantial quantity of attention has been given to developing executive system for a range of FACTS devices, like static synchronous compensator (STATCOM), the static synchronous series compensator (SSSC), and therefore the unified power flow controller (UPFC), to be ready to address and mitigate a large vary of potential bulk power transmission issues [12].

In the absence of energy storage, FACTS devices area unit restricted within the degree of freedom and sustained action within which they will facilitate the power grid. By the method of integration of energy storage system (ESS) into FACTS devices, associate degree temporary real and reactive power absorption or injection into and from the grid is feasible. This integrated system results in a lot of economical and versatile power transmission controller for the power system. Once a transmission line experiences vital power transfer variations in associate degree intermittent manner, FACTS with BESS combination may be installed to control and modify the power flow inside the loaded line. The improved superior performance of combined FACTS with ESS can have larger attractiveness to transmission service suppliers. Performance indices were projected for FACTS dynamic performance with energy storage in Zhang, et al. [13] and management schemes are mentioned in [14-16].

Power system deregulating, at the side of transmission limitations and generation shortage, has modified the power of grid conditions by making things wherever energy storage technology will play a really very important role in maintaining system dependability and power quality. There are multiple advantages of energy storage devices like the flexibility to speedily damp oscillations, reply to fast load transients, and still provide the load throughout transmission or distribution interruptions. Additionally, this technique will correct load voltage profiles with speedy reactive power management, and still enable the generators to balance with the system load at their traditional speed.

The major disadvantage of a standard UPFC is that it's solely two potential steady-state operative modes, namely, inductive mode (lagging) and capacitive mode (leading). Even if each normal STATCOM output voltage magnitude and point may be controlled, they cannot be severally adjusted in steady state recognition to the shortage of great active power capability of UPFC. Typically, the UPFC device voltage is maintained in component with the PCC voltage, so guaranteed that solely reactive power flows from the UPFC to the system. Thus, a little quantity of real power flows through the system from PCC to DC bus, to catch up on the losses. However, the important power capability of the UPFC is extremely restricted recognition to the absence of any energy storage the DC bus. Compared with the existing UPFC, the UPFC with BESS provide a lot of flexibility.

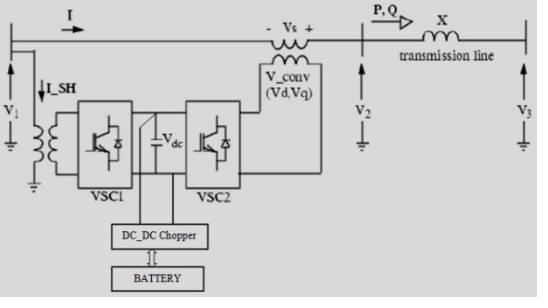

Figure-2.UPFC with ESS connected to power utility system.

In case of UPFC with BESS, the amount of steady-state operative modes is extended to varied effects like inductive mode with DC charge and DC discharge, electrical phenomenon mode with DC charge and discharge. Thus, in steady state, the UPFC with BESS have four operative modes and may operate at each purpose within the steady-state characteristic circle. Additionally, computation on the energy output of the battery or different ESS, the discharge/charge profile is usually comfortable to supply enough energy to stabilize the power regulation within the system and maintain operation till other long-term energy sources are brought into operation.

On sure occasions, giant battery systems tend to exhibit voltage instability on one occasion assorted cells are placed nonparallel. However, usually it is seen that even enormous oscillations may be alleviated with modest power injection from a storage system. The flexibility to executive each active and reactive powers in UPFC with BESS makes them ideal controllers for varied sorts of power regulation system applications, together with voltage fluctuation mitigation and oscillation damping. Among them, the foremost necessary use of the UPFC with BESS is to stabilize any disturbances occurring within the grid.

4. SIMULATION ANALYSIS

In order to exhibit the effectiveness of the UPFC with battery combination for stability enhancement, several cases are simulated. These cases are given in subsections below. To simulate dynamic oscillations in each case, a 3-phase fault is introduced at time =0.0166 sec and fault-clearing time 0.0833sec.

In this paper to analysis two cases,

Case A: Lead-acid battery energy storage system

Case B: Lithium-Ion battery energy storage system.

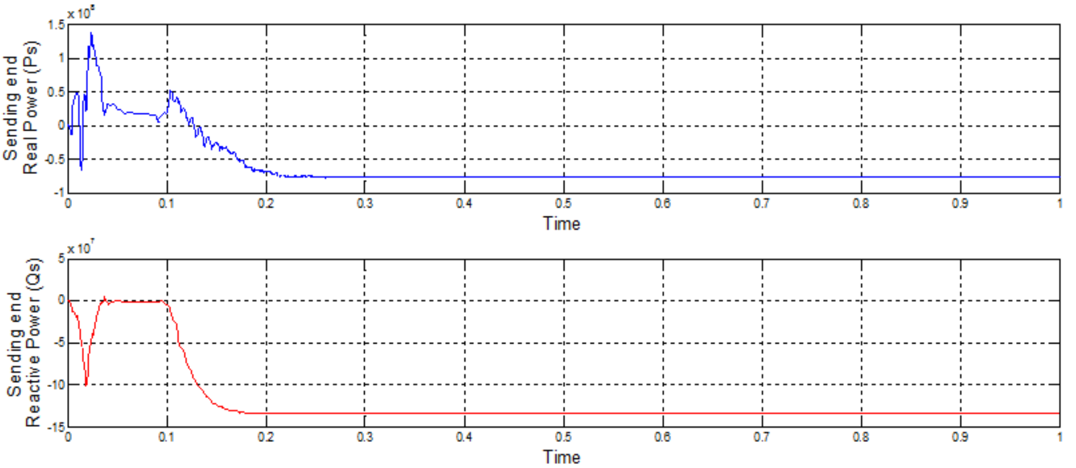

Figure-3. Sending end real and Reactive power in case A

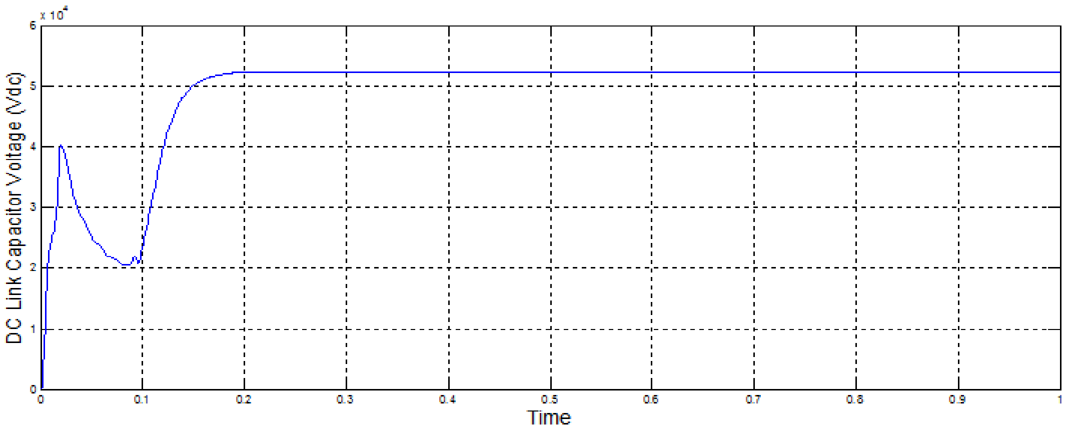

Figure-4.DC link voltage in case A

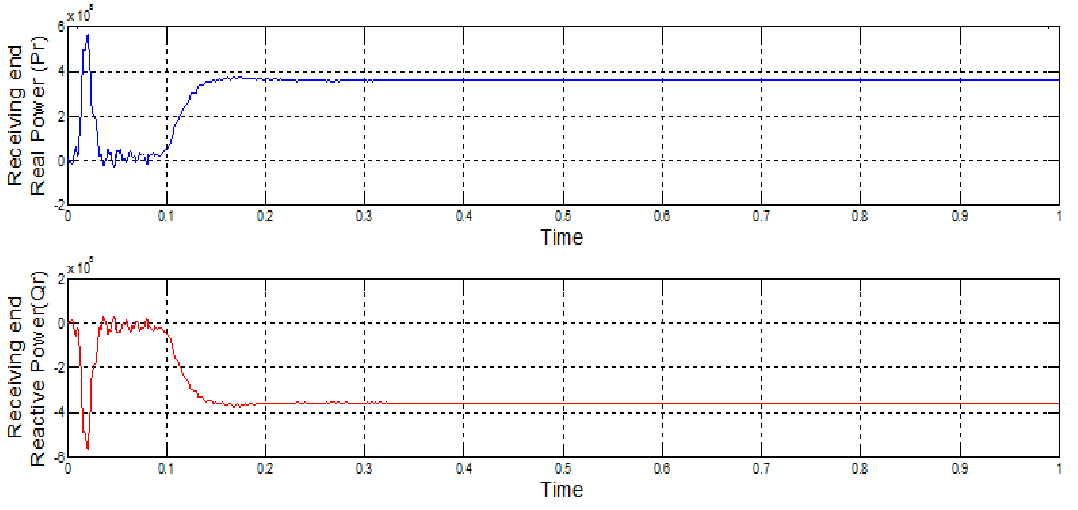

Figure-5. Receiving end Real and Reactive power in case A

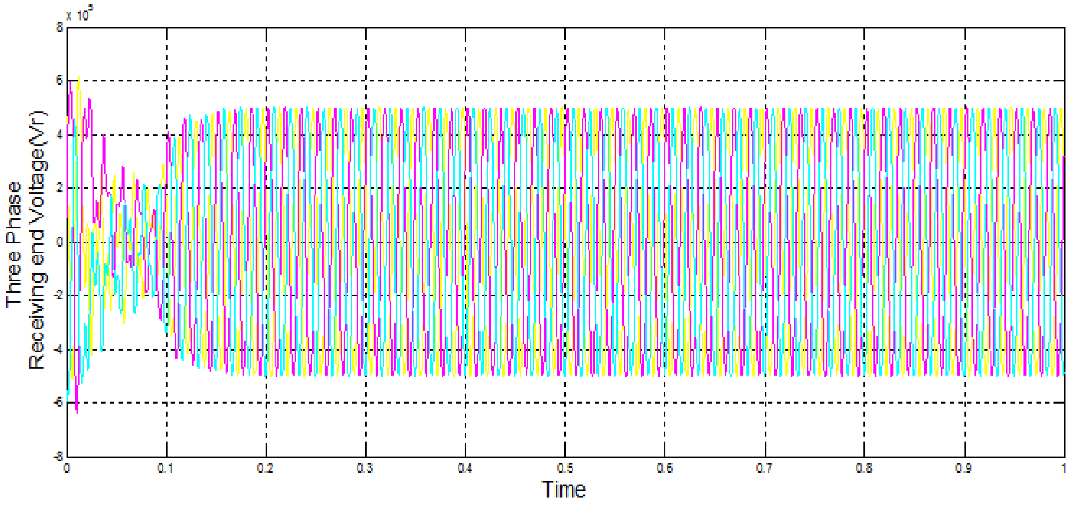

Figure-6. Three phase voltage in case A

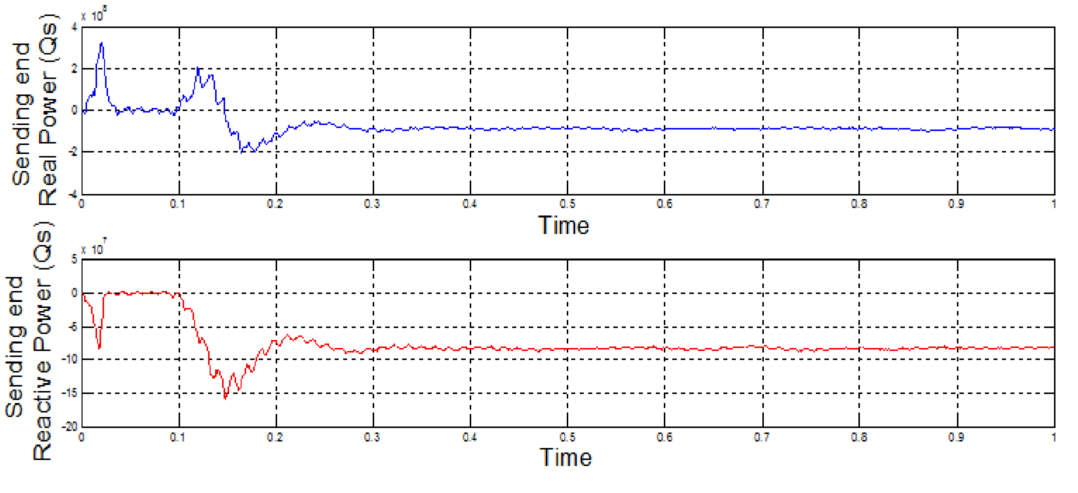

Figure-7. Sending end real and Reactive power in case B

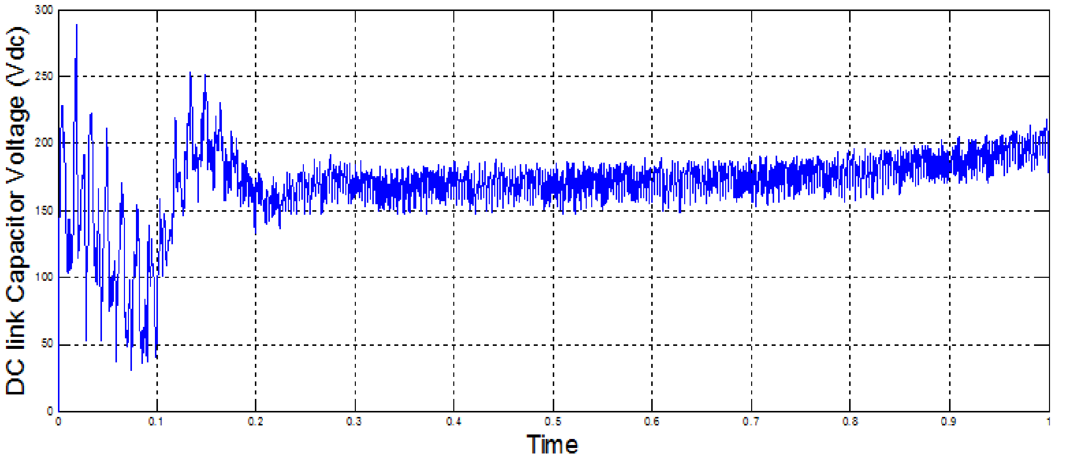

Figure-8.DC link voltage in case B

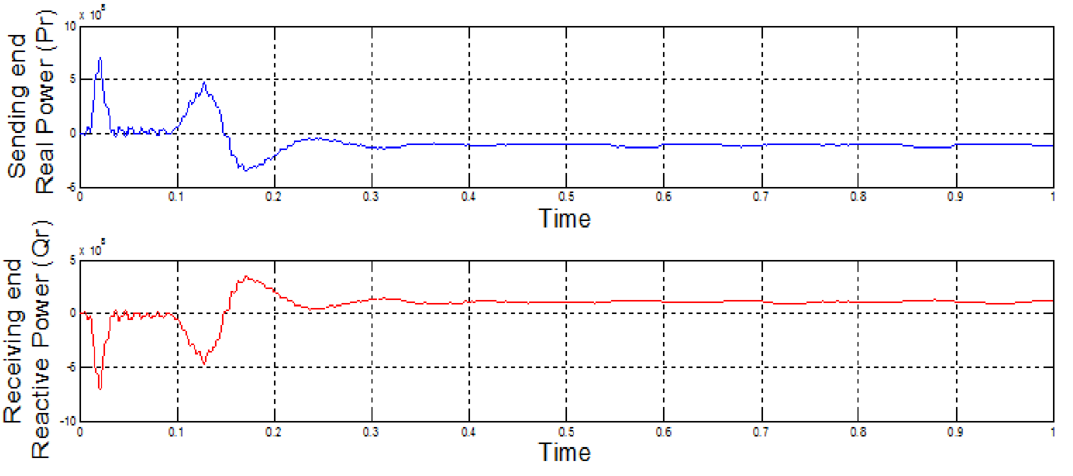

Figure-9. Receiving end real and Reactive power case B

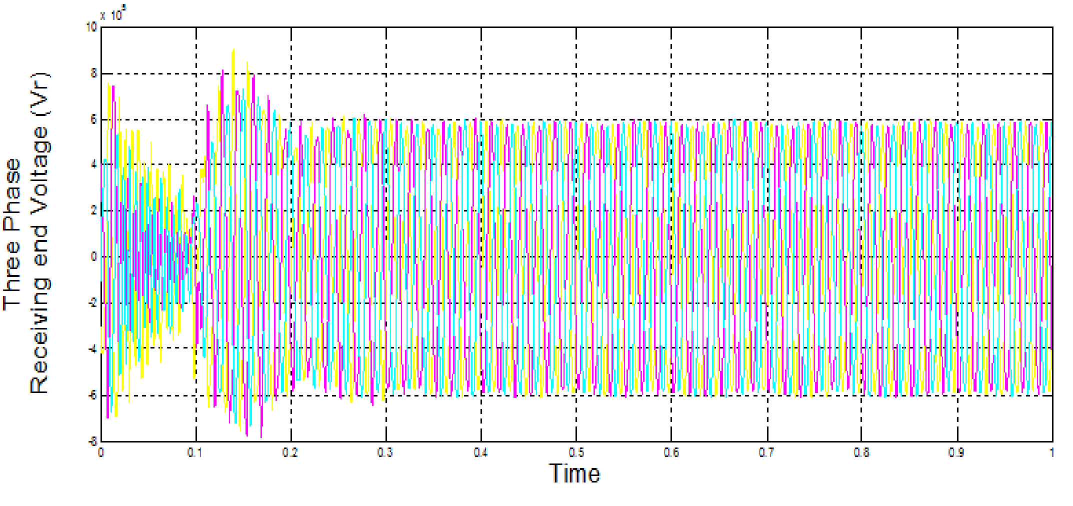

Figure-10. Three phase voltage in case B

Compared the case A and case B comments are table 1.

Table-1. Comparision of battery

Battery type	Comments
Lead acid (flooded type)	ɳ = 72–78%, life span 1000–2000 cycles at 70% depth of discharge, operating temperature −5 to 40° C ,25 Wh/kg, self-discharge 2–5%/month, frequent maintenance to replace water lost in operation, deep
Lead acid (valve regulated)	ɳ = 72–78%, life span 200–300 cycles at 80% depth of discharge, operating temperature −5 to 40° C ,30–50 Wh/kg, self-discharge 2–5%/month, less robust, negligible maintenance, more mobile, safe compared to flooded type)
Lithium ion	ɳ ≈100%, life span 3000 cycle at 80% depth of discharge, operating temperature −30 to 60 °C, 90–190 Wh/kg, self-discharge 1%/month, high cost due to special packaging and internal over charge protection

5. CONCLUSION

This paper presented an UPFC conjunction with battery energy storage system. This proposed system controlled the real and reactive power coordination. It had been observed that the UPFC-battery combination could be very effective in compensating voltage sag. This system is also appropriate for enhancement of transient stability and the dynamic behavior of the power system. UPFC provides a real power flow path for battery, but the operation of the battery independent of the UPFC controller. At the same time as UPFC is controlled to absorb or inject reactive power, the battery is controlled the real power. The battery storage device should be used for system performance such as Lead acid, and Lithium ion. Among all these batteries, the Lithium ion battery is the oldest and most mature technology, which has been used for majority power system applications. Lithium ion battery is ɳ≈100%, life span 3000 cycles at 70% depth of discharge, operating temperature −30 to 60 °C, 90–190 Wh/kg, self-discharge 1%/month, high cost due to special packaging and internal over charge protection.

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