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Simulation and Modeling of Super Capacitors Energy Storage System for Voltage Sags Compensation

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ABSTRACT

Role of instantaneous energy is important in supplying active power mismatch in reliable a power system. Super capacitor (SC) is the important and recent development in the area of electrical energy storage systems, and has many practical and commercial applications to store energy. It is useful in smoothing large magnitude and short duration power disturbances in a distribution network. Due to high power and energy density requirement from dc storage systems, SC are frequently gets used in low and medium voltage power systems. Energy density in SC is not as high as that of the electrochemical accumulators, but the level of stored energy and storage time are sufficient to fulfill most of the power system requirements. Applications of SC is limited to supplying or absorbing power pulses during transient periods, electric vehicle start up operation, and low voltage distributed generation system. There is a need to study the performance of SC storage in medium voltage power systems subjected to sudden active power variations and network faults.

Keywords

SC, Energy Storage System, Power Quality, SCES, voltage sag.

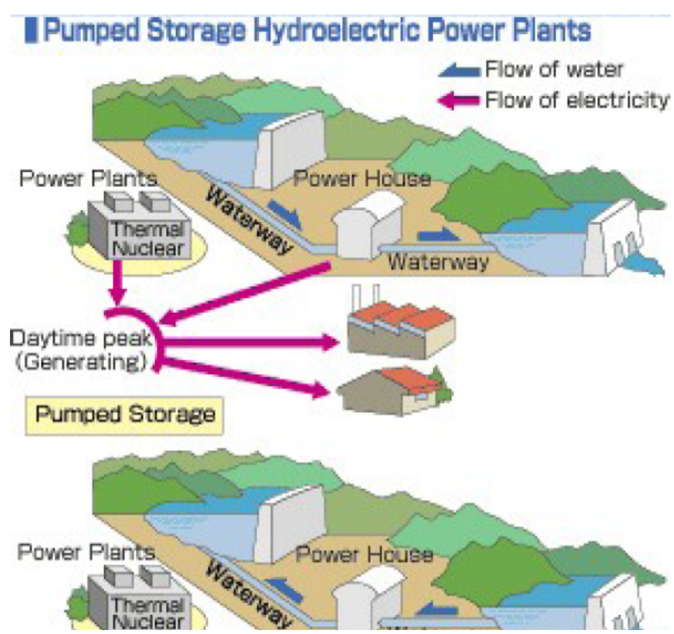
1. INTRODUCTION

Electrical power demand is continuously rising, and this demand is concentrated in major regions/ cities. Higher transmission voltage levels resulting large power transfer over long distances, geographically expanding power systems over geographical regions resulting in a large and complex interconnected network resulting in less secure and unreliable power system operation. Operation of Power system is effected due to same reasons like regulation, technical, governmental laminations, so that power experts need to find solution to secure more, flexibale and reliable operation. More attention is towards area like material science technology, automation, power quality, smart grid, renewable energy storage system etc .development in power electronics and material science make a vide choice for energy storage system, battery, capacitor, super capacitor. Battery and fuel cell are work on conversion of chemical energy into electrical energy so fuel cell and battery is proposed for hybrid vehicles. in capacitor electrical charge are physical separated across the dielectric material which is oxide layer or polymer film. Different type of device is providing a different combination of power energy density and power density. Super capacitor work on separation of chemically charge species at electrified interface between a solid electrode and an electrolyte. systems a valuable choice to solve some of the problems experienced in power systems.Batteries, fuel cells, capacitors, and super capacitors are all energy storage devices. Batteries and fuel cells rely on the conversion of chemical energy into electrical energy. Fuel cell and battery or super capacitor energy storage technology is proposed for a hybrid vehicle [1]. Capacitors rely Combination of high power density and relatively high energy density

2. ENERGY STORAGE SYSTEMS

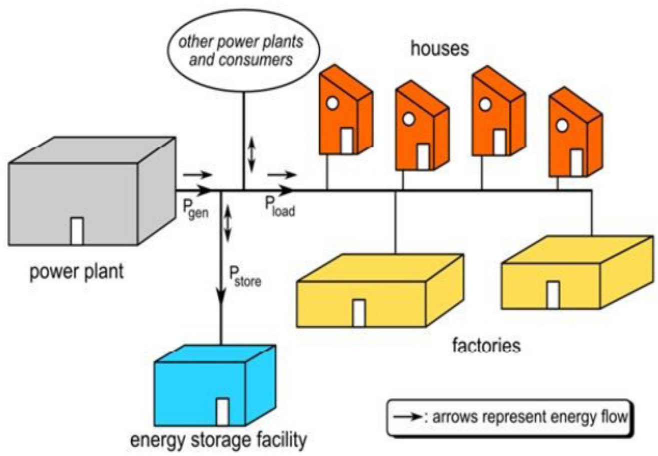
The various energy storage systems present in world.

2.1 Energy storage system (pumped):

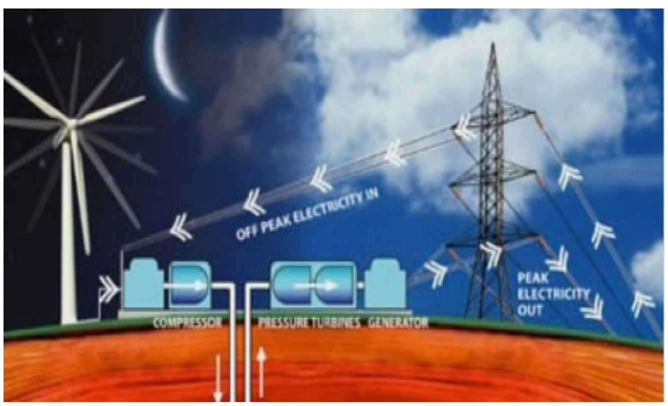


2.2 Battery Energy Storage

On the physical separation of electrical charge across a dielectric medium such as a polymer film or an oxide layer. Each type of device provides a different combination of power density and energy density.Super capacitors rely on the separation of chemically charged species at an electrified interface between a solid electrode and an electrolyte. Only super capacitors can provide a



2.3 Compressed Energy Storage



3. CAPACITOR ENERGY STORAGE SYSTEM

If a conductor is given more and more charge, its potential also goes in increasing. It is risky to handle a large charge at a high potential. It is therefore necessary to have an arrangement in which the capacity of the conductor is increased without an appreciable increase in its potential. Such an arrangement is called a condenser or a capacitor and it is used to store a large quantity of charge at low potential. Capacitor is one of the popular electronic components which have the ability to store electrical energy in the form of charge. All capacitors consist of two conducting plates and they are separated by a dielectric medium. The ability of a capacitor to store charge is called as capacitance given by,

$$C = \epsilon_0 \epsilon_r \frac{A}{d}$$

Where,

C = capacitance in farads (F).

A = area of the electrodes measured in square meters (m^2).

ϵ_0 = permittivity of free space ($\varepsilon_0 = 8.854 \times 10^{-12}$ F/m).

ε_r = dielectric constant (or relative permittivity) of the material between the plates, (for a vacuum ε_r=1).

d = distance between the plates, measured in meters (m).

Thus capacitance is directly proportional to absolute permittivity; hence for high value of C, dielectric medium with high relative permittivity is required. C is directly proportional area of parallel plates and inversely proportional to separation between plates.

Capacitor energy storage is given by,

$$E = \frac{1}{2}qV$$
$$= \frac{1}{2}CV^2$$

Where,

E = Energy (Joules) stored in a capacitor,

q = Charge (Coulombs),

V = Potential difference (Volts) between the electrodes.

C = Capacitance (Farads)

Electrode surface is used to store charge in capacitors and entire electrodes are not used, hence less energy density and capacity. Conventional capacitors do not require specially designed charging and discharging circuits and capacitors can be manufactured at higher voltage levels but designed voltage is generally restricted to volts. Capacitors do not store energy in chemical form as compared to batteries and hence number of charging and discharging cycles are large than that of the batteries.

Double layer capacitor and electrochemical capacitors are the two type of super capacitors.

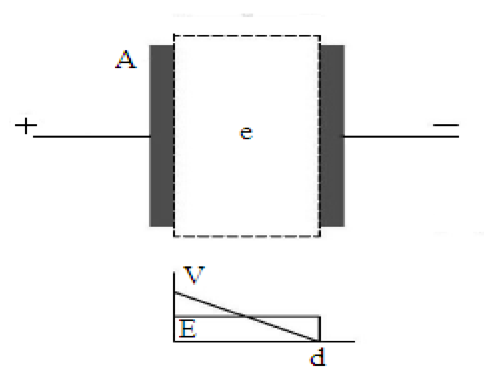


Fig . Electrostatic capacitor

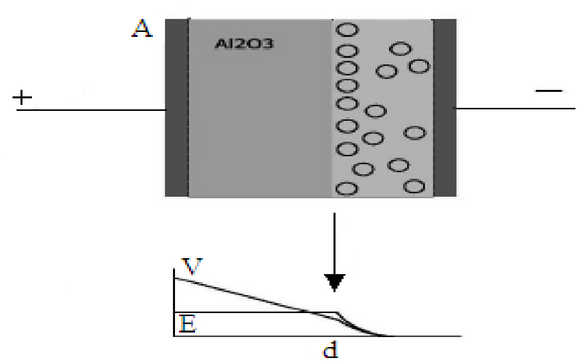


Fig .Electrolytic capacitor.

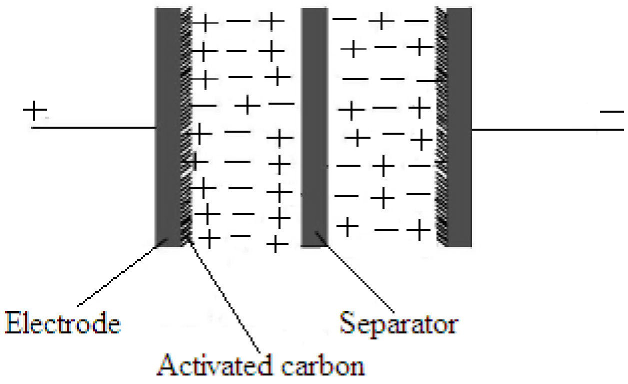


Fig. Electrochemical double layer capacitor (Supercapacitor)

4. MODELING OF DVR IN MATLAB

Fig.1 shows the configuration of our reference system which is also a typical configuration of a micro grid and a energy storage for grid support and peak power shaving. A 11 kV grid is fed by a 4 kV, 5MVA steam driven main generator. A Super capacitor (SC) storage and DC-DC chopper represents the alternate energy storage system coupled with the grid through 0.77 kV / 11 kV step up transformer. No long term back-up energy storage has been considered since our aim so far was to study the response of SC storage only.The modeling of generator as a constant voltage source (three phase programmable voltage source). There is a three-phase voltage source with programmable time variation of amplitude, phase, frequency, and harmonics. The amplitude is set as 4 kV and frequency as 50 Hz. Generator transformer is a three phase transformer rated 5 MVA, 50 Hz, 4kV star / 11kV delta. A point of common coupling (PCC) formedLoads are modeled and a three phase breaker is used for switching required loads at set times. And Loads are modeled as star connected constant active power load of 4.1 MW and 0.6MW at 11 kV, 50 Hz respectively. Load of 4.1 MW is continuously connected and 0.6 MW load is switched from 0.25 to 0.75 sec. This means during 0.25 to 0.75 sec, 4.7 MW load is connected otherwise 4.1 MW load is connected.

Voltage Sourced Converter (VSC) is the interface between the grid and the SC energy storage unit. The reference signal for the PWM control for the VSC is phase modulated by means of the phase angle.The Universal Bridge block implements a universal three-phase power converter that consists of up to six power switches connected in a bridge configuration. The Universal Bridge block allows simulation of converters using both naturally commutated (and line-commutated) power electronic devices (diodes or thyristors) and forced-commutated devices (GTO, IGBT, and MOSFET). The Universal Bridge block is the basic block for building two-level voltage-sourced converters (VSC). The device numbering is different if the power electronic devices are naturally commutated or forced-commutated.

Grid Voltage

$VG = [1/3\ (Va^2 + Vb^2 + Vc^2)]^{1/2}$................(1)

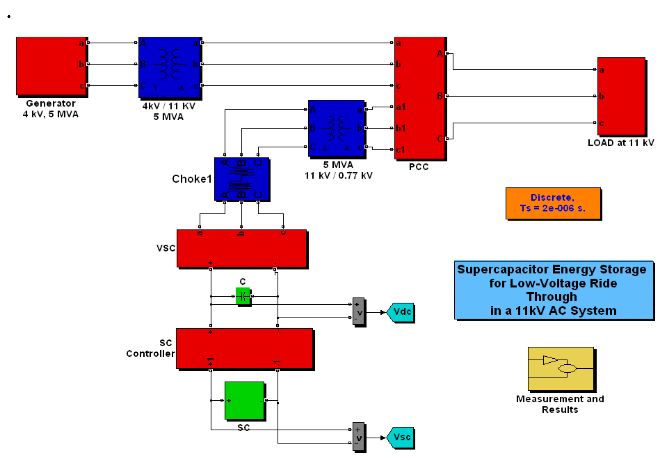


Fig.1Simulink model of power system under study

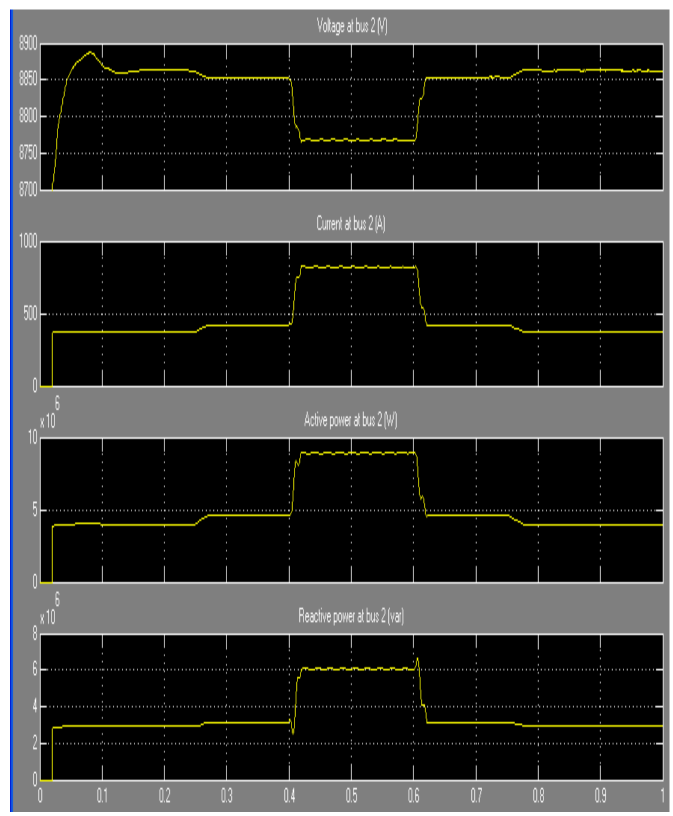


Fig.2.V, I, P, Q at load bus for a LG fault without SC support

Figure 2 shows Voltage, Current, Active power and Reactive power at load bus 2. As the load increase from 4.1 MW, 3 MVAR to 4.7 MW, 3.2 MVAR at 0.25 sec, voltage drops from 8865 V to 8850 V, current also increases, P and Q also shows the respective rise. As the LG fault is created at 0.4 sec, voltage shows a dip towards 9760 volts and shows a large increase in I, P and Q which is beyond control lasting up to 0.6 sec. At 0.75 sec load is again reduced to normal 4.1 MW, 3MVAR.

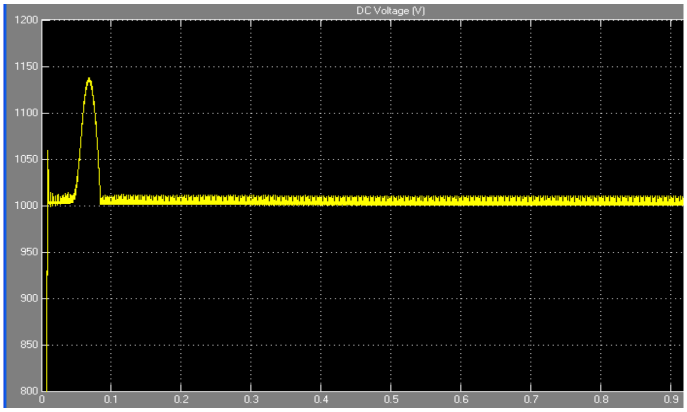


Fig.3 DC link voltage for a LG fault without SCSupport

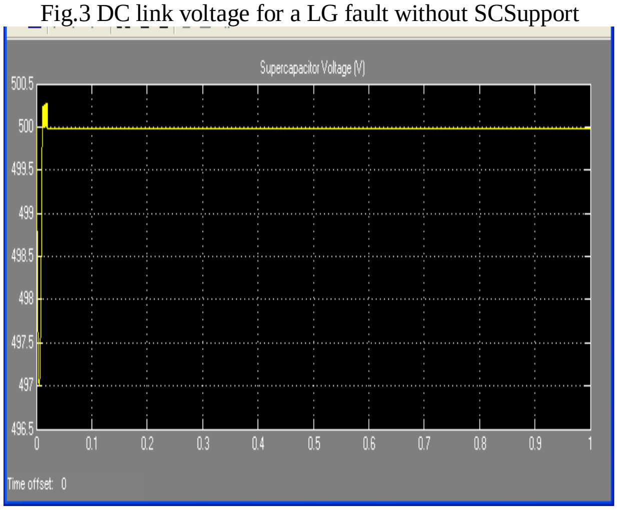


Fig.4 SC voltage for a LG fault without SC support

Fig.3 shows DC link Voltage which is maintained constant at 1000 V. Fig.4 shows SC voltage which is constant at 500 V. It is not showing any discharging or charging period and indicating thatit is not providing any support during load increase or LG fault period.

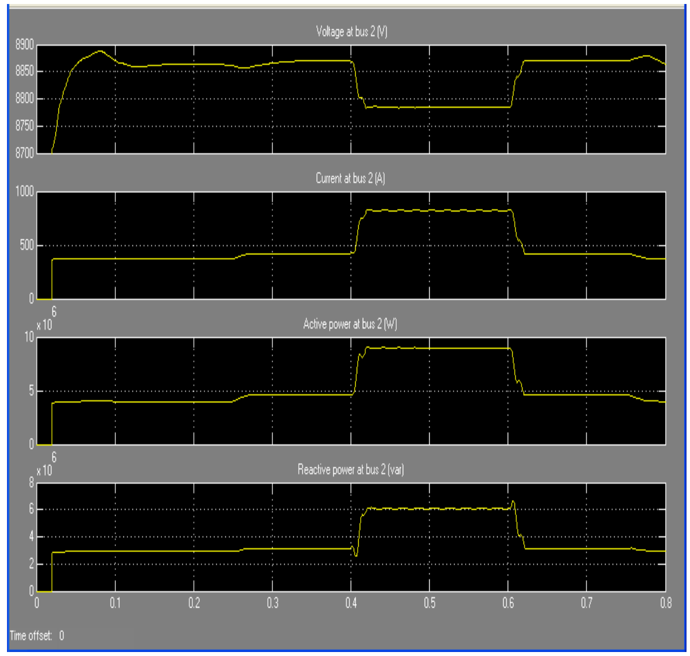


Fig..5 V, I, P, Q at load bus for a LG fault with SC support

The circuit is simulated for an L-G fault created where SC is offering Active power control support with a capacity of 2 MW for 1 sec to control the load bus voltage. From fig.5, we can observe that as the load increases from 4.1MW, 3MVAR to 4.7 MW, 3.2 MVAR at 0.25 sec, voltage drop observed without SC support is compensated by injected active power by super capacitor as shown in fig.7 and voltage is returned to normal immediately supplying rated P and Q to load. During this period SC discharging is observed at its own rate resulting in reduction in SC voltage as shown in fig.6 but during this still dc link voltage is maintained at 1000 V which is one of the control objectives. The SC is designed to support and supply Active power rise and not for reactive power compensation.

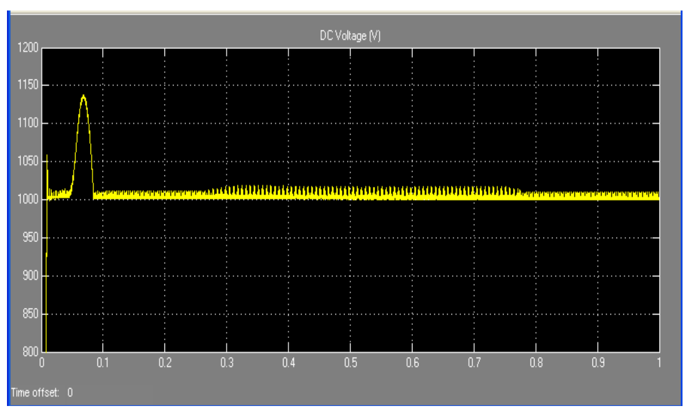


Fig.6 DC link voltage for a LG fault with SC support

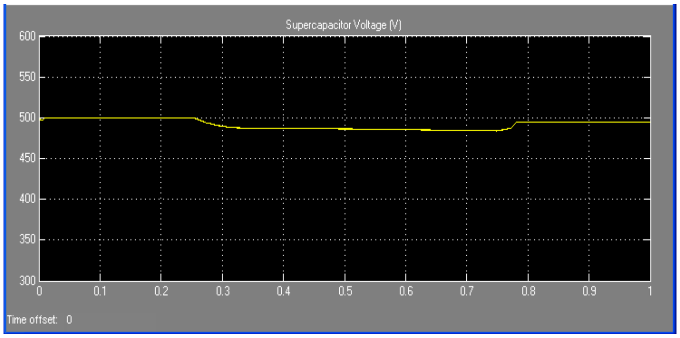


Fig.7SC voltages for a LG fault without SC support

5. CONCLUSION

Energy storage systems are being used more actively due to the great benefits they provide, confronting the challenges of dynamic loads, and leading to a more robust electrical system. The trend now is to use super capacitor energy storage systems (SCESS) as energy storage. Super capacitors have lower energy storage but higher power exchanging capability compared to batteries.

Finally, a MATLAB/Simulink simulation model for the super capacitor energy storage for low voltage ride is developed and the simulation results are presented.

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