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To Study Behavior of Controller Designed for Supercapacitor as Energy Storage in Medium Voltage AC Transmission Line Fault Condition

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Abstract: Supercapacitors have become an integral part of low voltage power electronic systems where high power density from dc storage device is required frequently. Now a day's Supercapacitors have become an integral part of low voltage power electronic systems where high power density from dc storage device is required frequently. In last paper we have designed the controller for charging and discharging control of Supercapacitor used as energy storage in medium voltage AC transmission line, while during transmission line fault condition controller should not feed the energy to fault. This paper analyses the performance of controller used for supercapacitor as energy storage in medium voltage AC transmission line in fault condition. In this paper we have considered three phase line to ground fault for 0.1 second and analyzed the behavior of controller.

Keywords: Supercapacitor, energy storage, Transmission line faults, DC-DC converter, voltage source converter.

1. INTRODUCTION

From last some years Supercapacitors have become an integral part of low voltage power electronic systems where high power density from dc storage device is required frequently. Supercapacitors have been popular candidates for meeting the need for sudden power demand. The supercapacitor has very high efficiency of around 95% with very good power density [1].

Prior works have incorporated supercapacitor storage with different energy sources in a common dc bus and their focus is to manage the power flow to and from the dc bus or the condition of multiple sources like batteries, photovoltaic, wind, gas cogeneration and flywheels [2]. Some discussed multiple modes of operation like power dispatch, voltage regulation and control of power flow to and from different sources and loads in small scale dc or ac distributed network, also some proposed a fault protection scheme applicable to a dc bus serving variety of loads and generators using modern voltage source converters as current limiting circuit breakers [3, 4]. So far use of supercapacitor has been limited to delivering or absorbing pulses of power during transient operation, such as starting up of an electrical motor, storing regenerated energy or supplying instant power in low voltage range within small scale distributed generation system [5]. Voltage sags have been found especially troublesome because they are random events lasting only a few cycles. The process equipment may not keep continuing its normal operation during these sags for many cycles and will trip or shut down, although the supply voltage is totally recovered a few cycles after the sag occurrence. Therefore, from the point of view of industrial customers, voltage sags and momentary interruptions might produce the same effect to their processes [6, 7].

In our previous paper discussed controller designed for supercapacitor charging and discharging control in medium voltage AC transmission lines. While the behavior of supercapacitor and its controller in remote lines fault condition not derived, so this paper attempts and investigate the behavior of supercapacitor controller in line fault condition [8]. There is very little research in this area where an intelligent controller on the dc side can determine whether or not to support a sagging voltage in the grid (depending on cause load or fault), and how much energy to deliver at any instant of voltage sag condition.

This paper begins to address some of the following important issues:

- Design and develop a controller intelligent enough to maintain continuity of power to loads and maintain stability.
- To intelligently manage the line fault condition and isolate the supercapacitor energy for feeding fault.

2. SYSTEM CONFIGURATION

Figure 1 shows the configuration of the reference system, which is also a typical configuration of energy storage for grid support and peak power shaving. A 13.8KV grid is fed by a 4KV, 5MVA steam driven main generator

(G). A supercapacitor storage and DC-DC chopper represents the alternate energy storage system coupled with the grid through 0.77KV/13.8KV step up transformer. No long term backup energy storage has been considered, the power source has been designed to ride through 2 seconds voltage sag.

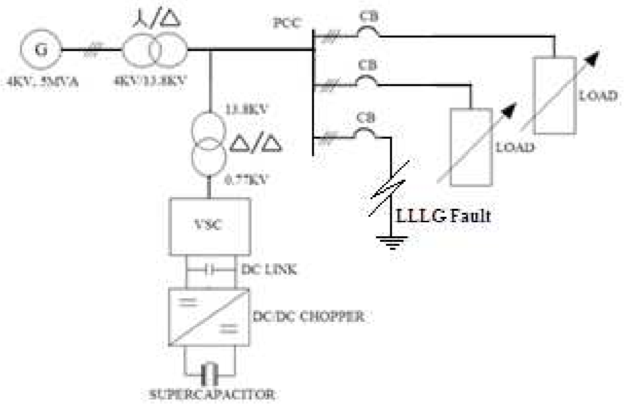

Fig.1. System configuration

Following modes of operation have been considered:

1) Normal operating mode: - In this mode there is no real power exchange between the supercapacitor and the grid as the main generator can deliver all of the required power.
2) Energy discharge mode: - Supercapacitor energy storage delivers energy to the grid to compensate the voltage sag due to a high load demand that exceeds the capacity of the main generator.
3) Charging mode: - Supercapacitors charge up during this mode if there is excess energy available in the grid due to a low load demand.
4) Fault mode: - Supercapacitor not discharged throughout the fault period, so that fault power restricted.

2.1 Voltage source converter control

Voltage source inverter is the interface between the grid and the supercapacitor energy storage unit. The reference signal for the PWM control for the voltage source inverter is phase modulated by means of the phase angle, α described in figure 2.

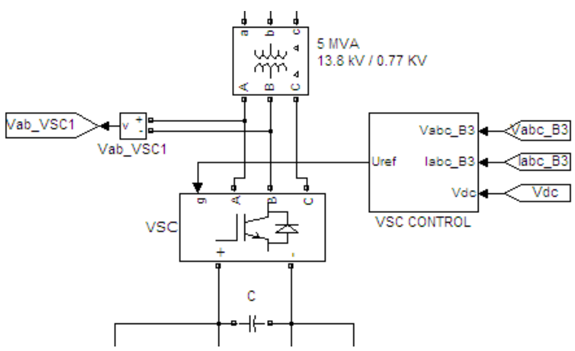

Fig.2. Control for voltage source inverter

2.2 DC-DC Chopper control

Figure 3 shows the control strategy for the DC-DC converter. DC-DC converter works as a simple buck-boost converter with P_grid as the main driving control signal obtained from calculating the three phase power in the grid. There is a window for the controller (3.8MW to 4.1MW) within which is operates in the normal operating mode. So the converter will operate in energy discharge mode when P_grid > 4.1MW and will operate in charging mode if P_grid < 3.8MW.

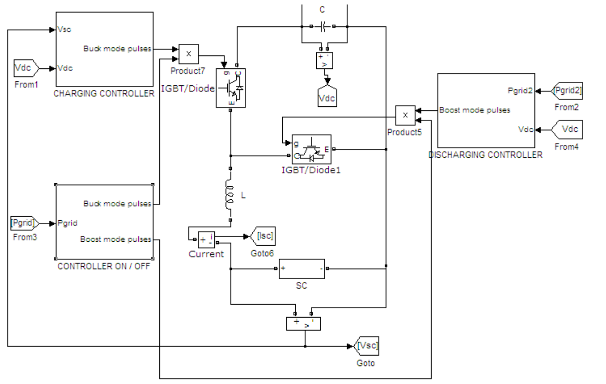

Fig.3. Control for DC-DC converter

2.3 The process of discharging control

The direct current control is used in the discharging control, through the realization of double-loop control. The outer ring is the output voltage control, and the inner loop is the input current control. Compared the actual output voltage with the command voltage signal, then put the error goes through PI regulator to get the DC current signal i_d. Compared i_d with the actual input current, and put the error goes through PI regulator. Then put the output go through the triangle-wave comparator to generate PWM waveform to control the switching device. By doing so, the actual input current will track the command current to control the output voltage. The control process is shown in Figure 4.

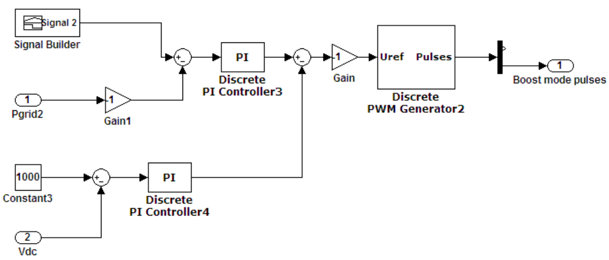

Fig.4. Block diagram of discharging control

3. PERFORMANCE ANALYSIS

Performance of controller observed for L-L-L-G transmission line fault. Grid power, Grid Voltage, supercapacitor power flow, Supercapacitor Discharging voltage, and dc link voltage observed for analysis of system performance in line fault period. The simulation is carried out in Matlab Simulink.

1. Normal Operating mode: - During starting period the load on line was 4.1 MW. So in that condition Source generator alone capable to deliver load demand as observed in figure 5.

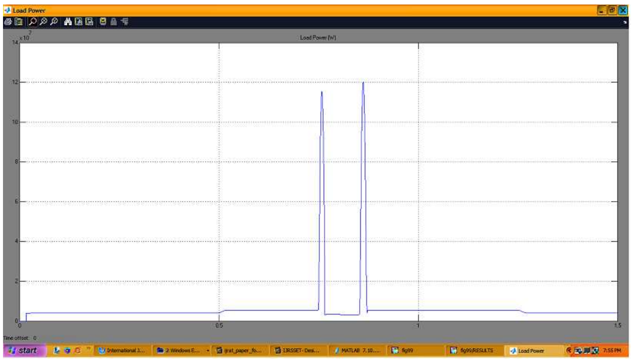

Fig.5. Grid power

2. Supercapacitor discharging mode: - At 0.5 seconds the load demand increased to 5.5 MW so to feed excess momentary load demand supercapacitor discharge controller starts discharging supercapacitor energy to grid/ load, this can observed in figure 6.

Fig.6. Power flow of Supercapacitor

3. Fault mode: - At 0.75 seconds the L-L-L-G fault occurred on transmission line and persists till 0.85 seconds, in this time period the supercapacitor discharge controller takes an action and stops supercapacitor energy discharging which prevent the excess energy supply to fault. In fault condition grid voltage drops severely as shown in Figure 7.

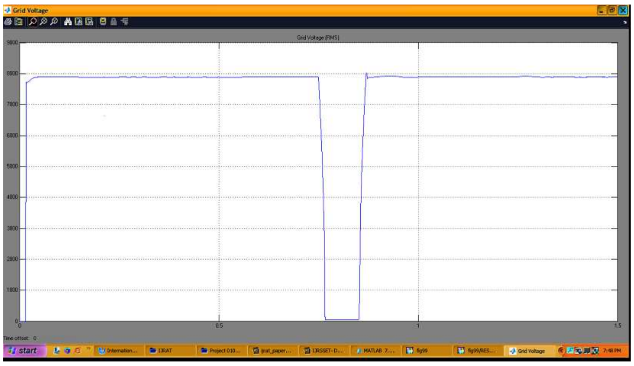

Fig.7. Grid voltage.

Fig.8. Discharging voltage of supercapacitor.

4. Supercapacitor discharging mode: - At 0.85 seconds transmission line fault cleared by protection and grid voltage came to normal so supercapacitor again starts discharging energy to grid till 1.25 seconds as observed in figure 8.
5. Normal operating mode: - Beyond 1.25 seconds load demand came to normal i.e. 4.1MW so Source can able to feed this much energy so supercapacitor discharging stops and system works in normal operating condition.

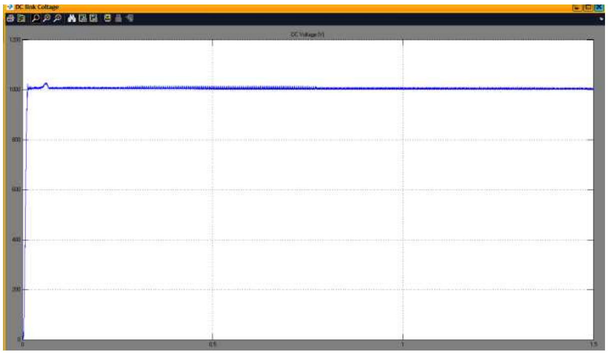

Fig.9. DC link voltage.

The load on system changed at different period, also fault occurred on transmission line but still DC link voltage maintained at desired levels observed in figure 9.

4. CONCLUSION

In energy discharge operating mode the grid voltage maintains its desired, also supercapacitor fed extra energy demand of grid without disturbing dc link voltage, as soon as fault occurred the supercapacitor controller takes an action and stops delivering amount of energy to feeding fault, after fault clearing controller again starts delivering power till grid requirement. During all operation the DC link voltage maintains steady.

Further future work to be involved in developing intelligent controller, which could have ability to determine feeder level faults and without affecting other system the grid voltage and power requirements should be taken care by supercapacitor controller.

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