# IMPLEMENTATION OF ELECTRICAL DEVICES FOR POWER SYSTEM APPLICATIONS USING SCESS

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**ABSTRACT-- Flexible AC Transmission Systems, called FACTS, got in the recent years a well-known term for higher controllability in power systems by means of power electronic devices. Several FACTS-devices have been introduced for various applications worldwide. The concept of FACTS refers to a family of power electronics-based devices able to enhance AC system controllability and stability and to increase power transfer capability. FACTS enhance the overall grid capacity and performance. They also increase the reliability and efficiency of your power system. By mitigating power oscillations, FACTS are able to offer you greater control over your energy. The main factor causing voltage instability is inability of the power system to meet the demands for reactive power in the heavily stressed systems to keep desired voltages. FACTS devices have been used, both for steady state power flow control and dynamic stability control. Usually a STATCOM is installed to support electricity networks that have a poor power factor and often poor voltage regulation. There are however, other uses, the most common use is for voltage stability. This paper presents the analysis of implementation of electrical devices for power system devices.**

**Keywords: FACTS, Power system, Statcom**

## I. INTRODUCTION

A circuit diagram of a STATCOM plus SCESS is shown in power circuit in Fig 1. The main components of a STATCOM plus SCESS are a normal STATCOM and super capacitor based energy storage system (SCESS) [6]. A normal STATCOM comprises of coupling reactor (Xc), a voltage source inverter(VSI), and a DC link capacitor (usually an electrolytic capacitor). The SCESS comprises the supercapacitors, and a bi-directional DC-DC buck-boost converter to control the charge and discharge of the supercapacitor modules.

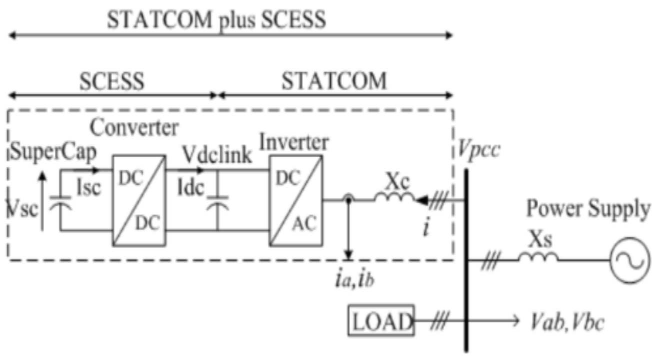


Fig 1. Power system with STATCOM plus SCESS

Where, Xs represents a reactance of the power supply(utility) and for this work, the effect of a large local load on the quality of the voltage at the point of common coupling(PCC) is considered[1]. Large step changes to the load can causes wells and sags at PCC. DC-AC power conversion is also required in the FACTS devices operation [7].

Simulink is a software package that is part of MATLAB. Modeling and analysis of dynamic systems in SIMULINK is simplified as compared to performing the same operations using code in MATLAB programming. A SIMULINK model has been built for the proposed SCESS system. It consists of two circuits namely:

(i) Power circuit and
(ii) Control circuit.

## II. PROPOSED CIRCUIT

The power circuit shown in fig.2 consists of the supercapacitor, the inductor, the boost and buck IGBTs, the dc link capacitor, the dc load, and the switched on/off dc source. The DC load and the DC source represent a simplification of the STATCOM [2] . The DC load is used to discharge the DC link capacitor while the DC source is used to charge it.

The power circuit parameters are:
Supercapacitor : C= 0.5 F, and V(0)=300V
Inductor:L=0.075H,and R=0.001ohm
DC link capacitor : C= 800uF, and R=0.01 ohm
DC load : R=120 ohm
DC source : V=610V, and R=0.01 ohm

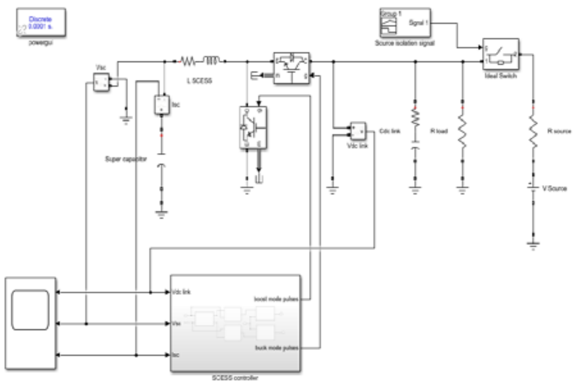

Fig.2 SCESS Simulation in MATLAB

## III. CONTROL CIRCUIT:

The control circuit shown in fig.3 consists of one boost/buck logic circuit, which selects the mode of operation of the SCESS, two PI controllers, which are tuned with suitable proportional and integral gains to control the dc link and supercapacitor voltages, and two peak current controllers, which control the supercapacitor current in buck and boost modes.

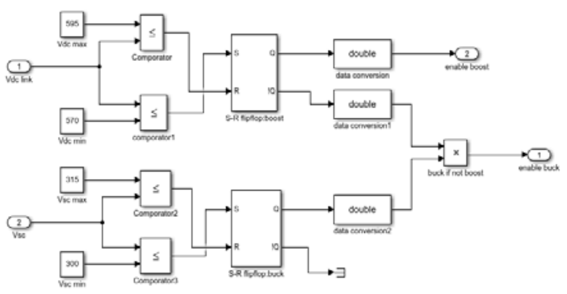

Fig.3 Buck Boost logic circuit in MATLAB

The logic circuit determines the mode of operation based on the following logic: If the dc link voltage is below 570V, the logic circuit will activate the boost mode until the dc link voltage is above 595V. If the supercapacitor voltage is below 300V, the logic circuit will activate the buck mode until the supercapacitor voltage is 315V, but the logic circuit does not allow starting the buck mode if the DC to DC converter is already in the boost mode [3].

**BUCK CONTROLLER:**

**The buck converter** reduces the input DC voltage to a specified DC output voltagei.e accepts the excess real power thus maintaining the voltage as constant. The control circuit of buck controller is very similar to the boost controller. The only difference is that it controls the Supercapacitor voltage instead of the dc link voltage. The output of buck controller is the PWM gating signal for the buck transistor.

This controller consists of two parts namely: dc link voltage controller and supercapacitor discharge current controller.

**DC LINK VOLTAGE CONTROLLER**

The dc link voltage controller compares measured supercapacitor voltage with the voltage reference signal i.e 300V, and the output of the comparator is connected to a PI controller to control the supercapacitor voltage. In addition, the output is subtracted by a small triangular signal which is important to eliminate small signal instability of the controller. The output is the buck mode reference current signal. The selected parameters are: Vscref = 300V, KP = 12, KI = 0.04 and clock frequency = 10 KHz

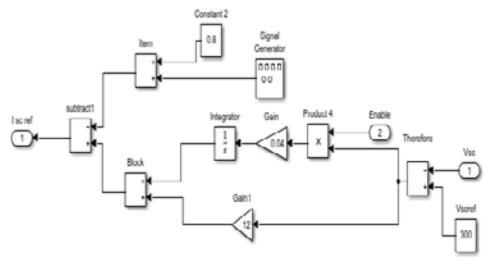


Fig.4 DC link voltage controller model in MATLAB

**SUPER CAPACITOR DISCHARGE CURRENT CONTROLLER**

The supercapacitor charging peak current controller compares measured current Isc with the current reference signal Iscref, and the output of the comparator is connected to a flip-flop. The flip flop with the clock together have the function of producing the pulses for the IGBT. This scheme allows generating pulses with fixed frequency and variable width to achieve a current which approximates the reference current signal. The frequency of switching is determined by the clock frequency which is set to 10 KHz.

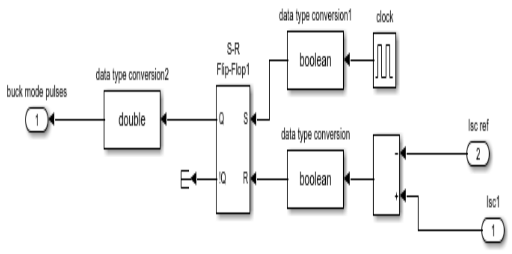


Fig.5 supercapacitor discharge current controller in MATLAB

**IV. RESULTS AND DISCUSSION**

**WITHOUT SCESS**

The simulation was run first with without SCESS system, and the DC link voltage profile is shown in Figure. The dc link voltage dropped to zero after 0.4 seconds. This is because there is no energy storage system to supply the voltage when there is a voltage drop shown in fig.6 [4].

**WITH SCESS**

The SCESS system was tested by disconnecting the main DC source at the dc link for 1 second. The dc source is disconnected at t=0 and reconnected at t=1s. While the DC source is disconnected, the dc link capacitor starts discharging its stored energy to the resistor. As a result, the supercapacitor shall provide its energy to the dc link to maintain the dc link voltage fixed. The energy discharged into the resistor represents the energy transferred from STATCOM to the load at the AC side. The objective of test is to check if the SCESS system has the ability to maintain the dc link voltage fixed at the pre-set value. Therefore this test is an indication of the proposed SCESS capability shown in fig.7

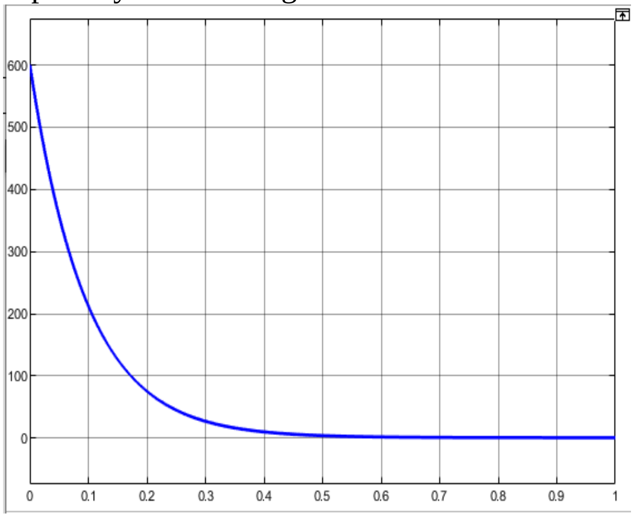


Fig6. DC link voltage (V) versus time (seconds) without SCESS

**DC LINK VOLTAGE**

The dc link voltage profile during the test while the SCESS is active is shown in Figure. When the DC link capacitor is discharged, its voltage is reduced to 300V which is supplied by the supercapacitor and raises to 600V when the DC source is turned ON at t =1sec . The supercapacitor maintained the dc link voltage with an initial voltage dip to 50% of the rated value i.e 300V when the DC source is OFF. This means the supercapacitor is delivering its energy to stabilize the dc link voltage.

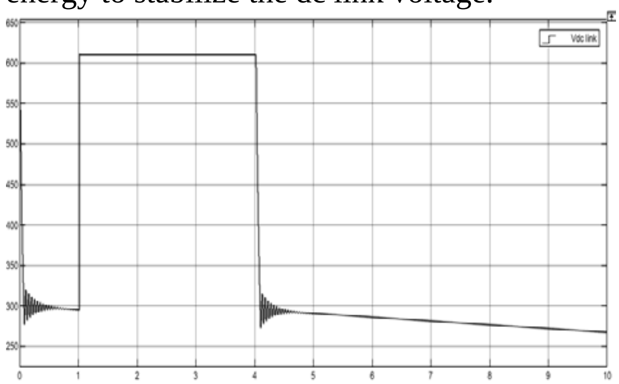

Fig.7 DC link voltage (V) versus time(s) with SCESS

STATCOM-SCESS is a promising technology for improving power system stability and quality. A brief survey was presented about the use of STATCOM-SCESS in various power system applications. A simulation model is built and tested for the SCESS system on MATLAB/SIMULINK. The test shows that the SCESS system can maintain the dc link voltage by exchanging real power, which gives the STATCOM-SCESS the ability to exchange real power with the system.

Also, a brief study is presented about the various energy storage systems and the superiority of SCESS over others in terms of performance in various power system applications. Supercapacitors have a cycle lifetime which is far greater than that of batteries. They also offer a wider application temperature range (–40 °C to +60 °C) as well as fast and similar charge and recharge rates. This makes them complementary storage devices to batteries in many applications [6].

## V. CONCLUSIONS AND FUTURE SCOPE:

The results are obtained related to implementation of electrical devices for power system applications.

The most promising future of supercapacitors is the combination of a double- layer charging interface with existing energy-storage technologies. The designs of supercapacitors have advanced through several generations ever since their first commercial launch. Research organizations and leading companies in the power electronics industry are still focusing on innovating around the manufacturing methods and materials to further improve the cost-efficiency and performance of supercapacitors.

The ongoing research activities and developments in the power electronics industry continue to hint at supercapacitors replacing batteries in the near future. Supercapacitors are coming up with solutions which could not be thought of earlier. There are many increasing applications of supercapacitors in various industrial sectors, such as electronics, energy & power, military & defense, and aerospace, etc. Some of the other future applications may be:

Medical implants like pacemakers, knee implants and others which will be powered by supercapacitors.

Robots will find use of supercapacitors due to quick charging capacity. IoT will find many uses for them.

By adding EC (electrochemical capacitor) technology to fuel-cell applications, there is a great opportunity to rapidly improve the charge/discharge cycle performance of hybrid-electric-vehicle applications.

Supercapacitor is also finding applications in renewable energy system, smart grids as well as micro and mini grids.

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