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DEVELOPMENT OF SHUNT STATIC VAR COMPENSATOR (SVC) AND PERFORMENCE ANAYLYSIS

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Abstract- *Load performance depends on flexibility of power transmission. The amount of reactive power decreases during the full load. As a result load performance becomes poor. On the other hand, during light load reactive power is plenty and consequently receiving voltage is high. As a remedy, we have to generate reactive power during full load and absorb reactive power during light load. Based on this strategy, the Static VAR Compensator (SVC) is constructed. SVC compensates reactive power consequently make flexible ac transmission. SVC consists of Thyristor, capacitor and inductor. A firing circuit is needed to operate the Thyristor. By varying firing angle reactive power can be generated or absorbed. In this paper, the fabrication and operation of firing circuit and implementation of this circuit to the SVC is explained. Consequential VAR compensation and overall analysis of the performance is also discussed. The study of the Shunt Static VAR compensator was constructed in the laboratory of Chittagong University of Engineering and Technology, Chittagong-4349, Bangladesh from July 2011 to February 2012.*

Keywords: Active and Reactive Power, Power Flow Control, FC, TCR, and FACTs Technology

1. INTRODUCTION

The focus of this project has been on a particular FACTS (Flexible AC Transmission System) device – the Static Var Compensator (SVC). The SVC is a proven technology for power factor correction and reactive power compensation. The SVC has been used as a shunt-connected device that offers voltage stability and load compensation to the power system at particular points such as transmission line midpoints or near varying loads. In the past, many SVCs were based on the effect of self-saturation of the iron core of a so called saturated reactor. Since the end of the seventies, Thyristor controlled SVCs have been available on the market and for a few years one has been able to observe the development of new SVC technologies based on GTO or IGBT semiconductors [1]. The objective of this project is to develop a small and easy accessible controlling SVC with available equipment. SVC (Static VAR Compensator) is the shunt compensation type FACTS for providing or absorbing fast acting reactive power on high voltage electricity transmission networks. The term „Static" means that, SVC has no moving parts. It is an automated impedance matching device, designed to bring the system closer to unity power factor. Traditionally the SVC has been used as a shunt-connected device that offers voltage stability and load compensation to the power system at particular points such as transmission line midpoints or near varying loads.

2. LITERATURE REVIEW

Flexible AC Transmission System (FACTS) is a new emerging technology. Dr. N. Hingorani introduced the concept of FACTS as a total network control philosophy. The principle role of FACTS is to enhance controllability and power transfer capability in ac system. FACTS technology uses switching power electronics to control power flow the range of a few tens to a few hundred of megawatts [2].

FACTS devices that have an integrated control function are known as the FACT controllers. These may consist of Thyristor devices with only gate turn-on and no gate turn-off, with power devices with gate turn-off capability. FACTS controller are capable of controlling the integrated line parameters and other operating variables that govern the operation of transmission systems including series impedance, shunt impedance, current, voltage, phase angle and damping of oscillation at various frequencies bellow the rated frequency. By providing added flexibility, FACTS controllers can enable a transmission line to carry power closer to its thermal rating.

The philosophy of FACTS is to use for controlling power flow in a transmission network, Thereby allowing the transmission line to be loaded to its full capability. Power electronic controlled devices, such as static volt-ampere reactive (VAR) compensator, have been used in transmission network for many years[2].

The FACTS technology characterized by two categories:

1. Series compensation
2. Shunt compensation

SVC is the shunt compensation type FACTS. By placing SVC at the middle of transmission line and proper operating it the power flow of the transmission line can be controlled properly. SVC increases power transfer capability by varying its operating variable- impedance.

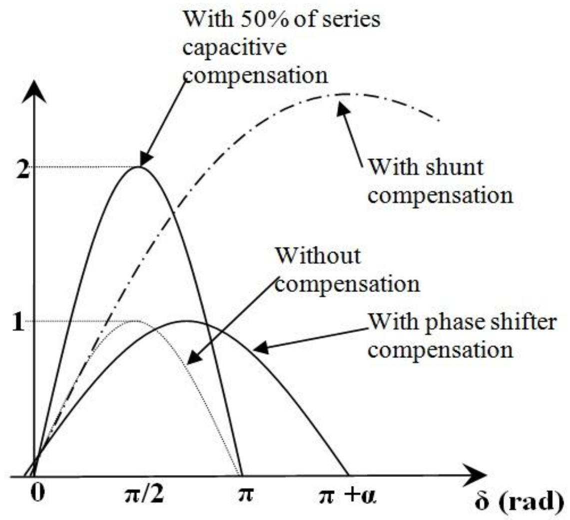

Fig. 1: Power transfer characteristics with and without compensation

Figure 1 shows the active power transfer characteristics for ac system without compensation, with shunt and series compensation, and phase shifter compensation. The shunt compensator is the best option to increase the stability margin. Hence, shunt compensator SVC is developed under this project.

The static var compensator (SVC) is regarded as the first FACTS (Flexible AC Transmission System) devices [3]. Basin Electric Power Cooperative installed the first SVC in Nebraska in 1977 [4]. Since then, the SVC has become known for its ability to offer voltage stability to the power system and to compensate reactive loads. The SVC, however, does not provide a means for controlling real power flow directly.

3. METHODOLOGY

Firing or driving circuit is the heart or main component of SVC. According firing angle, Svc produce or absorb definite amount of reactive power. Thyristor acts switches. It need gate pulse to be on. Once a Thyristor conducts, it behave like a conducting diode and there is no control over the device. That is the device cannot be turned off by another positive or negative gate pulse. It became off only when the anode current cross the zero level [5,7]. So firing pulse is generated from the synchronous supply and triggers the gate at specific angle. As a result rms value of current changes.

The firing angle α is related to the inductance of SVC, consequently impedance of SVC. As a result VAR change according to α. In SVC, two Thyristor are needed to be turn-on. So we need two firing pulses.

Table 1: Logic Choice

Supply	Positive portion	Negative portion
Gate T1	1	0
Gate T2	0	1

One pulse would work during first half cycle of the synchronous supply i.e. one Thyristor would be on. Another pulse would work during negative half cycle of the synchronous supply. The timing of pulse with the positive and negative half cycle of the synchronous supply maintained accurately and precisely. [8]

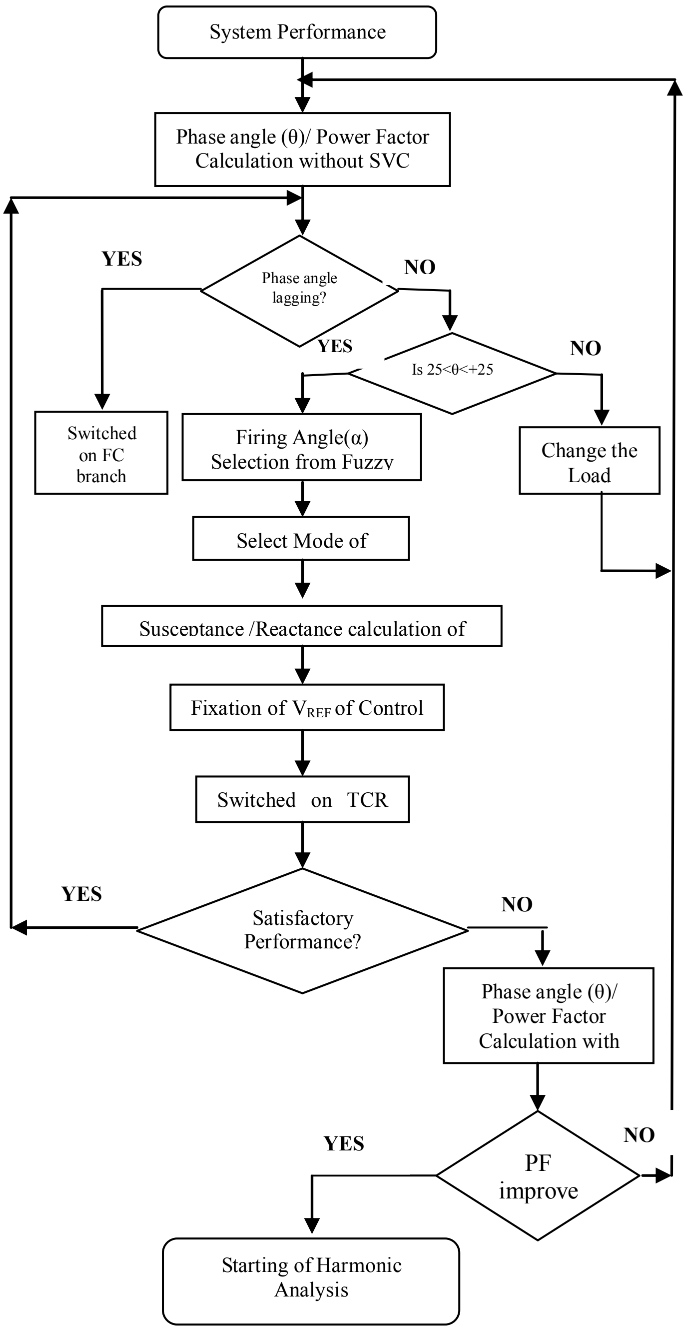

Fig.2. Logic Flow Chart

The process should be such that the gate pulse can change its position from 0 to 90^0.

Table 2: Firing Angle Selection

For Thyristor T1	For Thyristor T2
α=0	α=180
α=10	α=180+10

Two pulses needed to change their position simultaneously at the same angle i.e. by this we need to be varied from 0 to 90^0.

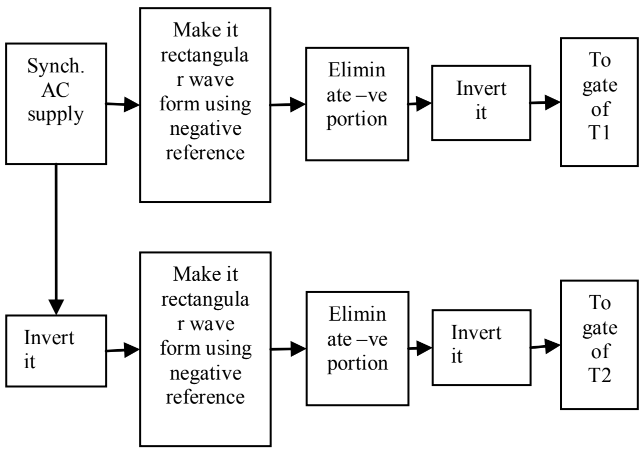

Fig. 3: Driving circuit design process blocks

The width of the gate pulse should be less than 10ms. Based on the logic of driving circuit we designed the firing circuit by the process bellow:

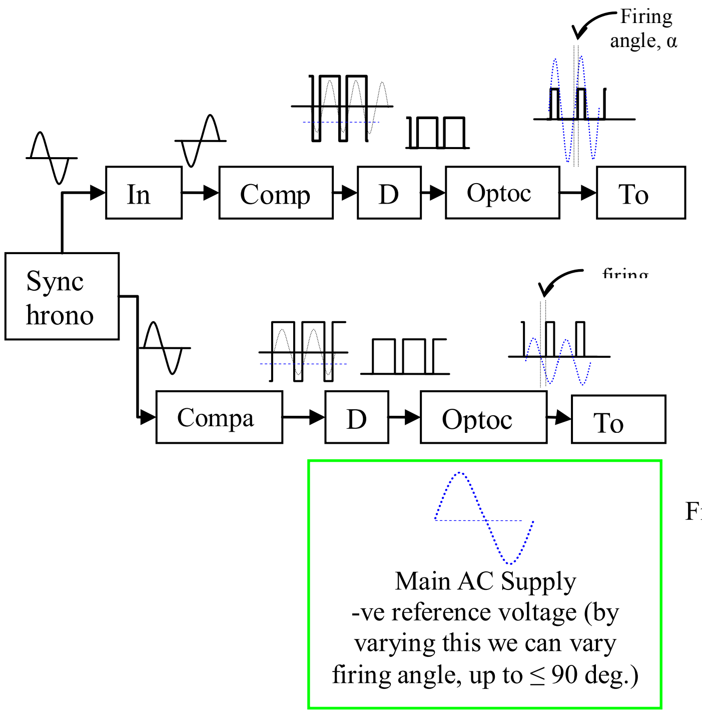

Fig. 4. Block Diagram of Thyristor

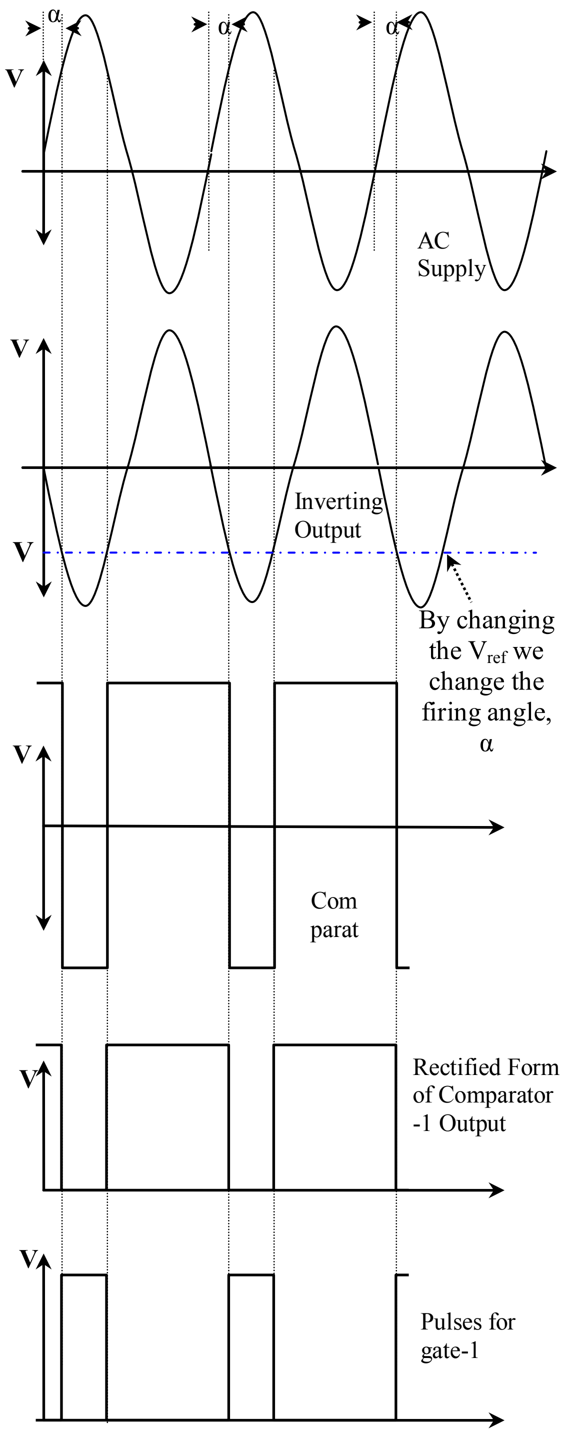

Fig.5. Gate pulse for firing Thyristor during positive half cycle

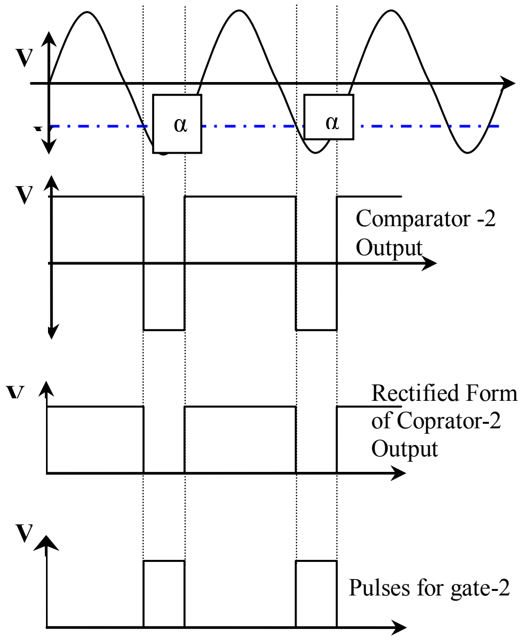

Fig.6. Gate pulse for firing Thyristor during negative half cycle

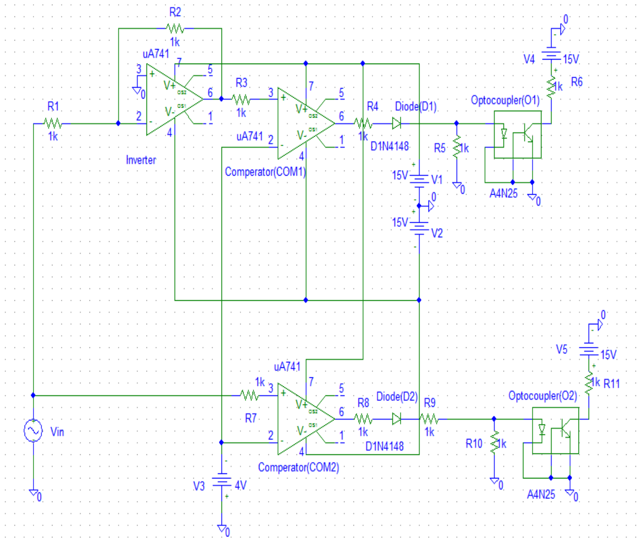

Fig.7. Schematic Diagram of Driving circuit

4. PERFORRMANCE ANALYSIS OF SVC

Since the large majority of loads are inductive, motors and transformers for example, most power systems will operate at a lagging power factor. To correct for a lagging power factor, capacitors are sized to provide VARs equal to the amount drawn by the system. The reactive power provided by a capacitor is shown in equation (1)

$$Q=V2/XC=2\pi fCV2 \qquad (1)$$

When parallel compensation is used in a non-linear system containing harmonics only the VARs resulting from phase lag may be compensated for by the parallel capacitance [5].

A fixed capacitor over compensation will be needed by the TCR branch to yield a finely tuned PFD to as close to unity as possible. The constant variable is used to define an "allowable overcompensation range" for the phase angle difference θ.

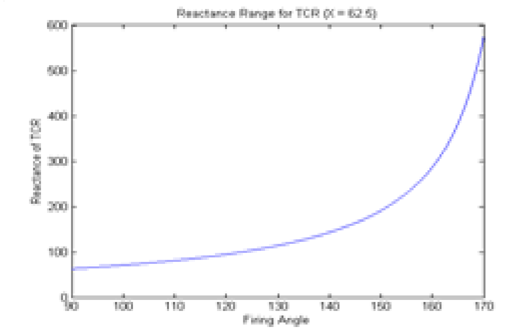

Fig.8. Reactance Range for the SVC TCR

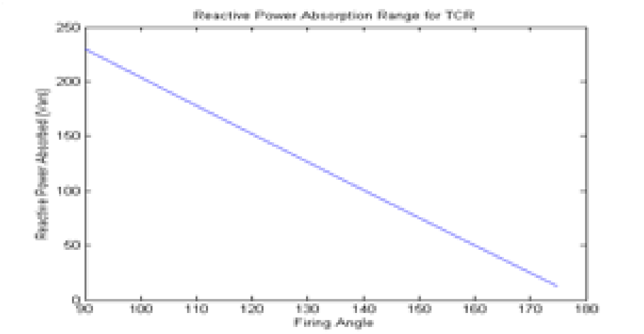

Fig.9. Reactive Power Absorption Range for the SVC TCR

4.1 System Evaluation

Table 3: Evaluation of System

Phase angle,θ degree	Firing angle,α degree	$X_L(\alpha)$ ohm	X_T (α) ohm	I(α) mA	Q(α) var
14.3(lagg)	12	201.3	235	600	120
12 (lagg)	16	253	389	303	94
6 (lagg)	22	409	523	172	54
15.7(lead)	41	653	1212	60	30
19 (lead)	50	1187	7380	27	3
21 (lead)	53	1455	-51046	3	-0.7
24 (lead)	61	8616	-1693	118	-23
29 (lead)	82	77612	-1441	138	-29

Evaluation operators are given below

C = 2.5 UF

XC = -j1/(2πfC) = -1415 ohm

L = 0.81 mH

XL = j2πfL

XL(α) = (XL * π) / (π-2α-sin2α)

XT(α) = XC * XL(α) / (XL(α) + XC)

4.2 Waveform for Varying Firing Angle (α)

Fig.10. Wave form across resistance when $\alpha = 18^0$

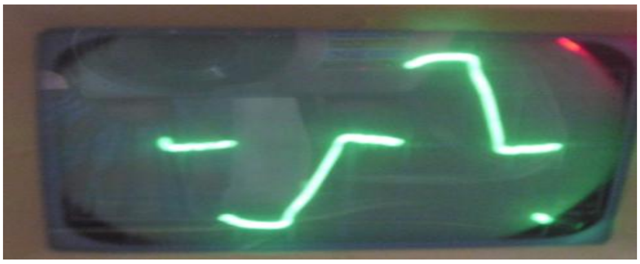

Fig.11. Wave form across resistance when $\alpha = 58^0$

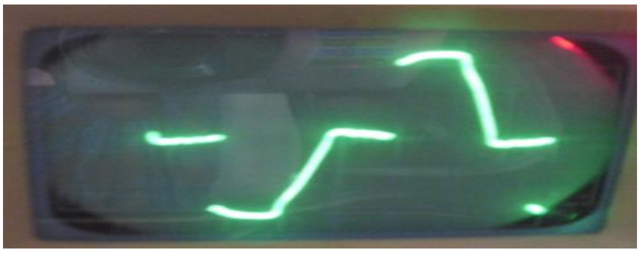

Fig.12. Wave form across resistance when $\alpha = 90^0$

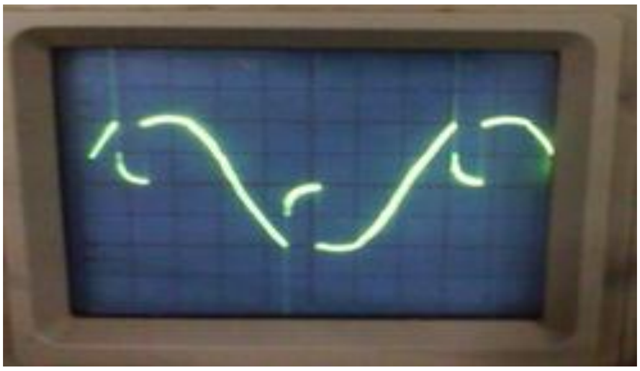

Fig.13 Wave form across inductance when $\alpha = 60^0$

Fig.14. Wave form across inductance when $\alpha = 85^0$

5. HARMONICS EFFECTS

Since impedance of SVC is regulated by switching Thyristor the input current is distorted and harmonics are generated. As the Thyristor are fired symmetrically during both positive and negative cycles, only odd harmonics are generated [6].Typical current harmonics for a theoretical TCR as a percentage of the fundamental are shown below

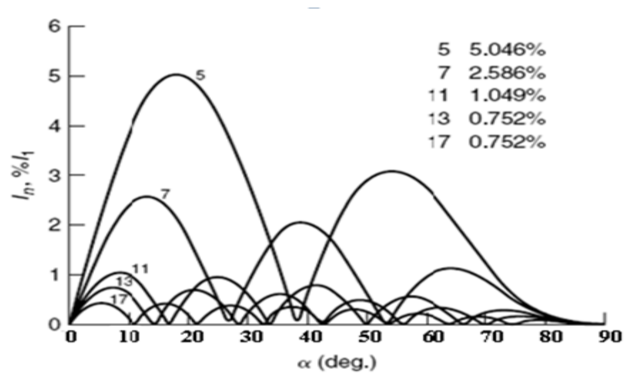

Fig.15. Typical Current Harmonics in a TCR

The figure shows that the SVC generates significant harmonics but they vary greatly depending on the firing angle (α).

The harmonics in a system are usually quantified in terms of the Total Harmonics Distortion (THD) and Total Demand Distortion (TDD).

These harmonic indices are defined, for either voltage or current, by the IEEE as

THD= $[\sqrt{(\sum_h^{50} V_h^2)}/V_1] *(100\%)$

TDD= = $[\sqrt{(\sum_h^{50} I_h^2)}/I_{rated}] *(100\%)$

The two indices are identical except THD compares he harmonic content to the fundamental, whereas TDD compares to it to the rated value.

5.1 Solution of Harmonic Problem

Harmonic problem can be mitigated through a combination of shunt and series filters. Selected components may be protected from harmonics by series inductances and capacitance tuned to appear harmonic order. Nonlinear loads require certain harmonic components; series filtering is usually not the preferred method of reducing source harmonics. A shunt filter attempts to provide a low impedance path to ground for the harmonics to redirect them away from the source.

Parallel resonant L-C branches are often tuned to appear as a short to specific harmonics, thereby giving them a path to ground and filtering that harmonic out of the system.

6. Conclusion and Future Work

Professional SVC‟s are designed for large reactive power control in a convenient way, which require large size of properly designed bank of capacitors and bulky inductor. Protection systems of these professional SVC are also complex to design. So, we have developed a

simple low power, low cost , small, relatively good-looking, easy accessible controlling ,protection of SVC with available equipments, which helped us to learn about the operation of FACTS devices.
The adaptive harmonic filter could be designed to either work in conjunction with the SVC or independently. Either way, the adaptive filter could be evaluated using the SVC and a reactive load . Another possible advancement would be automated supply and control strategy turns it into laboratory experimental setup at much chipper cost.

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