AN SVC BASED POWER QUALITY IMPROVEMENT MODEL FOR CONSUMERS CONNECTED TO WEAK BUSSES IN DISTRIBUTION SYSTEMS

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ABSTRACT

Power quality is a major concern considering weak bus systems. In order to improve power quality, residential consumers go with voltage stabilizers as a cheap solution consequently overstressing weak busses. Industrial consumers use other alternatives like switched capacitor banks to cope with low power factor but the limitation is step-wise reactive power injection which does not meet the changing load requirements. Real time improvement requires constant monitoring and real-time injection of Volt-Ampere-Reactive (VAR) which is possible with the help of a Static VAR Compensator (SVC). An SVC based Power Quality Improvement (PQI) is proposed in this paper which addresses the real time varying reactive VAR requirement with reduced harmonic content.

KEYWORDS: *Volt Ampere Reactive (VAR), Static VAR Compensator (SVC), Power Quality Improvement (PQI), Power Factor Correction (PFC)*

INTRODUCTION

Pakistan is faced with crises in energy sector from the last one and a half decade. Though the gap between demand and supply is getting narrow with newly introduced power generation schemes in the national grid, losses in the system (both technical and non-technical) has made the situation even worse. The existing infrastructure is overburdened specially in summers where the load requirements are on the higher side (Khan, 2014). Poor power quality has badly affected the overall system performance (Sorensen & Madson, 2000). In low power factor scenarios, connected loads try to draw high currents that endanger equipment performance and useful life (Schipman & Delince, 2018).

Highly inductive loads when connected to weak busses in overstressed conditions may result in considerably low power factor, thus allowing the utility companies to impose penalties. In order to avoid this situation, stabilizers and switched capacitors are employed by residential and commercial consumers respectively (Ponnle, 2015). Stabilizers draw more current to keep the voltage constant thus threatens the equipment's life. On the other hand switched capacitors cannot cope with changing VAR requirements. Flexible Alternating Current Transmission System (FACTS) devices work well under both high and low voltage conditions (Pradhan, 2014). An SVC needs to be incorporated in order to address the changing VAR requirements. This proposal is explored and tested in this paper.

MATERIALS AND METHODS

Technical Background

The electricity generation reforms initiated in Pakistan in early 90's were a complete failure and that has resulted in crises in power sector. No satisfactory progress has been shown in the mentioned sector in the past two decades. This has resulted in load shedding conditions across the country and is a major barrier in sustainable industrial growth of the sector. Now the aim of the authorities is to meet the demand, improve the efficiency, and upgrade the existing infrastructure (Khan, 2014). It has been observed that low power factor has contributed to technical losses on the distribution system (Sorensen & Madson, 2000). Same loads connected to a distribution network results in higher losses when operated at low power factors. The equipment draws more than rated current and is thus harmful (Schipman & Delince, 2018). Lower power factor results in higher losses forcing the utility companies to impose penalties on such consumers (Ponnle, 2015). FACTS are good at compensation at both low and elevated temperatures but are slower in response (Pradhan, 2014). SVC can address the changing active and reactive power requirements (dynamic load conditions). By controlling the firing angle of thyristor,

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the reactive power injection from the SVC's can be controlled (Sreenivasulu & Basha, 2013).

Related Work

TSC consists of thyristor valves, capacitors, and current limiting inductors. The inductor limits the rate of change of current thus suppressing transients. Thyristor valve consist of two SCR's connected in anti-parallel configuration in order to ensure the bidirectional conduction. Numbers of SCR's can be increased in series in order to cope with high reverse voltages. TSC can be controlled using thyristor valve. A typical TSC is shown in Fig. 1.

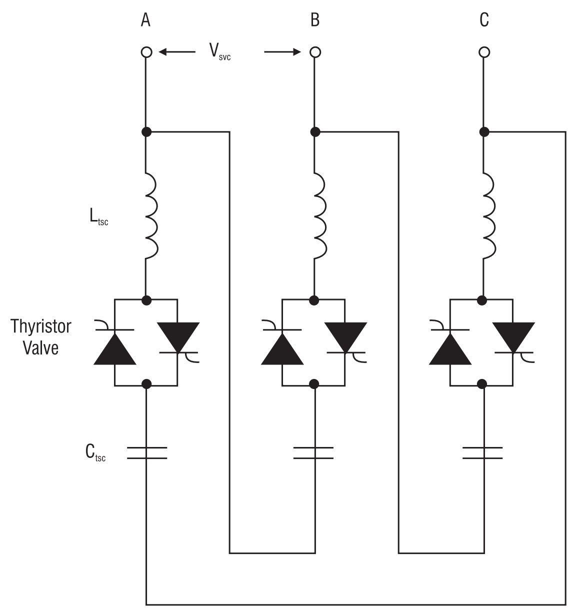

Fig. 1: Thyristor Switched Capacitors

Thyristor Switched Reactor shown in Fig. 2 is a combination of thyristor valve, VAR absorption reactor, and current limiting reactor. They are normally used under light loading conditions in order to avoid the possible rise in voltages. For capacitive power factor of system, it provides leading VARs to the system, and can be operated in phase control manner to absorb VARs if required (Reid, 1996). TCR is usually connected in delta fashion to filter these harmonics.

A typical Static VAR Compensator is shown in Fig. 3. An SVC consists of thyristor switched capacitors, thyristor-controlled reactors, and some harmonic filters in order to reduce the distortion. Sometimes mechanically

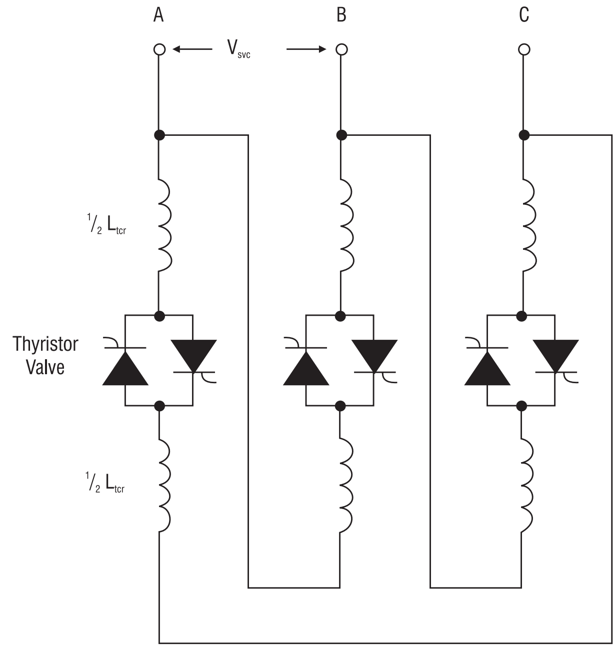

Fig. 2: Thyristor Switched Reactor

switched capacitors and inductors are incorporated so that to improved power factor in case of failure of TSC and TCR.

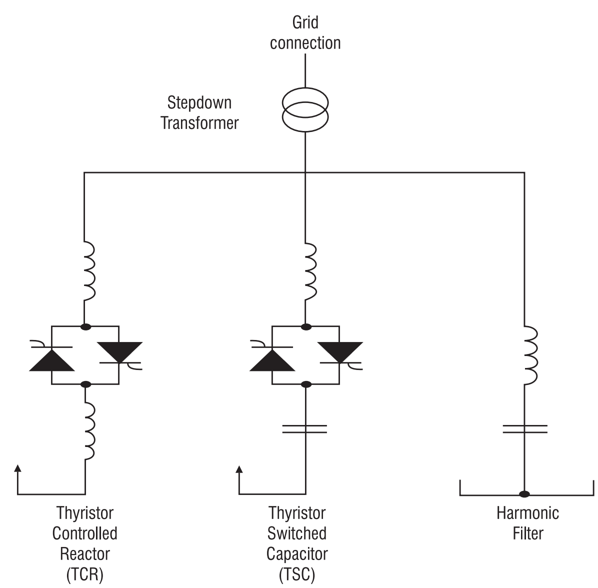

Fig. 3: A typical SVC

Proposed Model

A model of SVC was introduced that had TSC with TCR. Results showed remarkable improvement compared to ordinary switched capacitors. The introduction of fully controlled switch (GTO) added to the controllability of bidirectional switches (Khan, 2018).

The model that is proposed in this paper would omit TSC because of their limitations of harmonics control (Hart, 2011). Instead of TSC, a static capacitor bank that is mechanically switched is introduced. The rating of this capacitor is such that it can inject the required VAR's for worst case scenarios. In case of lightly loaded conditions where there is a possibility of receiving-end voltage exceeding the sending end voltage, TCR comes into play and absorbs the VARs in order to balance the leading VAR's. The proposed model is shown in Fig. 4 & Fig. 5.

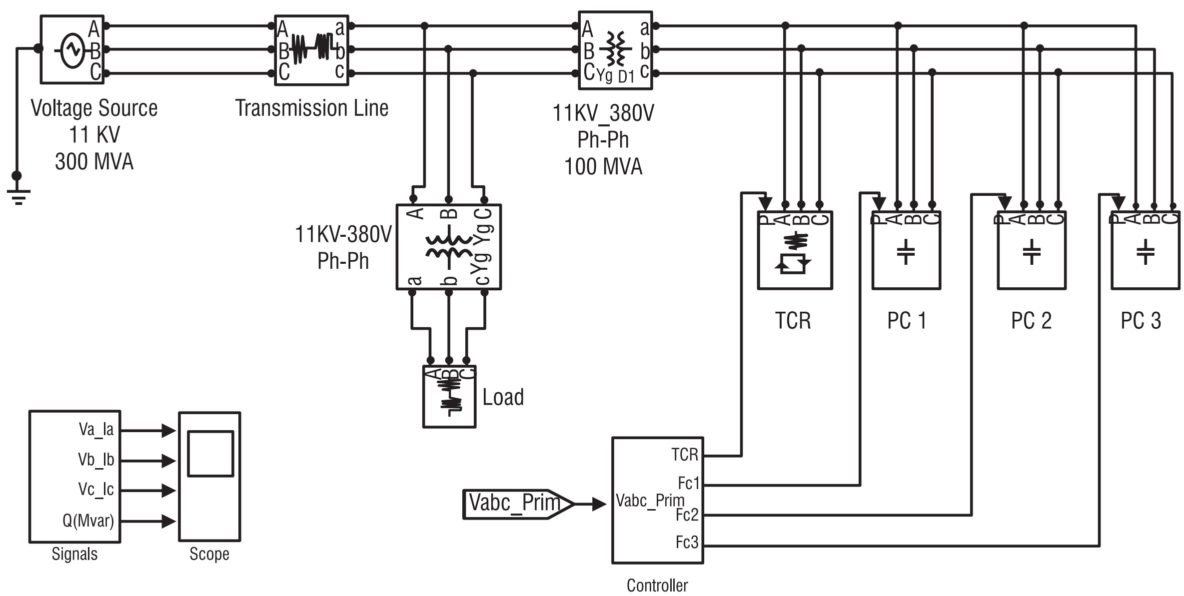

Fig. 4: Simulink Model of Thyristor Controlled Reactor with fixed Capacitor Bank

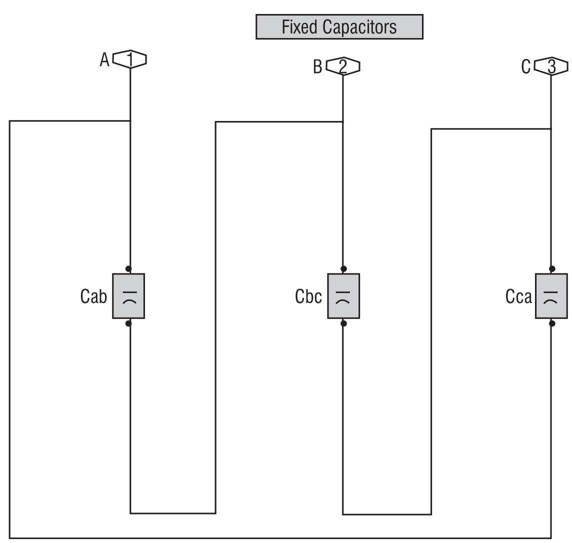

Fig. 5: Fixed Capacitor Bank

The rating of capacitor bank is calculated using the below mentioned relation (1).

$$Q_C = V_{line} 2\pi fc \qquad (1)$$

Where V_{line} is the line voltage and f is the frequency of the system. Line voltage and frequency here are fixed parameters the only variables are the capacitance of the capacitor and its VAR ability. For worst case scenario, the number of VARs to be injected in to the system is known. Using the same relation, the capacity of capacitor can be computed. Now, thyristor switched reactor can be controlled by controlling the firing angle to introduce lagging VARs using light loading conditions. A controller was designed for the control of reactive VAR's through TCR.

DISCUSSION AND RESULTS

Table 1, shows the reactive power requirement before and after the installation of power factor correction scheme. It can be seen that the reactive power demand is balancing out and the power factor is approaching unity.

Table 1: Power Factor and MVAR before and after PF Correction Scheme

Apparent Power MVA	Active Load MW	Reactive Load before PFC MVAR	Reactive Load after PFC MVAR	PF before PFC	PF after PFC
28	25	12	9	0.9	0.95
29	25	15.5	7	0.85	0.97
31	25	18.75	5	0.8	0.99
33	25	22	3	0.75	1
56	50	24.2	0	0.9	1
58	50	30	4	0.85	1
63	50	37.5	8.7	0.8	0.99
67	50	45	1308	0.75	0.97
111	100	48.5	20	0.9	0.99
118	100	62	28	0.85	0.97
125	100	75	35.5	0.8	0.95
133	100	88	43.64	0.91	0.96

The Power Factor before and after correction is plotted in Fig. 6. Considerable improvement can be seen in the above analysis. The improved power factor is shown by blue line, whereas the power factor before improvement is shown in red. Another comparison is shown in Fig. 7, this shows reactive VAR requirement before and after power factor correction.

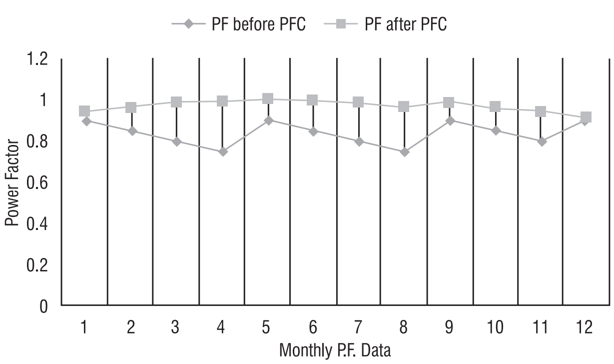

Fig. 6: Power Factor Comparison (before and after power factor correction)

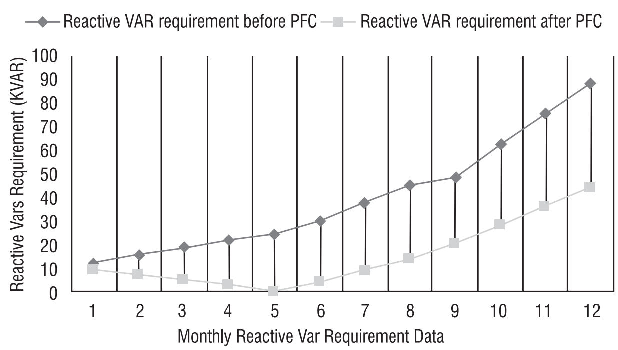

Fig. 7: Reactive VAR requirement (before and after PFC)

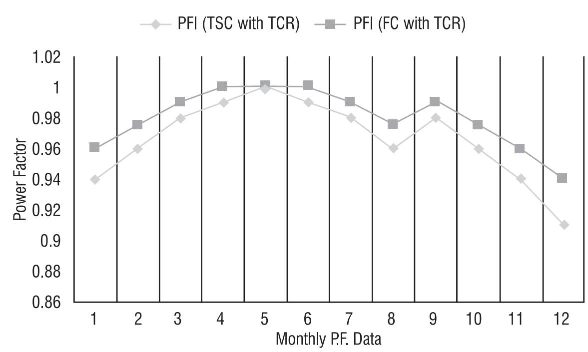

Fig. 8: Corrected Power Factor with TSC and TCR in comparison to FC with TCR

In Fig. 8, Power Factor is improved in a similar fashion, but the harmonic content has been reduced. As the harmonics get reduced, there is further improvement in power factor.

CONCLUSIONS AND FUTURE WORK

SVC model improve results up to a greater extent but with the limitation of introduction of harmonics in to the system. Though harmonics cannot be completely eliminated but can be reduced to a greater extent by using fixed capacitors with thyristor switched reactors. This is in accordance with the analysis that TSC introduces greater harmonics compared to TCR.

The switching has been improved with the help of GTO's that bring more controllability compared to ordinary thyristors. Voltage controlled switches can replace current controlled switches with the ease of simpler driving circuits. This would improve the switching times and would in effect limit the switching losses.

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