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A Balanced Operation of Static VAR Compensator for Voltage Stability Improvement and Harmonic Minimization

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Abstract:
The conduction angles variation in operating a static var compensator can be used to meet the balanced and varying cyclic load of reactive power demand. However, this operation creates harmonics current into the system. An optimum combination of balanced reactive power from SVC and reactive power from the generator based on telephone influence factor (TIF), the total harmonic current factor (IT), and the distribution factor D is proposed. This approach is simulated to a typical distribution network. However, this operation creates harmonics currents into the AC system. This strategy is implemented to a conventional distribution network for various loading conditions is presented.

Keywords: static Var compensator, phase-wise balanced, reactive power, performance factor, harmonics, distribution factor

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1 Introduction

Large single phase loads and fluctuating industrial loads cause unbalance operation of the system networks. These loads may lead to voltage fluctuations and instability condition to the entire system. These types of industrial loads absorb large reactive power from the system supply. In this condition, the system lead to unable supplying the reactive power demand, increases the system loss, and low load power factor. The system need to compensate to restore to its balance operation. There are two main reasons for compensating large fluctuating loads, i. e., the AC system is too weak to maintain the terminal voltage within the acceptable bounds, and it is neither economical nor practical, to supply the reactive power demand from the AC source.

Shunt Compensators are used to increase the power transfer capacity and to compensate the reactive-voltage drop in the system, minimize the reactive power drawn from the supply source and to minimize the system loss. Static Var Compensator (SVC) has the advantages of fast response, high reliability, flexibility and low maintenance cost. SVC will typically regulate and control the voltage to the acceptable range under normal and contingency conditions and thereby provide dynamic, fast response reactive power following system contingencies. SVC can also increase transfer capability, reduce losses, mitigate active power oscillations, prevent overvoltages, control of reactive power and damping power oscillations. An SVC includes a combination of a fixed capacitor-thyristor controlled reactor (FC-TCR), or thyristor switched capacitor-thyristor controlled reactor (TSC-TCR). The main advantage of using a topology with thyristor switched capacitor branch is to reduce the losses. The combination of thyristor-controlled reactor and thyristor-switched capacitor use to vary the reactive power continuosly. The harmonic generation will be low because the controlled reactor is small compared with the total controlled power.

Applications of the thyristor-controlled compensator in regulating the balanced reactive power demand in a system can be advantageous by the various sets of conduction angle, but generated harmonics and flow into the system. This harmonics can be minimized internally or install an external harmonics filter.

A method of determining the effect of harmonics in terms defined performance indices has been proposed [1]. A new configuration for the reactors to reduce the harmonic generation has been proposed [2]. They suggested a parallel combination of two phase-controlled reactors in series with a fixed reactor. It is shown that, by using this arrangement the reactors in a static var compensator, magnitudes in certain order harmonics

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can be reduced, thereby eliminating the need for filters. Gyugyi et al. [3] examined the theoretical foundations of thyristor-controlled shunt compensation. They established conditions for balanced load compensation and voltage stabilization with the use of symmetrical components and suggested a scheme which employs a fixed capacitor in parallel with a thyristor-controlled inductor for the realization variable susceptances. The harmonics generated by controlling the thyristor switches were kept out of the line currents by placing the fixed capacitor in series with filter network that draws the same fundamental current the system frequency and provides low impedance shunt paths at the harmonic frequencies.

Two methods have been proposed to minimize the harmonics generated by the thyristor-controlled reactors [4]. One method uses n reactor banks, each being with $1/n$ of the total rating, the reactor banks being controlled sequentially, that is, only one of the n reactors is delay angle controlled, and each of the remaining n-1 reactors is either fully ON or fully OFF. The other method uses two identical delta connected thyristor-controlled reactor banks, one operated from the wye-connected secondary winding the other from the delta-connected winding of a supply transformer, respectively, have been suggested. They also reported that the harmonic cancellation is theoretically possible by operating three, four, or more delta-connected thyristor-controlled reactor banks with appropriately phase shifted voltages. An algorithm has been presented to find optimum phase-wise unbalanced reactive absorption of the TCR based on harmonic performance indices for load balancing [5]. Unbalanced operation of SVC has been discussed [6] and the optimum reactive power combination for firing angles in the range of 35–45 degrees.

An optimum combination between reactive power inject from the SCV source and balanced reactive power generated from the AC source is presented. To obtain the size of the TSC and the firing angle of the TCR, the defined performance indices of telephone of telephone interference factor, total harmonic current factor and distortion factor are used. A small reactive power draw from the source results in minimizing the harmonics effect, thereby reducing the burden of the external harmonic filter.

A simulation studies conducted on a distribution network for a cyclic and a balanced load conditions are presented to illustrate the approach.

2 System and compensation model

The block schematic arrangement of a typical SVC isillustrated in Figure 1, where Bus-1 represents the AC system source node, and Bus-2 represents the load bus node. A combination of FC-TCR and TSC-TCR of SVC are considered for the study analysis. To obtain the compensation procedure, the system load assumed to be balanced. A steady state loads at a discrete time are used to represent time-varying loads. With this assumption, the compensator will generate or absorb balanced reactive power to or from system network.

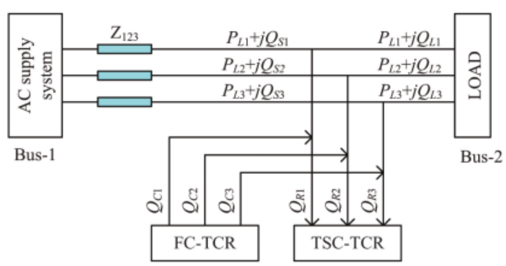

Figure 1: System line diagram.

If we define the phase-wise load demand before and after compensation seen from the source (Bus-1) as $P_{L1} + jQ_{S1}$, $P_{L2} + jQ_{S2}$, $P_{L3} + jQ_{S3}$ and $P_{L1} + jQ_{L1}$, $P_{L2} + jQ_{L2}$, $P_{L3} + jQ_{L3}$, respectively and the phase-wise voltages as $V_1\angle\delta_1$, $V_2\angle\delta_3$, and $V_c\angle\delta_c$, at the load bus (Bus-2), then

$$[E_L]_{123} = [E_S]_{123} - [Z]_{123}[I]_{123} \tag{1}$$

where,

$$I_1 = (P_{L1} - jQ_{S1})/V_1^*\angle - \delta_1 \tag{2}$$

$$I_2 = (P_{L2} - jQ_{S2})/V_2^*\angle - \delta_2 \tag{3}$$

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$$I_3 = (P_{L3} - jQ_{S3})/V_3^* \angle - \delta_3 \tag{4}$$

and

$[E_L]_{123}$: phase-wise complex voltages at load bus;
$[E_S]_{123}$: phase-wise complex voltages at source bus;
$[Q_S]_{123}$: phase-wise reactive power supplied by source;
$[Z]_{123}$: line impedance.

The procedure of phase load flow analysis can be used to obtain the solution of load bus voltages from the non-linear complex set of eq. (1). The phase-wise reactive power balance equation at the load bus can be written as,

$$[Q_S]_{123} + [Q_C]_{123} = [Q_R]_{123} + [Q_L]_{123} \tag{5}$$

For a given phase-wise balanced reactive power demand $[Q_L]_{123}$, setting balanced values for $[Q_C]_{123}$ of the FC-TSC and $[Q_S]_{123}$ of the source, the balanced reactive power $[Q_R]_{123}$ absorptions of the TCR can be obtained from the set of eq. (5).

Considering the compensators, Q_{R1}, Q_{R2}, and Q_{R3} are variables of delta connected reactance absorbed in the unsymmetrical reactance x_{12}, x_{23}, x_{31} of the TCR as shown in Figure 2.

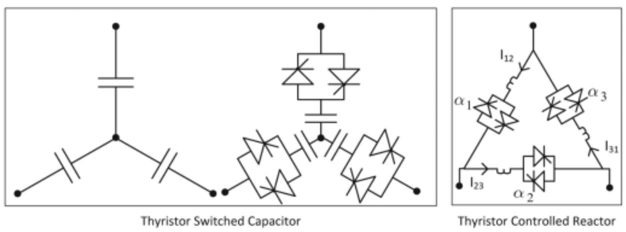

Figure 2: Thyristor-switched capacitor and thyristor-controlled reactor.

The following relation can be obtained:

$$[Q_R]_{123} = [A][B] \tag{6}$$

where,

$$[B] = [B_{12}, B_{23}, B_{31}]^t \tag{7}$$

with $B_{12} = 1/x_{12}, \quad B_{23} = 1/x_{23}, \quad B_{31} = 1/x_{31}$

$$A(1,1) = V_1V_1 - V_1V_2\cos(\delta_1 - \delta_2);$$

$$A(1,2) = 0;$$

$$A(1,3) = V_1V_1 - V_1V_3\cos(\delta_1 - \delta_3)$$

$$A(2,1) = V_2V_2 - V_2V_1\cos(\delta_2 - \delta_1);$$

$$A(2,2) = V_2V_2 - V_2V_3\cos(\delta_2 - \delta_3);$$

$$A(2,3) = 0$$

$$A(3,1) = 0;$$

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$$A(3,2) = V_3V_3 - V_3V_2\cos(\delta_3 - \delta_2);$$

$$A(3,3) = V_3V_3 - V_3V_1\cos(\delta_3 - \delta_1)$$

The solution of eq. (6) can be used to solve the value of delta connected reactance compensator for balanced reactive power absorption in the case of voltage conditions at supply bus. Considering the fundamental component, unsymmetrical firing angles α_1, α_2 and α_3 of the asymmetrical delta connected reactance and the thyristor switch closure is delayed by an angle α ($0 < \alpha > \pi/2$), the delta connected reactances can be obtained by the expression,

$$x_{12} = x_{12}^o / \left[1 - \frac{2\alpha_1}{\pi} - \frac{\sin(2\alpha_1)}{\pi}\right] \tag{8}$$

$$x_{23} = x_{23}^o / \left[1 - \frac{2\alpha_2}{\pi} - \frac{\sin(2\alpha_2)}{\pi}\right] \tag{9}$$

$$x_{31} = x_{31}^o / \left[1 - \frac{2\alpha_3}{\pi} - \frac{\sin(2\alpha_3)}{\pi}\right] \tag{10}$$

Where x_{12}^o, x_{23}^o and x_{31}^o are the reactance for full conduction of thyristors corresponding to zero firing angles, $\alpha_1 = \alpha_2 = \alpha_3 = 0.0$.

3 Measurement of harmonics effect

The effect of harmonic in the system network is generally measured by the calculation of the performance indices, TIF, IT and D. TIF is a dimensionless value used to describe the interference of a power transmission line on a telephone that may result from the presence of harmonic voltages adjacent to the point of connection of the SVC, IT provides a measure of the TIF that may result from harmonic currents injected into the AC system by the compensator, and D is a measure of a voltage distortion. The performance indices are computed by the equations,

$$TIF = \left[\sum_{h=1}^{m} (TIF)_h^2\right]^{1/2} \tag{11}$$

$$IT = \left[\sum_{h=1}^{m} (IT)_h^2\right]^{1/2} \tag{12}$$

$$D = \sum_{h=2}^{m} \left[\frac{I_h}{I_f}\right] \tag{13}$$

where,

$$(TIF)_h = [I_h/I_f]\, W_h \tag{14}$$

$$(IT)_h = I_h.W_h \tag{15}$$

$W_1 = 0.01$; $W_5 = 2.05$; $W_7 = 5.9$;
$W_{11} = 22.5$
W_h = the harmonic weightage factor
m = maximum order of harmonics considered.
The fundamental component $[I_f]$ of the line current can be solved from eq. (16),

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$$I_f = \frac{V_m}{2\pi\omega L}(G_f^2 + H_f^2)^{1/2}\sin(\omega t - \varphi - \theta_f) \tag{16}$$

and the harmonic components $[I_h]$ of the line current is given in (17),

$$I_h = \frac{2V_m}{\pi\omega L}(G_h^2 + H_h^2)^{1/2}\sin[h(\omega t - \varphi - \theta_h)] \tag{17}$$

Where

V_f = maximum of source voltage (rms)
I_f = fundamental line current (rms)
I_h = harmonic line currents (rms)
ω = fundamental frequency (rad/sec)
L = inductance of each delta connected reactance (henries)

$$G_f = 3\pi - 4\gamma - 2\sin(2\gamma) - 2\beta - \sin(2\beta) \tag{18}$$

$$H_f = \sqrt{3}[\pi - 2\beta - 2\sin(2\beta) \tag{19}$$

$$G_h = \left\{\frac{\sin[(h+1)\gamma]}{h+1} - \frac{\sin[(h-1)\gamma]}{h-1} - \frac{2\sin\gamma\cos(h\gamma)}{h}\right\} + \frac{1}{2}\left\{\frac{\sin[(h+1)\beta]}{h+1} - \frac{\sin[(h-1)\beta]}{h-1} - \frac{2\sin\beta\cos(h\beta)}{h}\right\} \tag{20}$$

$$H_h = \frac{\pm\sqrt{3}}{2}\left\{\frac{\sin[(h-1)\beta]}{h+1} - \frac{\sin[(h-1)\beta]}{h-1} - \frac{2\sin\beta\cos(h\beta)}{h}\right\} \tag{21}$$

$\theta_f = \tan^{-1}(H_f/G_f)$; $\theta_h = \tan^{-1}(H_h/G_h)$;
h = harmonic order, $(6k\pm1)$, $k = 1,2,3, \ldots$;
the + sign is for harmonics of order $(6k+1)$; the - sign is for harmonics of order $(6k-1)$; $\phi = 0$, $\gamma = \alpha_1$, $\beta = \alpha_3$ for line current i_a; $\phi = 2\pi/3$, $\gamma = \alpha_2$, $\beta = \alpha_1$ for line current i_b; $\phi = 4\pi/3$, $\gamma = \alpha_3$, $\beta = \alpha_2$ for line current i_c;
For triple harmonics (3rd, 9th, …);

$$G_h = \left\{\frac{\sin[(h+1)\gamma]}{h+1} - \frac{\sin[(h-1)\gamma]}{h-1} - \frac{2\sin\gamma\cos(h\gamma)}{h}\right\} + \left\{\frac{\sin[(h+1)\beta]}{h+1} - \frac{\sin[(h-1)\beta]}{h-1} - \frac{2\sin\beta\cos(h\beta)}{h}\right\} \tag{22}$$

$$H_h = 0$$

4 Computational steps

The particular combination which gives minimum TIF, IT and D can be selected as the most optimum operation of Static VAR compensator to meet the balanced reactive power demands. A computational step of the computer program developed for this purpose and implemented on a distribution network is shown in Figure 3. Results obtained for a typical system for different conditions are presented and discussed in the following section.

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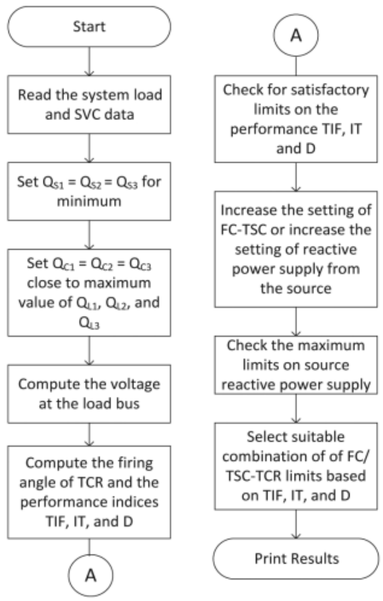

Figure 3: Flow chart for optimum selection of phase-wise reactive power compensation.

5 System studies

A computer program based on the proposed algorithm for evaluating the optimum operation of static var compensators to meet the balanced reactive power demands has been developed and implemented on a distribution system. Results obtained for a typical system for different conditions are presented and discussed.

The system considered is a 220/70 kV substation (source) feeding a radial load through a 70 kV line as shown in Figure 1. FC-TCR and TSC-TCR are two of the SVC which is considered for this analysis.

The line resistance and reactance between source and load bus are 0.08855 p.u per phase and 0.08033 p.u per phase, respectively. Two types of loads i. e., Balanced Cyclic Load and Balanced Load are considered for the studies.

6 Balanced cyclic load

The cyclic load being considered is shown in Table 1. The load is cyclic varying load, but assumed to be phase-wise balanced.

Table 1: Cyclic load at different of time in each phase.

Time range(seconds)	Real Load(MW)	Reactive Load(MVAR)
0–10	3.6	3.6
11–50	29.0	29.0
51–61	56.0	39.0
62–75	38.0	28.6
76–90	3.6	3.6

Harmonics analyses have been carried out with various sizes of SVCs and for different loading conditions. Results for a TSC-TCR type SVC with TSC of 30 MVAR and TCR of 30 MVAR per phase rating are presented. With TSC fixed at 30 MVAR and the reactive load of 3.6 MVAR and 39.0 MVAR. For the reactive load of 3.6 MVAR, the source reactive power will vary from −26.4 MVAR (leading power factor) to 3.5 MVAR (lagging power factor) corresponding to TCR absorption from 0.1 MVAR (88.62° firing angle) to 29.9 MVAR (33.4° firing

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angle), while for reactive load of 39.0 MVAR, source reactive power will vary from 9.0 MVAR to 39 MVAR corresponding to TCR absorption 0.1 MVAR (88.6° firing angle) 39 MVAR (29.4° firing angle).

Figure 4 shows the plots of harmonic indices TIF, IT and D versus TCR reactive power absorption. It can be observed that all the three indices TIF, IT and D show a similar picture in respect of exhibiting the harmonic effects. With TSC settings at 30 MVAR for initial load condition (i. e., cyclic load initial period), harmonic indices are computed for TCR operation from 0 MVAR to 30 MVAR.

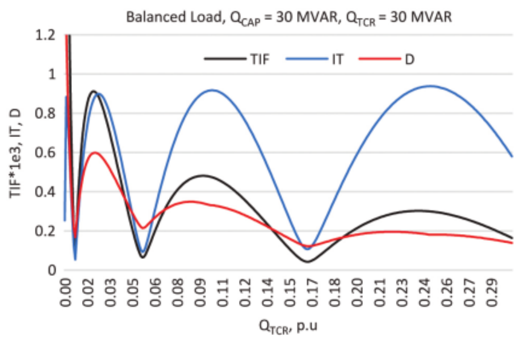

Figure 4: TIF, IT, and D versus Q_{TCR} for reactive load of 3.6 MVAR.

Figure 5 shows the plot of harmonic index TIF versus TCR absorption for different load levels. The effect of harmonics (TIF values) is shown to be similar for different settings of TSC.

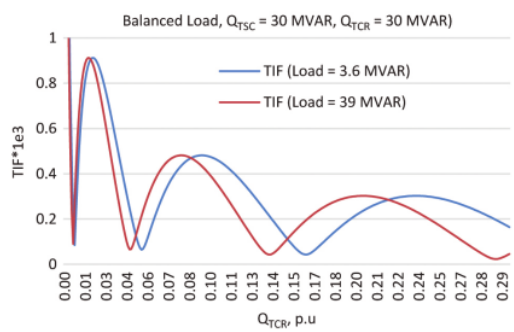

Figure 5: TIF profiles for different load conditions.

Figure 6 shows the TIF, IT, and D profile with respect to firing angles variation from 88.62° to 33.4° (corresponding to 0 MVAR to 30 MVAR) absorption of TCR for a reactive load of 3.6 MVAR). It can be observed that effect of harmonics is minimum when the TCR is operating at around firing angles of around 30°, 45°, 60° and 75° for both load conditions. Though the same low harmonics injection be realized at firing angles of around 30°, 45°, 60° and 75°, the effect of harmonics is rapidly increasing with deviation in firing angles around 75° compared to the corresponding deviation of firing angle around 60° and the effect is progressively decreasing for lower firing angles.

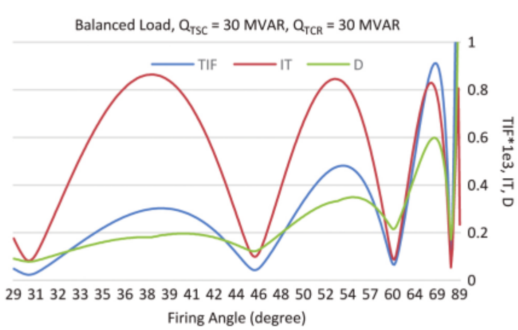

Figure 6: TIF, IT, and D versus firing angle.

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Analysis of these plots shows that the effect of harmonics is minimum at the same MVAR absorption levels (firing angles) of TCR irrespective of the loading condition. Thus for minimization of harmonic effects, the TCR should be made to operate at firing angles which are integral multiples of 15^0 within the possible operating range of the TCR.

The system operating conditions with different loads condition with TSC of certain values is shown in Table 2. It gives the results showing the optimum combination of TSC-TCR with TCR firing angles for various load conditions of the cyclic load. Summary of the results from Table 2 giving the optimum combination of TSC-TCR and firing angles are shown in Table 3. The system operation condition, such as a load of 39 MVAR with TSC of 30 MVAR, that the greater the optimum firing angle, the lesser the demand for the source to supply the reactive power for a given load. Also from Table 2, it is observed that, though minimum TIF can be realized at four regions of firing angles for a given set of TSC, the MVAR absorption of TCR increases as the firing angles decrease resulting in increased MVAR supply from the source. Thus for meeting the dual propose of minimum MVAR supply from the source and minimum harmonics effects.

Table 2: Acceptable values of TIF in different load conditions with TSC of certain values.

Load(MVAR)	TSC(MVAR)	TCR(MVAR)	Source(MVAR)	Alpha(degree)	TIF
	20	**16.0**	**–4.0**	**45.3**	**43.0**
		7.0	–15.7	74.9	97.2
3.6		5.1	–11.3	60.3	65.5
		7.0	−25.7	75.9	85.2
	30	5.2	–21.2	60.3	64.9
		16.2	–10.2	45.3	43.1
		29.9	3.5	33.4	164.6
		6.0	9.6	75.2	82.6
	20	4.6	13.6	60.4	71.0
29		14.6	23.6	45.3	43.0
		20.0	29.0	39.6	292.9
		6.0	−4.0	73.3	95.8
	30	**4.8**	**3.8**	**60.2**	**65.0**
		14.9	13.9	45.2	43.1
		29.9	28.9	31.3	61.0
		6.0	19.6	75.1	79.0
	20	4.5	23.5	60.1	65.0
39		14.0	33.0	45.3	43.2
		20	39.0	38.8	301.4
		6	9.6	75.0	90.3
	30	**4.4**	**13.4**	**60.3**	**65.8**
		13.8	22.8	45.3	43.0
		29.0	38.0	30.2	23.4

Table 3: The optimum of TSC and TCR firing angles.

Load (MVAR)	TSC (MVAR)	Alpha (degree)	TIF	IT	D
3.6	20	45.3	43.0	0.107	0.122
29.0	30	60.2	65.0	0.09	0.215
39.0	30	60.3	65.8	0.087	0.216

An optimum combination of TSC-TCR settings and firing angles are required. Table 2 gives the results showing the optimum combination of TCS-TCR with TCR firing angles for various load conditions of the cyclic load. Summary of the results from the Table 2, giving the optimum combination of TSC-TCR and firing angles are shown in Table 3.

7 Conclusions

An approach for optimum control of FC-TCR and TSC-TCR of Static VAR Systems is presented based on combining the minimum harmonic injections into the system and the minimum reactive demand supplied by the

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source. The approach method strategy meets both the requirements of load balancing as well as reducing the reactive power supply from the sources. The proposed approach also helps in the caclulate the optimum rating of SVCs for a given type of load.

Acknowledgements

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References

[1] Barthold LO, et al. (CIRGE Working Group 31-01). Modelling of static shunt VAR systems (SVS) for system analysis. Electra. 1977;51:45–74.

[2] Hammed AE, Mathur RH. A new generalized concept for the design of thyristor phase controlled VAR compensators. Part I: steady state performance; Part II: transient performance. IEEE Trans. 1979;PAS-98:219–226.

[3] Gyugyi L, Otto RA, Putman TH. Principles and applications of static, thyristor controlled shunt compensators. IEEE Trans On. 1978;PAS-97:1935–45.

[4] Gyugyi L, Taylor ER, Jr. Characteristic of static thyristor controlled shunt compensators for power transmission system applications. IEEE Trans On. 1980;PAS-99:1795–804.

[5] Thukaram D, Ramakrishna Iyengar. BS, Parthasarathy K. An algorithm for optimum control of static VAR compensators to meet phase wise unbalanced reactive power demands. Electric Power Syst Res. 1986;11:129–37.

[6] Lomi A. Planning and operation of reactive power sources for voltage stability improvement and harmonics minimization. Ph.D thesis, Asian Institute of Technology, Bangkok, 2000.

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