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A Study of Static Var Compensation Using TSC – TCR Shunt Compensator

Ruhaan Rashid[1], and Krishna Tomar[2]

[1]M. Tech Scholar, Department Electrical Engineering, RIMT University Mandi Gobingarh , Punjab, India
[2]Assistant Professor, Department. of Electrical Engineering, RIMT University Mandi Gobingarh, Punjab, India

Correspondence should be addressed to Ruhaan Rashid; sneharajput9393@gmail.com

ABSTRACT- The notion of reactive power management encompasses a wide range of system and customer challenges, particularly those connected to power quality, because most power quality issues may be mitigated or remedied with proper reactive power control. When strong inductive loads are coupled to transmission lines, the trailing load current causes a problem with power factor. In some cases, very low current flows through the transmission line due to minor load, resulting in a leading parasitic capacitance in the line, resulting experience extreme, causing the load side hand voltage must become twice that of the sending end side voltage (Ferranti effect), especially in long transmission system. To avoid this problem, we developed a new hybrid reactive power control model that uses a simultaneous combo of thyristor-controlled reactor (TCR) and thyristor switched capacitor (TSC), which will immediately include a sleek current control spectrum from touch sensitive to deductive approach values by varying the firing angle of the transformer via a computer.

KEYWORDS- Lagging load, Thyristor switched capacitor, Thyristor controlled Reactor, Reactive power,

I. INTRODUCTION

The regulation of reactive power to improve the operation of ac power systems is known as voltage regulation. The idea of voltage regulation encompasses a wide range of system and customer difficulties, particularly those connected to power quality issues, because most power quality issues may be mitigated or handled with proper reactive power management. A TSC-TCR model was focused on one thing, allowing for full system compensation and a power factor of unity.[1] Reactive power compensation, imbalanced load compensatory damages, and minimization are the approaches employed. The use of reactive power compensation technologies to enhance the power factor and stabilise the supply voltage of a supply network with an increased number of loads over time. Static VAR correction is accomplished using thyristor-switched capacitors (TSC) and thyristor-controlled reactors (TCR) (SVC).

A. Midpoint Voltage Regulation for Line Segmentation

Take a simple multiple (two-bus) estimation procedure, as illustrated in figure 1, in which an ideal VAR adjuster is shunt coupled at the distribution line's midway (a). The series line inductor is used to illustrate the line for simplicity. The action of the voltages at the transmitter and receiver ends (Vm= Vs = Vr= V) The midpoint compensator, which is illustrated by a sinusoidal ac voltage source (of rms value), in phase with the halfway voltage (Vm), and with a magnitude similar to the control scheme, divides the power line into two separate sections [2]

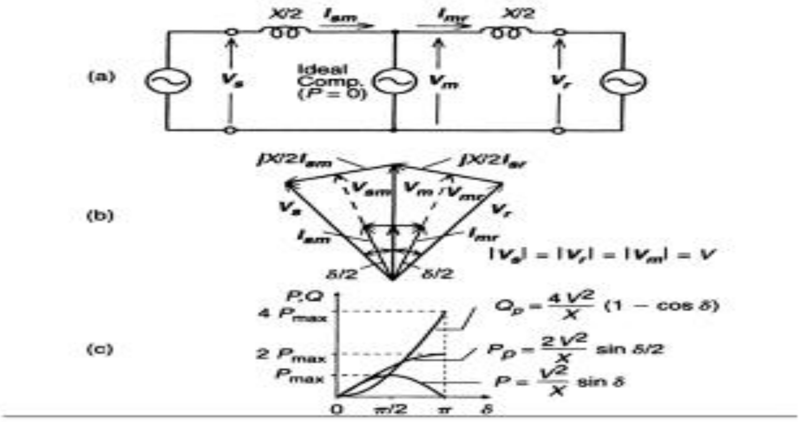

Figure 1: Two machine power system with an ideal midpoint reactive compensators (a) corresponding phasor diagram (b) Power transmission vs angle characteristic showing the variation of power p and reactive output of the compensator.

Power is carried from the transmitting end to the middle by the first segment, which has an inductance of X/2, and from the midpoint to the receiving end by the second segment, which likewise has an impedance of X/2. The phasor diagram in Figure 1 demonstrates the connection between voltages Vs,Vr, Vm (together with Vsm,Vrm) and polyline currents Ism and Imr (b). In this operation, the midpoint VAR compensator solely exchanges reactive power with the transmission line. The actual power is the same at each terminal (sending end, midpoint, and receiving end) of the line for the frictionless system postulated, and it can be easily calculated from the phasor diagram in Fig. 1. (b).With

$Vsm = Vmr = Vcos\frac{\delta}{4}$; $\quad Ism = Imr = \frac{4V}{X}sin\frac{\delta}{4}$

The transmitted power is,

$P = IsmVsm = VmrImr = VmIsmcos\frac{\delta}{4} = VIcos\frac{\delta}{4}$

or

$$P = 2\frac{V^2}{X}sin\frac{\delta}{2}$$

Similarly,

$$Q = VIsin\frac{\delta}{4} = \frac{4V^2}{X}(1\text{-}cos\frac{\delta}{2})$$

Figure 1 plots the connection between real power P, reactive power Q, and angle for the case of optimal capacitor banks (c). It can be shown that midstream shunt adjustment can double the highly communicable power at the price of a rapidly growing peak load on the midpoint converter (and also on the end-generators). The midway of the transmission network is likewise the optimal place for the compensatory in the single-line system shown in Figure 1.. Because the voltage sag of an unwaged transmission network is greatest roughly in the middle, this is the case. Furthermore, the midpoint compensation divides the transmission line into two equal pieces, each with the same max highly contagious power. The transmittable power of the longer section would clearly dictate the data transfer limit in the case of uneven parts. The notion of transmission line segmentation may be expanded to include numerous compensators placed at equal intervals along the transmission network, as shown in Figure 2 for four-line segments[3]. The Hydro-Quebec power system's large, 600-mile-long 735 KV transmission line, constructed to transfer up to 12000 MW electricity, has proved the viability of restricted line fragmentation utilising inductor static VAR flash suppressors. More significantly, multiple projects throughout the world have proved the transmission benefits of voltage support via regulated capacitor banks at crucial transmission line points.

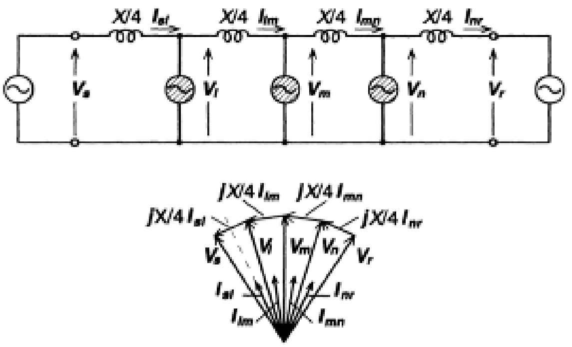

Figure 2: The machine system with ideal reactive compensators maintaining constant transmission voltage profile by segmentation and associated phasor diagram

B. *End of Line Voltage Support to Prevent Voltage Instability*

The above-mentioned midway voltage support for a transmit and receive electricity system may simply be applied to the much more unique scenario of radially production. Indeed, if a passive load utilizing power P at voltage V is coupled to the midway instead of the receipt section of the system (which includes the recipient producer and transport link X/2), the mailing generation with the X/2 resistor and load would be a simple radial system. Figure 3(a) depicts a basic radial system with feeder line reactance X and load impedance Z, as well as the normalised total power (Vr) vs power (P) plot for different loads power issues stemming from 0.8 lag to 0.9 lead. As can be seen in Figure 3, the intrinsic circuit qualities of the basic section discuss the methodology, as well as the Vr versus P plots, clearly show that shunt shall issue can probably enhance the voltage stability limit through distributing the experiences and regulating its terminal voltage (V – Vr = 0). (b) The loss of one of the power sources might increase system load upon this remained section of the system, resulting in severe voltage deflation and eventual voltage collapse.[4]

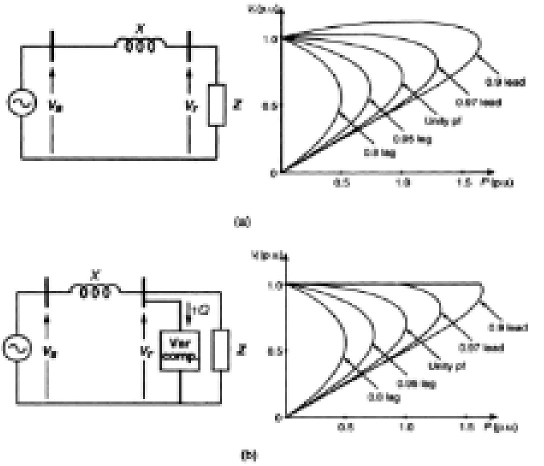

Figure 3: Variation of voltage stability limit of a radial line with load power factor (a) and extension of this limit by reactive shunt compensation (b)

C. Improvement of Transient Stability

The maximum transmittable power can be greatly increased using reactive shunt adjustment. Shunt compensation, with appropriate and quick controls, should be able to adjust the power flow in the system during and after dynamic instabilities, increasing the transmission line limit and providing effective power oscillating attenuation.[5] The equal area criteria can be used to assess the possible usefulness of shunt (as well as other compensation and flow control strategies) in improving transient stability. With the help of the basic two machine (the receiver is an infinite bus), two-line system illustrated in Figure 4(a) and the associated P versus curves displayed in Figure 4(b), the significance of the identical area criteria is explained (b) . Assume that when a failure occurs at line segment "I," the whole system is defined by the P versus curve "" and is running at angle 1 to transfer power PI. The system is defined by the P against curve "b" during the fault, and therefore the received electric power declines drastically over this period, while the mechanically input power to the sending-end machine remains relatively constant equivalent to P1. As a result, the producer increases and the output angle rises from 1 to 2, at which point the safe circuits connect the defective line segment "1" and the sending-end generator absorbs advancing energy, as shown by area "A1." Lacking line segment "1," the degraded system is identified after fault clearing.

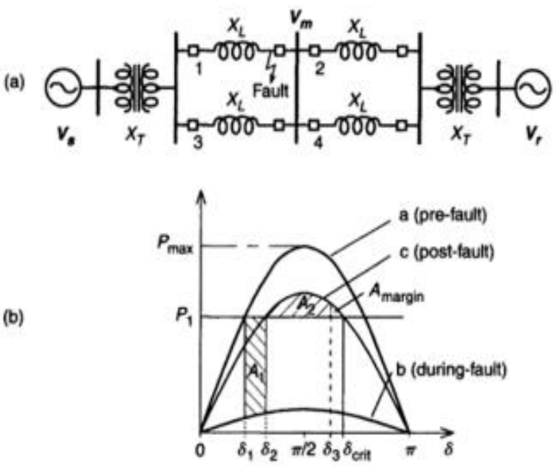

Figure 4: Illustration of the equal area criterion for transient stability of a two-machine two-line power system

D. Power Oscillation Damping

Any slight perturbation in an under-damped power supply can cause the machine angle to oscillate about its steady-state value at the whole electromechanical system's inherent frequency. Of course, the angle oscillation results in a power oscillation around the steady-state power transmitted. In some power systems, a lack of appropriate damping can be a severe issue, and in other circumstances, it can be the limiting factor for the transmittable power. Because power oscillation is a long-term vibrant event, it's important to adjust the applied shunt compensation, and as such the transmission line's (midpoint) voltage, to compensate for the agitated hair dryer)' accelerating and slow it down swings.). To cover the extra manual input power, the electric power transferred must be raised when the circularly oscillate generation accelerate and angle 6 increases(dδ/dt> 0). When the producer slows down and the angle drops (d/dt0), the electric power must be reduced to compensate for the lack of mechanical inrush current. .

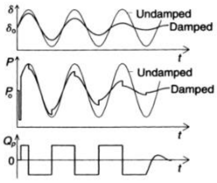

Figure 5: waveform illustrating power oscillating by reactive shunt compensation: a) generator angle b) transmitter angle c) VAR output of the shunt compensator

II. OBJECTIVES

By using reactive viewed as a valuable, the steady-state highly communicable power may be raised and the voltage profile along the line can be regulated. The goal of reactive compensation is to alter the transmitting line's intrinsic electrical properties to make it more acceptable with the current load profile. Thus, under low load situations, shunt connection, fixed or actively switched breeders are used to reduce line sparking, while under high load conditions, shunt connected, fixed or mechanically shifted capacitors are used to maintain voltage levels. The fundamental factors for increasing transmittable power via optimal shunt-connected VAR compensation will be discussed, laying the groundwork for power electronics-based comp and control solutions to satisfy specific compensation targets. This may be necessary to improve the platform's steady-state antenna performance and stability. Vary adaptation is therefore employed for voltage regulation only at transfer line's midway (or some intermediate) to segment it and at the end of the (radial)line to limit overvoltage, as well as for dynamical voltage control to improve transient stability and damp power oscillations.

III. LITERATURE REVIEW

Static VAR correction is often not performed at line voltage; instead, a bank of capacitors reduces the transmission voltage (for example, 230 kV) to a considerably lower level (for example, 9.0 kV). [5] Although the lines must be quite big to manage the high currents accompanied with the lower voltage, this decreases the size and number of components required in the SVC. In some static VAR controllers for industry sectors, such as steelmaking, where a medium-voltage busbar is already present (for example, at 33 kV or 34.5 kV), the static VAR compensator can be directly attached to save on transducer costs. Another typical SVC connection site is on the delta tertiary winding of Y-connected provided some useful, which is used to link one sfect to another.[6]

The employment of thyristors coupled in series and inverse-parallel, producing "thyristor valves," gives the SVC its dynamic aspect. The disc-shaped semiconductors, which have a diameter of several inches, are normally kept indoors in a "valve house." SVCs have a significant advantage over basic mechanically switched compensation methods in that they respond very instantly to changes in the system voltage. [7] As a result, they are frequently operated near their zero-point to optimise the reactive power adjustment they can offer quickly when needed. They are, on average, less expensive, have a greater capacity, are quicker, and are more dependable than dynamic compensating techniques like synchronous condensers. [7] Because static VAR converters are more substantial than slip rings capacitors, many grid operators combine the two approaches (sometimes in the same facility), employing the static VAR buffer for quick changes and constantly switching capacitors for steady-state VARs..

IV. METHODOLOGY

When linked to an ac power source, capacitors create reactive power, while reactors (inductors) absorb it. Since the dawn of ac power transmission, they've been utilised with mechanical switches for (coarsely) regulated VAR production and absorption. Over- or under-excited rotating generating units, and subsequently, saturation boilers in combination with fixed capacitors, allowed continuously variable VAR production or absorbent for dynamic system adjustment. High-power, plot thyristors, in combination with caps and reactors, have been used in various circuit designs to create -reflection discharge since the early 1970s. By simultaneously switching shunt capacitors and/or reactors "in" and "out" of the network, they effectively give variable shunt impedance. The VAR output may be changed repeatedly from peak reactive to max inductive emission at a certain bus voltage using proper switch control. In switched inverter circuits, gate field - effect rectifiers and other power circuits with internal deal breaker capability have lately been employed to create and absorb reactive power without the usage of ac banks or neutrons. . The amount of the domestically produced ac voltage is changed to regulate the VAR output in these ideal synchronised statcom (condensers). All semiconductor power circuit with internal management that allows them to create VAR output proportionate to an input reference are generally known to as static VAR generators per the IEEE and CIGRE definitions (SVG). A static VAR converter (SVC) is a static VAR generator whose emission is modified to manage or regulate specified parameters (e.g., voltage, frequency) of the electric power system, according to the IEEE CIGRE co-definition.

As a result, a static VAR generator becomes a static VAR compensator, according to the IEEE-CIGRE definition, when it has been armed with distinct outside (or system) oversight that derive the nessecary remark for its information from the strength control algorithm specifications and dominant characteristics in order to execute the desired electrical transmission renumeration. This means that multiple types of VAR generators can be controlled by the same external control to perform almost identical compensating operations. The basic operating aspects (e.g., voltage vs. VAR output, response time, harmonic generation) are obviously determined by the type and structure of the VAR generator, meanwhile the static VAR compensator's functional capabilities (e.g., voltage regulation, power factor control, electric oscillation damping) are controlled by the external forces. . High-power semiconductor switching circuits are used in modern static var generators. These switching circuits evaluate some of the important controlling qualities, such as the voltages versus purchasable reactive inverter, harmonic era, loss vs that of var signal, and manageable response time, legislating for the var generator's and, subsequently, the static var compensator's, order to achieve project success. The performance parameters and features of the two types of static var generators currently in use are described in the following two sections: those that use thyristor-controlled nuclear reactor with fixed and/or voltage-controlled battery cells to achieve a complicated by the fact electrical resistance and those that use an inverter converter to achieve an adjustable synchronous voltage source. Following sections cover the external control's application requirements, structure, and operation, which apply to both types of var generators and establish the compensator's functional capabilities and operating rules under various system situations.[7]

V. SYSTEM ARCHITECTURE

The primary thyristor-controlled parts of resistive type VAR power sources: the voltage-controlled engine and the converter capacitor, govern their efficiency and sustainable characteristics.

A. The Thyristor-Controlled and Thyristor-Switched Reactor (TCR and TSR)

Figure 6 depicts a simple single-phase thyristor-controlled reactor (TCR) (a). It comprises of a bidirectional thyristor valve (or switch) sw and a fixed (typically air-core) reactor of inductance L. Large thyristors can currently block voltages ranging from 4000 to 9000 volts and conduct currents ranging from 3000 to 6000 amperes. To reach the requisite blockage line voltage for a particular power rating, numerous thyristors (usually 10 to 20) are linked in series in a practical valve. A thyristor valve can be forced into circuit by applying a gate wave to all mosfets with the same pole at the same time. Unless the path analysis is reapplied, the valve will disallow when the ac current reaches zero. . The firing delay angle control method may regulate the current in the reactor from maximum (thyristor valve closed) to zero (thyristor valve open). That is, the inductor valve's closing is staggered with regard to the applied voltage's peak in each half-cycle, allowing the duration of current conduction intervals to be adjusted. In Figure 6(b), the administered voltage v and the reactant current IL(α), at zero delay angle (switch fully closed) and at an arbitrary delay angle, are shown sequentially for the pro and con electric half-cycles. When the valve's gates is delayed by an angle of α(0 ≤α≤π/2) with regard to the voltage crest, the valve's gating is late by an angle of α(0 ≤α≤π/2) with reference to the power crest.

$$i_L(t) = \frac{1}{L}\int_{\alpha}^{\omega t} v(t)\,dt = \frac{V}{\omega L}(\sin \omega t - \sin \alpha)$$

Because the thyristor valve opens when the current hits zero, (4) holds true during the interval α≤wt≤(π–α).. The same statement certainly holds true for successive positive half-cycle periods. The sign of the components in the following calculation reverses for consecutive negative half-cycle periods.

The term (V/wL) sin in the eq.1 is essentially a dependent constant that shifts the sinusoidal waveform obtained at = 0 down for larger current half-cycles and up for negative current half-cycles, as seen in Figure 6. (b). Because the valve simply switches off at the exact moment of present zero crossing (which, for a digital audio reactor, is asymmetric here on time angular to the exact moment of turn-on with regards to the apex of the current), as the wait time angle increases, the consequently vastly increased offset results in the valve's charge transfer angle declining, and the fission current lowering.

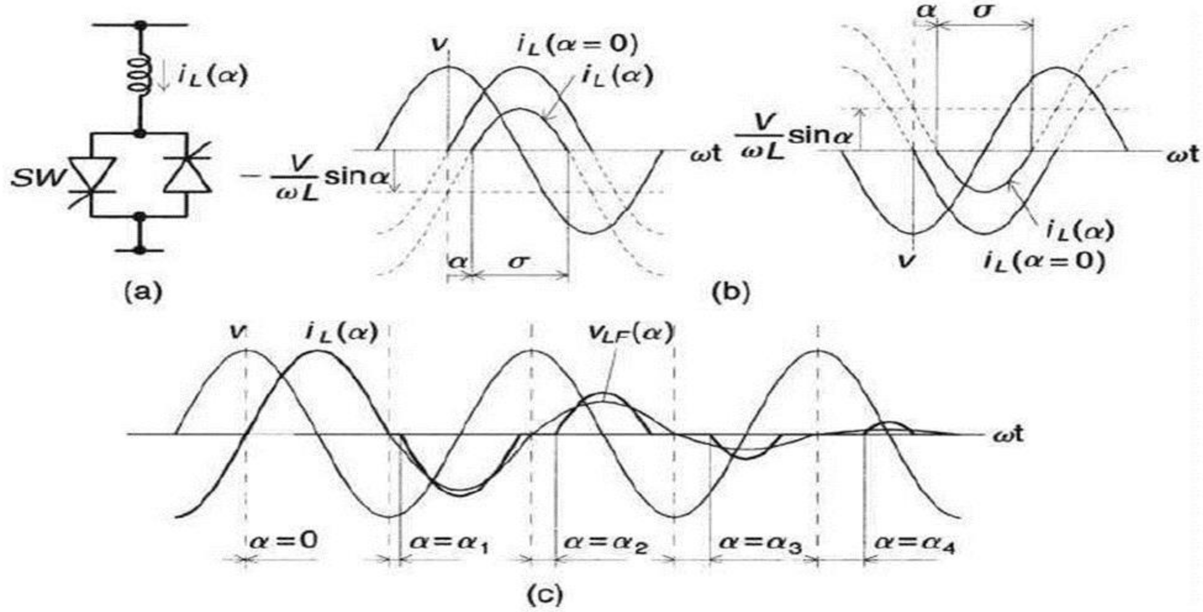

Figure 6: Basic thyristor-controlled reactor (a), firing delay angle control (b), and operating waveforms (c)

B. The Thyristor-Switched Capacitor (TSC)

Figure 7 depicts a single-phase thyristor-switched capacitor (TSC) (a). It comprises of a capacitor, a reversible thyristor valve, and a surge current limiting reactor that is quite tiny. This reactor is principally used to limit the surge current as in inductor valve under unnatural system parameters (e.g., a control device failure causing capacitor going to switch at the "bad direction" when transient free switching terms are not met); however, it can also be used to avoid vibration with the ac system impedance at frequency bands. When the thyristor valve is closed and the TSC branch is tied to a sinusoidal ac voltage source in steady-state circumstances, v = Vsin wt, the current in the branch is given by the amplitude of the voltage across the capacitor is

$$i(\omega t) = V\frac{n^2}{n^2-1}\omega C\cos\omega t$$

$$n = \frac{1}{\sqrt{\omega^2 LC}} = \sqrt{\frac{X_C}{X_L}}$$

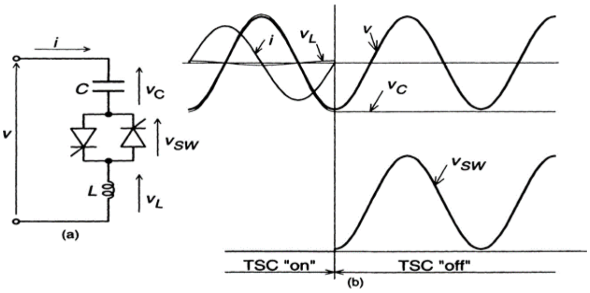

Figure 7: Basic thyristor-switched capacitor (a) and associated waveforms (b)

$$V_C = \frac{n^2}{n^2-1}V$$

As a result of the unconnected capacitor remaining charged to this voltage, the voltage across the non-conducting thyristor valve swings around zero and the transmitted ac voltage's peak-to-peak value, as shown in Figure 7. (b).

C. Fixed Capacitor, Thyristor-Controlled Reactor Type VAR Generator

Figure8 shows a functional diagram of a basic VAR generator employing a fixed (permanently connected) capacitor and a thyristor-controlled furnace (FC-TCR) (a). The current in the reactor is controlled using the delay angle control approach described above. In reality, the fixed capacitor is frequently replaced, whole or partially, by a filter network with the needed capacitive impedance at the fundamental frequency to create the reactive power, but high frequency at set dates to shunt the TCR's main harmonics. . The fixed capacitor, thyristor-controlled reactor type VAR generator may be thought of as a combination of a flexible nucleus (controlled by delay angle) and a fixed resistor, with a VAR need versus VAR parameter extraction similar to that depicted in Figure 8. (b). To produce the overall VAR output (Q), the fixed capacitor's constant capacitive VAR creation (Qc) is countered by the voltage-controlled reactor's changeable VAR absorption (QL). The inductive current grows stronger than the reactive current as the angle decreases (providing the reactor's rating is greater than the capacitor's), resulting in a net inductive VAR emission. . The thyristor-controlled neutron transmits modern across the whole 180-degree period when the delay angle is zero, resulting in the high inductive VAR output measured by the difference between vars created by the capacitor and those absorbed by the fully conduct reactor.

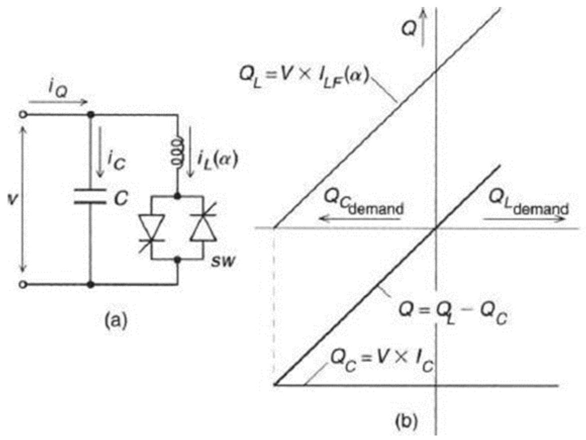

Figure 8: Basic FC-TCR type static VAR generator) and its VAR demand versus var output characteristic(b)

As illustrated in Figure 8, the control of the thyristor-controlled reactor in the FC-TCR type VAR generator must perform four essential tasks (a). Synchronous timing is one of the functions. A phase-locked loop circuit, which operates in synchronism with the ac system voltage and provides suitable timing pulses with regard to the peak of that voltage, generally performs this purpose. The reactive current (or admittance) to firing angle conversion is the second function. This may be achieved by implementing the mathematical connection between the amplitude of the fundamental TCR current ILF(α) and the delay angle αin a real-time circuit..

There are three basic types of inefficiencies experienced in the FC-TCR type VAR generator: (1) capacitor (or capacitive filter) losses (which are very minor but constant), (2) reactor losses (which rise with the inverse of the current), and (3) thyristor costs . As a result, overall losses rise as TCR current increases and reduce as sensitive VAR output increases. These losses diminish when sensitive VAR output (lower current) in the TCR increases, but they rise as inductive VAR output increases . When the average touch sensitive VAR yield is considerably large, as in advanced manufacturing applications that demand power supply, this type of loss distinguishing feature is useful; however, when the median wage VAR voltage drops, as in the case of dynamic reimbursement of gear box, it is disadvantageous.

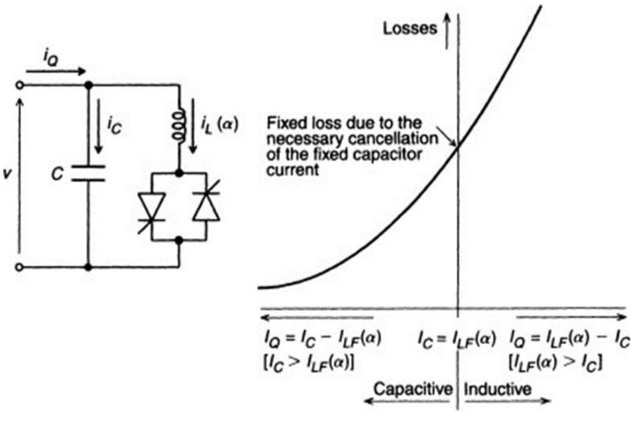

Figure 9: Loss versus VAR output characteristic of the FC-TCR type static VAR generator

D. Thyristor-Switched Capacitor, Thyristor-Controlled Reactor Type VAR Generator

The voltage-controlled cell, converter nuclear (TSC Section TCR) type regulator was designed to reduce standby losses and enhance operating flexibility in power transmission networks.

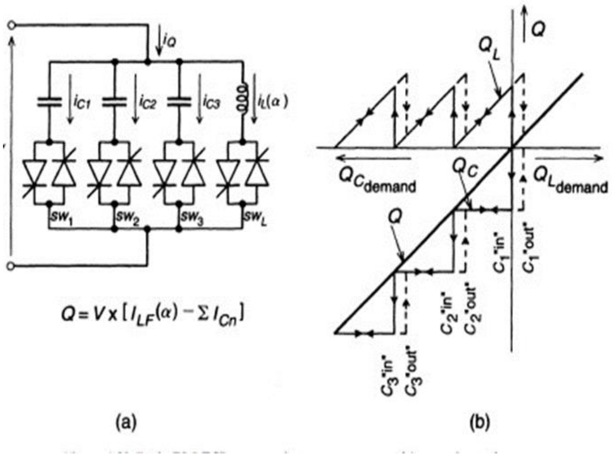

Figure 10: Basic TSC-TCR type static VAR generator and its VAR demand versus VAR output characteristic

Figure 10 depicts the VAR demand vs VAR output characteristic of the TSC-TCR type VAR generator. As can be seen, the TSCs modify the capacitive VAR output, Qc, in a step-like fashion to approach the VAR demand with a net capacitive VAR surplus, while the TCR's comparatively tiny inductive VAR output, QL, is employed to cancel the excess capacitive vars. In some ways, this scheme could be thought of as a special fixed capacitor, thyristor-controlled reactor arrangement, in which the reactor's rating is kept low (1/n times the maximum multitouch output), and or the capacitor's rankings is modified in discrete packets to keep the TCR's action within its current control ballpark. Figure 11 depicts a functional control method for a VAR generator of the TSC-TCR type.

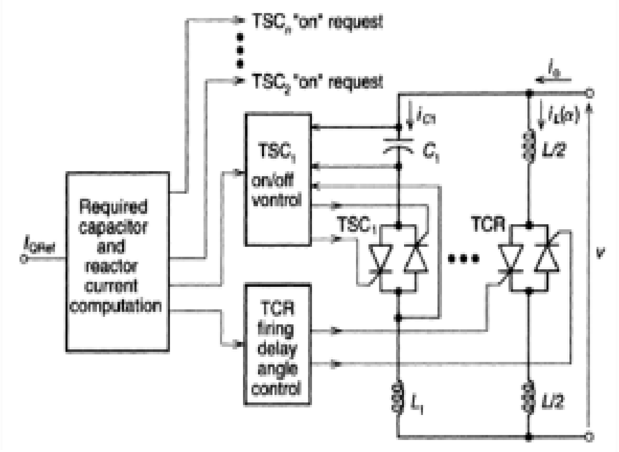

Figure 11: Functional control scheme for the TSC-TCR type static VAR generator

Figure 11 depicts a simple single-phase TSC-TCR configuration. It generally consists of n TSC branches and one TCR for a specific capacitive output range. The total number of the oscillograms in Figure 12 show the functioning of the TSC-TCR type VAR generator with three capacitor banks. The oscillograms depict the reactive current reference signal IQR ef, total output current iQ(= ie+ iL), current drawn by the thyristor-switched capacitor banks, and current drawn by the thyristor-controlled reactor. Figure 13 shows the V- I characteristic of the TSC-TCR type generator, which is identical to that of its FC-TCR counterpart.

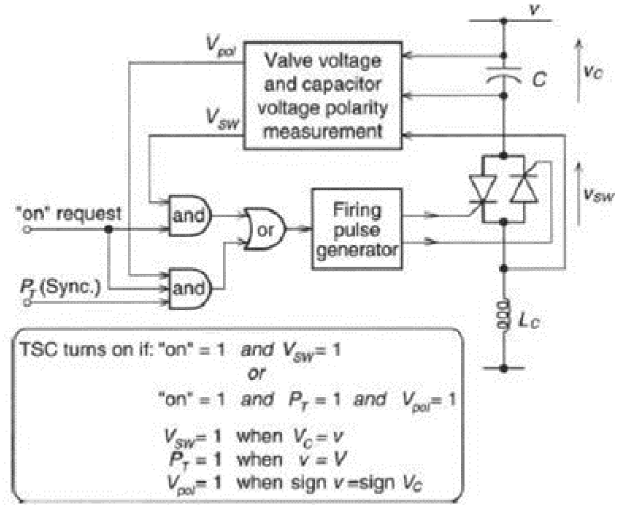

Figure 12: Functional logic for the implementation of "transient-free" switching strategy for the TSC

The reaction of the TSC-TCR type VAR generator may be quite slower than that of the FC-TCR equivalent, based on the quantity of TSC branches employed. This is due to the fact that the greatest flipping delay in a single TSC with a charged capacitor is one complete cycle, but the TCR's duration time is only half a cycle.

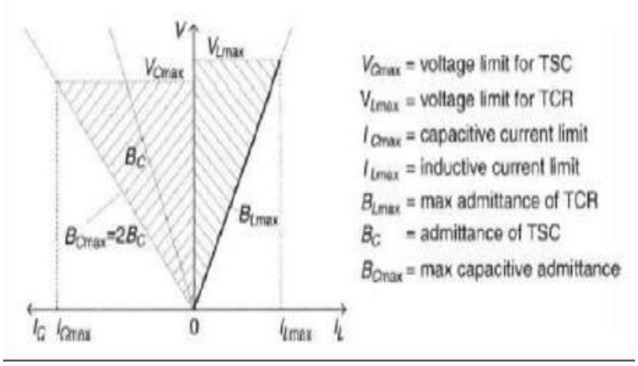

Figure 13: Operating V-I area of the TSC-TCR type VAR generator with two thyristor-switched capacitor banks

The TSC-TCR type VAR alternator has had the same equivalent circuit as its FC-TCR equivalent, with the exception that the additional shared lag Td, which occurs when the multitouch output is increased, is philosophically twice as large: 1/f = T for single phase execution and 1/3f = T/3 for stable three-phase execution. The performances of the TSC-TCR type VAR producer in transmission and distribution apps is often different from that of its FC-TCR counterpart in the linear operating range. The TSC-TCR type VAR generator's loss versus VAR output characteristic is derived from its core working concept. All capacitor banks are cycled out at or just below zero VAR output, the TCR current is zero or marginally tiny, and the loses are negligible or almost zero. As the reactive output rises, a higher number of TSC banks are activated, with the TCR absorbing the excess sensitive vars. As a result, the losses increase with each TSC bank that is switched on.

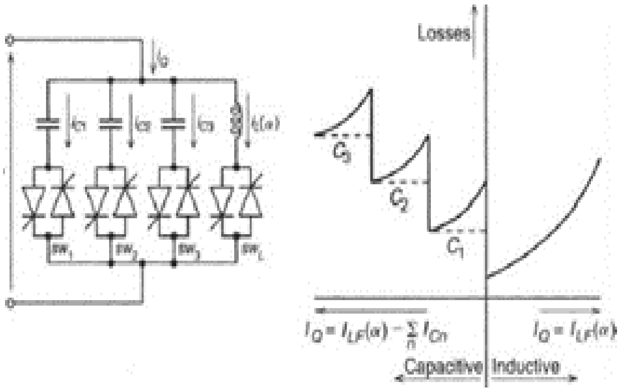

Figure 14: Loss versus VAR output characteristic of the TSC-TCR type static VAR generator

. The TCR's additional losses, which range from greatest to zero during every switching of the TSC banks, are new to this fixed loss, as shown in Figure 14. The rates of the TSC-TCR type VAR converter vary in proportional to the VAR yield, on average. This sort of loss character trait is clearly helpful in instances where the VAR generate is utilised for dynamic mitigation and is not necessary to give a high average VAR production for the power system to work smoothly.

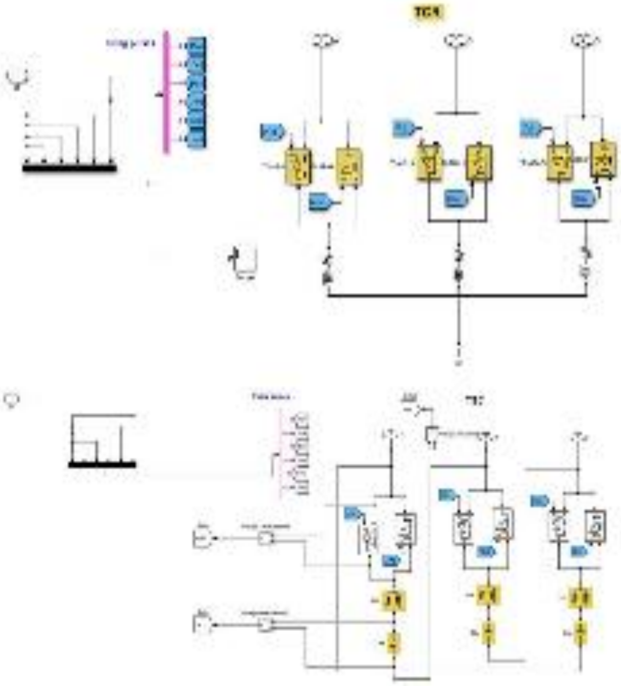

Figure 15: Simulink Model

VI. RESULTS

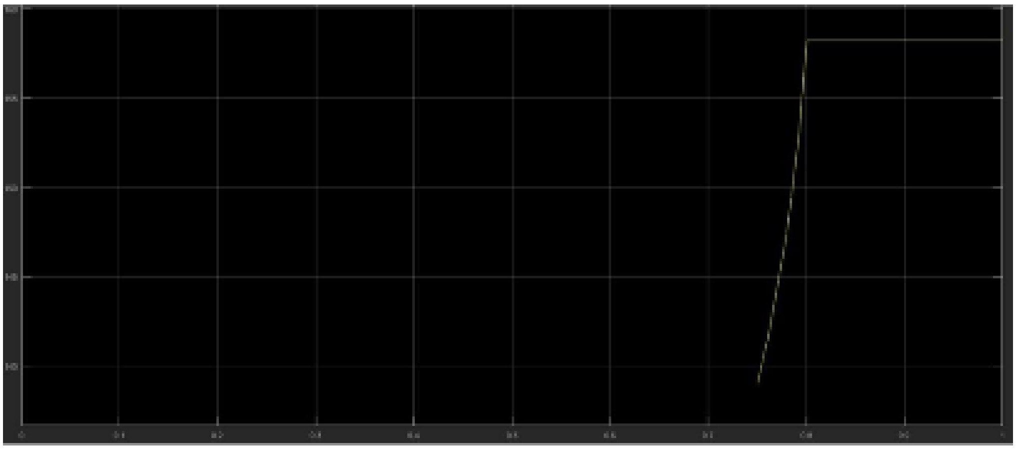

Figure 16: Determined the SVC result-I

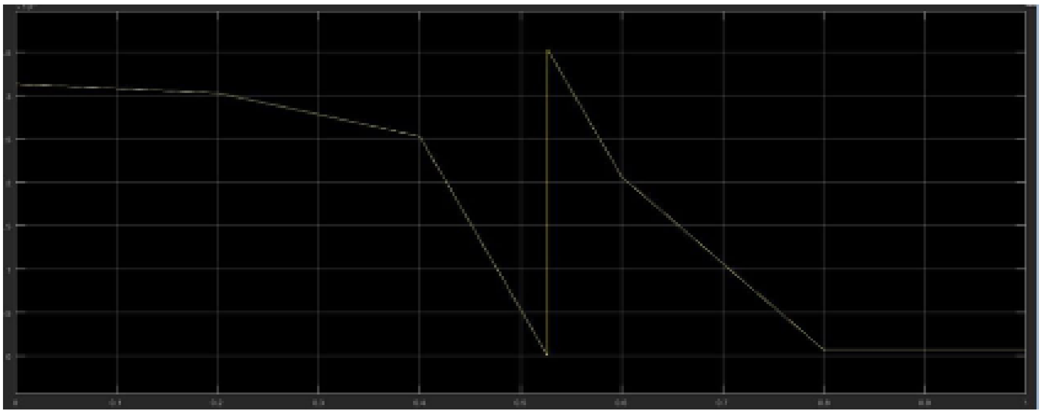

Figure 17: Determined the SVC result -II

VII. CONCLUSION

As a result, it is determined that the SVC (Static VAR Compensator) will efficiently control the dynamically operation of power system as well as the system periodic oscillations and voltages. The suggested controller performs better and regulates both active and reactive power as well as voltage stability.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

REFRENCES

[1] Hingorani, Narain G. and Laszlo Gyugyi, Understanding FACTS, 1st ed. Piscataway: IEEE Press, 1999, ISBN 978-0780334558.

[2] Akagi, Hirofumi, Edson H. Watanabe, and Mauricio Aredes, Instantaneous Power Theory and Applications to Power Conditioning, 1st ed., Piscataway: IEEE Press, 2007, ISBN 978-0470107614.

[3] Sood, Vijay K., HVDC and FACTS Controllers, 1st ed., Boston: Kluwer Academic Publishers, 2004, ISBN 978-1402078903.

[4] T. J. Miller, “Reactive power Control in Electric Systems,” John Willey & Sons, 1982.

[5] “Thyristor based facts controllers for electrical transmission systems” by R. Mohan Mathur, Ontario Power Generation Toronto, ON, Canada & Rajiv K. Varma Indian Institute of Technology Kanpur, India

[6] Amirnaser Yazdani; Reza Iravani, "Static Compensator (STATCOM)," in Voltage-Sourced Converters in Power Systems: Modeling, Control, and Applications, IEEE, 2010, pp.311-333, doi: 10.1002/9780470551578.ch11

[7] Hsieh, Harry, Felice Balarin, and Alberto Sangiovanni-Vincentelli. Synchronous Equivalence. Boston, MA: Springer US, 2001. http://dx.doi.org/10.1007/978-1-4615-