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Reactive Power Compensation by Innovative TSC-TCR type SVC Controller

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ABSTRACT

This Paper describes the assessment of reactive power control on a three-phase transformer, 6.9 kVA, 10A and 440V. We know very well that reactive power is essential to support active power, but it should be at the level of desire if not then problems occur. In this paper, technically sound, a more reliable, fast acting, and low cost scheme is proposed by arranging the thyristor capacitor elements switched into binary sequential steps. This allows the reactive power to be varied with the lowest possible resolution. A thyristor controlled reactor of the lowest step size is operating in a conjunction with a capacitor bank so as to achieve a continuously variable reactive power. In addition, the charging capacity of the shunt capacitor enhancement transformer also increases the performance of the feeder, reduces the voltage drop in the power supply and the transformer, increases the voltage at the load end, Improves power factor, develops system safety with higher utilization of transformer capacity, increases efficiency, saves energy due to concentrated system losses, avoids penalties of low power factor and reduces the maximum demand charges.

Keywords: Reactive Power, Thyristor Binary Compensator, Static Var Compensator, Thyristor Switched Capacitor, Binary Sequential Stages, Power Factor etc.

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I. INTRODUCTION

This article uses the Static VAr Compensator which is an advanced electrical device for quick action, that is, reactive power of automatic adaptation in high voltage electricity transmission networks. SVC is one of the part of the FACTS (Flexible AC transmission system) device, stabilizing the system and regulating the voltage [1]. Unlike a rotary electric machine which is a synchronous capacitor, the Volt Ampere reactor static compensator (VAr) consisting of no significant moving parts. Prior to SVC innovation, the maintenance of huge spinning machines such as synchronous capacitors or banks of capacitors switched made by power factor compensation [13]. The SVC is used to regulate the network voltage, system stability, in transmission applications. The SVC will use thyristor controlled reactors to consume VArs from the system when the reactive load of the power system is capacitive (leading) and decreases the system voltage. In addition to the capacitor banks, they are automatically connected under inductive (delayed) conditions, thus providing a higher system voltage [7]. The net result is the continuously changeable advance or delay power by connecting the thyristor controlled reactor, which is continuously irregular, along with steps of a capacitor bank. In industrial applications, Var Static Compensators are placed particularly close to high loads and rapid variation, such as arc furnaces etc.

In solution of this study of paper performance of the static VAr compensator (SVC) through the thyristor binary compensator is performed. The appraisal work focuses on performance evaluation by logical studies and the implementation of the simulation model of the VAr static compensator (SVC) to the 3Φ, 50Hz, 11kV / 440V, DY-11, 500 KVA. The thyristor containing SVC switched the capacitor bank in binary sequential steps in combination with the lowest step thyristor controlled reactor. In addition, the work deals with performance assessment and done with the analysis and realization of the SVC hardware circuit model at 3Φ, 50Hz, 6.9kVA transformer. The SVC involves the thyristor switched capacitor bank in binary sequential steps. Sequential binary steps "n", satisfying the equation:

$$\mathbf{Q = 2n\ C + 2\ n\text{-}1\ C + \ldots\ldots\ldots\ldots\ldots. + 22\ C + 21C + 20C}$$

II. PROBLEM IDENTIFICATION

In power system different type of loads are present like R-L, R-C or R-L-C. Therefore power factor changes with respect to load conditions. Power factor is depending upon the presenting reactive power and apparent power.

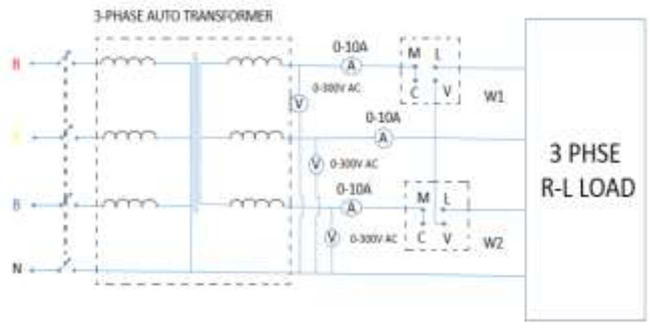

Figure1: Simplified circuitry of measurement of electrical parameters without SVC

A. Operation of R-L load without SVC

If reactive power in the system is huge in quantity, there is straight impact on power factor. So, to improve the power factor it is necessary that to diminish the reactive power in the system and sustain it at a desire level. To identify complexity from system we took R-L and R-C-L load and their results are shown in below Figure.

Table no. 1 Performance of Transformer without Compensator with R-L Load

Vr-phase (volts)	Ir-phase (Amp)	Vy-phase (volts)	Iy-phase (Amp)	Vb-phase (volts)	Ib-phase (Amp)	Cos ¢	Active power (W)	Reactive power (VAR)
240	1	245	1	246	1	0.59(lead)	141.60	192.00
235	3.2	245	3.2	245	3.2	0.76(lead)	571.52	481.28
233	5	245	5	245	5	0.77(lead)	897.05	733.95
235	7	245	7	245	7	0.8(lead)	1316	970.55

B. Test Results

In practice, mainly the distribution system, have plenty of nonlinear loads, which drastically affect the stability and quality of power supplies. As a conclusion of the nonlinear loads, the purity of the waveform of supplies is lost. This ends up producing lots of power quality problems as voltage sag, flickers, phase unbalance, low power factor, and Harmonics [2].

In radial system, during peak load conditions at consumer's end or end users low voltage problems occurs. Due to those problems the apparatus can be destructed. After the completion of test we concluded that Reactive power is in huge quantity as per as Ideal theoretical case. So, we have to need to control the voltage at the receiving end [12].

C. Observations under Load Condition

From above test results conclusion is that there is relation between reactive power and power factor. We examine that the reactive power is very large in this circuit test, therefore power factor is very low (lagging). While power instability take place on all electrical power systems, the consideration of today's difficult electronic devices makes them more responsible to the quality and stability of power supply. For a few sensitive devices, a quick disorder can cause twisted data, broken up communications, system crashes and equipment breakdown etc. A power voltage spike can damage valuable components. Power Quality problems include an extensive range of instability such as voltage sags/swells, flicker, impulse transient, harmonics distortion, and interruptions [15]. Reactive power compensation is necessary for voltage regulation, saves energy, reduction in current, stability development and for growing power transmission ability, Thus by controlling reactive power, power factor can be enhanced. There are many inventions on the reactive power compensation by different techniques.

III. SVC WITH BINARY SEQUENTIAL SWITCHED CAPACITORS

In planned paper, for making the fine resolution we use a binary sequential capacitor bank set up. To obtaining transients free switching we have to need to keep the following two conditions with respect to Capacitors and thyristor;

a. The thyristor fired at the negative/positive maximum value of voltage, and/or
b. Capacitor is pre-charged to the negative/positive maximum value voltage.

The first condition can be met precisely by timing the control circuitry and the second condition is only met instantly after switching off thyristor. The arrangement for three capacitor bank steps in binary sequence weight with thyristor switch is shown in Figure1.

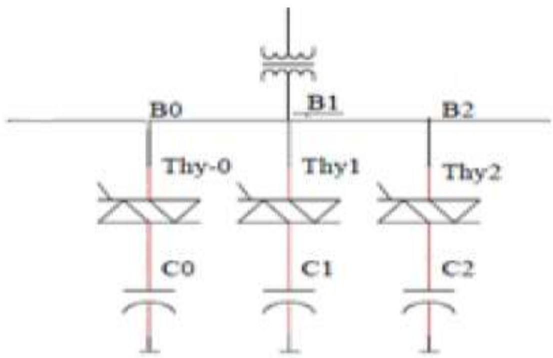

Figure 2: Thyristor Binary Compensation (TBC)

At the distribution transformer for improving the power factor from selected primary value Pf1 to the desired value Pf2 at the load, total reactive power Q is responsible. This Q can be structured in binary sequential „n" steps, fulfilling the following equation [6];

$$Q = 2nC + 2n-1C + ...+ 22C + 21C + 20C$$

An error adaptive controller is designed, developed and tested for switching operations of the capacitor bank as required for the system under consideration. It possesses the following features.

1. The control approach is error activated to match with the load reactive power for the selected time interval.

2. It removes achievable over compensation and resulting leading power factor.
3. It is elastic to select required number of steps as per the determination.

Resolution can be made small with more number of steps.

IV. SIMULATION AND RESULTS OF THREE PHASE UN-COMPENSATED AND COMPENSATED SYSTEM

Performance Analysis of Three Phase Un-compensated Simulation Model at 500 kVA Distribution Transformer:-

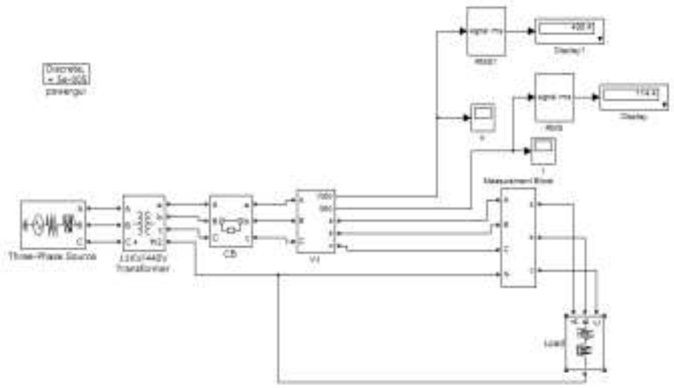

Figure 6.1 Un-compensated Simulation Model

The Figure 6.1 shows the block diagram of uncompensated simulation model of DY-11, 500 kVA distribution transformer. The purpose of simulation was to check the performance of existing system virtually and monitor the system parameters such as V, I, active power (P), reactive power (Q) and power factor (cosΦ) using measurement block for preliminary idea of performance analysis before going for development of simulation model and then hardware model of SVC on existing system.

The simulation model consists of 3-phase transformer of DY-11 type means primary winding (delta) leading secondary winding (Y) by 30 degrees, where primary winding (delta) is connected to 11kV supply and secondary winding (Y) forms 440V bus. The 3-phase R-L-Load is connected to 440V bus.

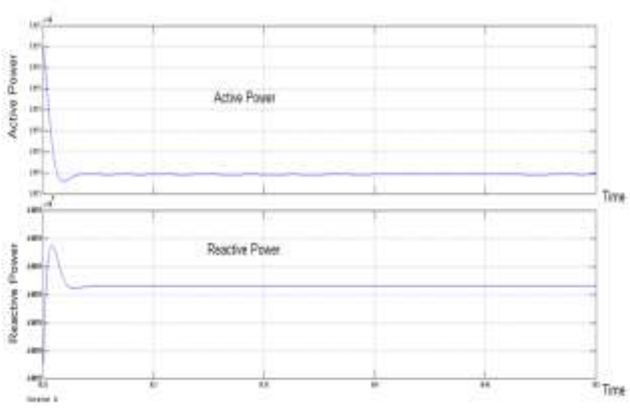

Figure 6.2 Un-compensated Simulation Output Waveform

Figure 6.2 shows that result of un-compensated system in the form of waveforms. In this un-compensated Simulation system it is clearly show that Reactive power is more consumed by load in system, hence Active power is less consumed by load, so there is more power loses are occurred as well as bus voltage is varied, as well as power factor goes on decreasing and it is lagging power factor.

SVC Results of Simulation Model:

Table No. 6.1 Distribution Feeder Performance without Compensator at 500 kVA Transformer

Sr. No	Load Current (A)	Receiving End Voltage (V)	Power Factor	Real Power (kW)	Reactive Power (kVAR)	Apparent Power (kVA)
1	114.3	430.4	0.70	59.7	60.8	85.2
2	223.0	421.7	0.72	117.2	113.1	162.8
3	326.2	413.7	0.74	172.9	157.3	233.7
4	392.8	409.1	0.76	211.6	180.8	278.3
5	473.3	403.6	0.78	258.1	206.9	330.7

A) Distribution Feeder Performance without Compensator:-

The SVC results of simulation of Distribution Feeder Performance without Compensator at 500 kVA Transformer is as shown in Table no. 6.1.

Performance Analysis of Three Phase Compensated Simulation Model at 500 kVA Distribution Transformer

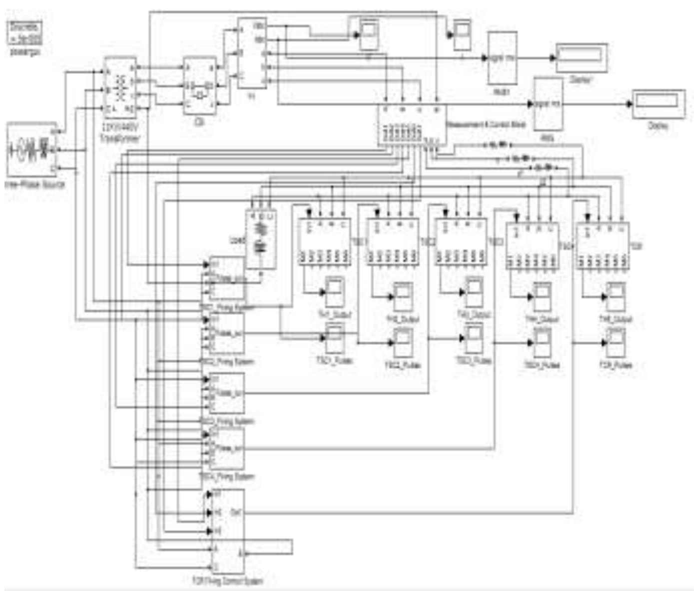

Figure6.3 Simulation Model for TSC-TCR type SVC at 500 kVA Distribution Transformer:

kVArerror =kVArset – kVArsensed = e(t)

B) Distribution Feeder Performance with Compensator:-

The SVC results of simulation of Distribution Feeder Performance with Compensator at 500 kVA Transformer is as shown in Table no. 6.2. Reactive power (VAr) is Compensated in Four Binary Sequential Steps. In this case as per the requirement of Reactive power (VAr) Capacitor banks out of Four TSC-Banks which is responsible to switch the capacitor bank that bank should be ON. Thyristor controlled Reactor is used to control he excessive capacitive reactive Power and maintain it at unity Power factor.

Table no. 6.2 Distribution Feeder Perfomance with Compensator at 500 kVA Transformer

Compensated Reactive power VAr In Binary Sequential Steps				Reduced Load Current Amp(A)	Receiving End Voltage (V)	Power Factor	TCR Value In kVAr	Real Power (kW)	Reactive Power (kVAr)	Apparent Power (kVA)
TSC-4 Q4=160 (kVAr)	TSC-3 Q3=80 (kVAr)	TSC-2 Q2=40 (kVAr)	TSC-1 Q1=20 (kVAr)							
OFF	OFF	ON	ON	106.8	439.3	0.80	0.0	76.52	8.08	76.94
OFF	ON	ON	OFF	179.1	437.4	0.82	6.9	131.6	14.55	132.5
ON	OFF	OFF	OFF	228.7	438.3	0.86	2.7	168.2	8.13	168.4
ON	OFF	OFF	ON	247.1	436.6	0.90	0.0	182.1	16.52	182.8
ON	OFF	ON	ON	273.8	436.3	0.96	13.1	203	15.58	203.5
ON	ON	OFF	OFF	296.4	437.7	0.99	6.1	220.2	20.09	221.11

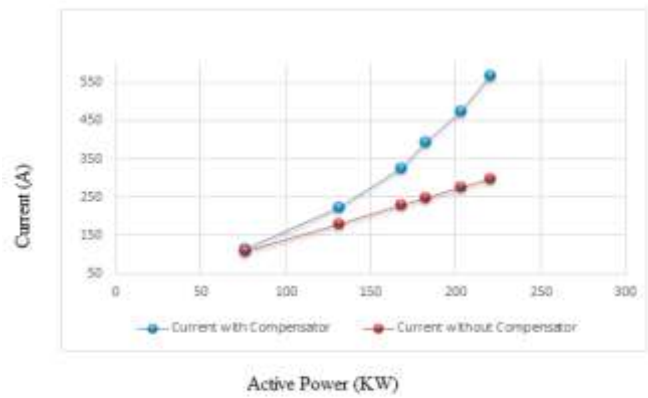

Figure 6.4 Load Current with and without SVC Compensation

Figure 6.4 shows Load Current with and without SVC Compensation of Three phase Distribution Feeder Performance at 500 kVA Transformer.

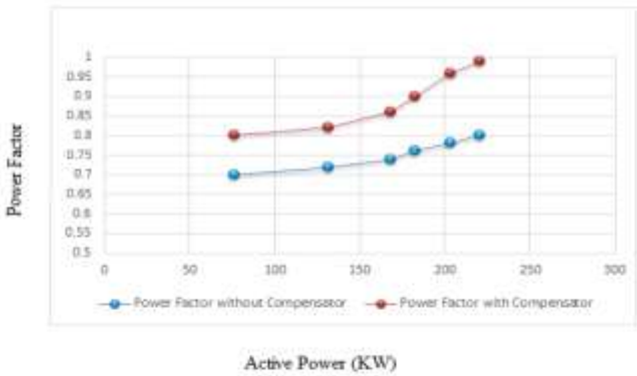

Figure6.5 Load Power Factor with and without SVC Compensation

Figure 6.5 Load Power Factor with and without SVC Compensation of Three phase Distribution Feeder Performance at 500 kVA Transformer.

DEVELOPMENT OF HARDWARE CIRCUIT MODEL OF SVC

A) Three phase hardware system:-

The Figure 2 shows block diagram of three phase hardware system in which the three phase supply of 440V, 50Hz is given to three phase, 50 Hz, 10A, 6.9 KVA distribution transformer which further give supply to 3 stages TSC‟s bank and R-L load up to 10A. The switch on and switch off operation of TSC‟s bank are controlled with the help of AVR 8-bit microcontroller and 89c51 microcontroller but Mmicro-controller system is programming at low dc voltage signal up to 5V. Hence the convert the 230V ac signal to 5V dc signal the CT, PT, ZCD and Signal conditioning blocks are provided.

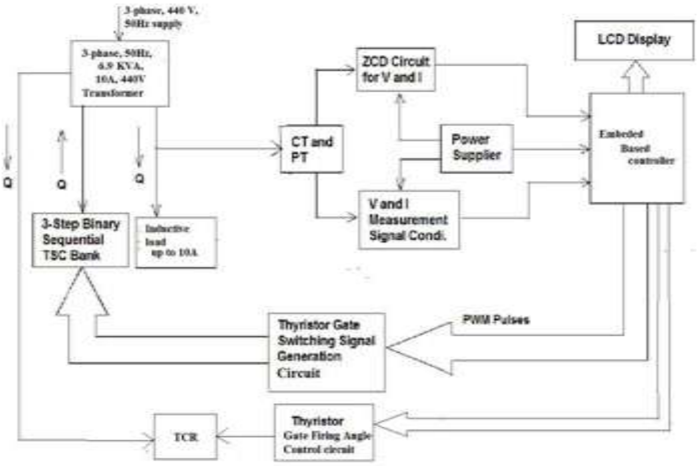

Figure3:- Proposed Block Diagram of three Phase Hardware System

B) Circuit Diagram of Three Phase Hardware System:-

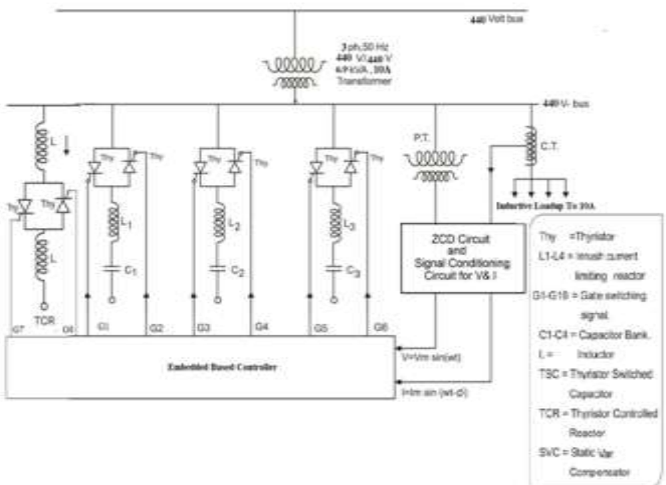

Figure 4: Proposed Circuit Diagram of three Phase Hardware System

The Figure 3 shows the circuit diagram of TSC-TCR type SVC at 6.9 kVA distribution transformer of prototype proposed 3-phase model in which important elements as like Transformer, CT, PT, Thyristor, Capacitors, Resistive and Inductive Load Banks, TCR, Microcontrollers and Inductor with six coils are connected in proper manner.

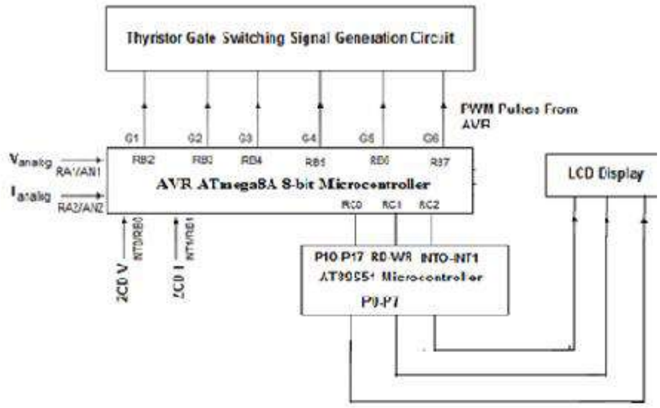

Figure5:- Block Diagram of AVR 8-bit Microcontroller & 89C51 Microcontroller Operation

V. CONCLUSION

After the observation from Table No.4, it is to be clear that

- The receiving end voltage gets improved.
- The load current gets decreased.
- Less reactive power consumed by load as shown in Figure 10.
- Active power consumed by the load tends to bring the power factor to unity. Because of the above results the efficiency gets improved.
- The relief in maximum demand and effective utilization of transformer capacity are achieved.
- The monthly bill saved on account of unity power factor, and results in reasonable demand charges.The conservation of the electrical energy achieved.

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