

IMPLEMENTATION OF DIGITAL STATIC VAR COMPENSATOR (SVC) WITH THYRISTOR BINARY COMPENSATOR AT 2 KVA TRANSFORMER

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Abstract— Electrical distribution systems are incurring large losses as the loads are wide spread, inadequate reactive power compensation facilities and their improper control. In solution the experimental studies of static VAR compensator (SVC) with thyristor binary compensator is carried out. The work deals with the performance evaluation through analytical studies and implementation of hardware circuit model of SVC at single phase, 50Hz, 2kVA transformer. The SVC consisting of thyristor switched capacitor bank in binary sequential steps. This compensation technique facilitates control on the reactive power depending on load requirement so as maintain power factor near unity always, which results in efficient electrical power system.

Keywords-- reactive power, static VAR compensator, thyristor binary compensator, capacitor bank, binary sequential steps, hardware circuit model, power factor, electrical power system.

I. INTRODUCTION

SVC is an electrical device for providing fast-acting reactive power on high-voltage electricity transmission networks. SVCs are part of the Flexible AC transmission system device family [1], regulating voltage and stabilizing the system. Unlike a synchronous condenser which is a rotating electrical machine, a static VAR compensator has no significant moving parts (other than internal switchgear). Prior to the invention of the SVC, power factor compensation was the preserve of large rotating machines such as synchronous condensers or switched capacitor banks. The SVC is an automated impedance matching device, designed to bring the system closer to unity power factor. SVCs are used in two main situations [2]:

- Connected to the power system, to regulate the transmission voltage ("Transmission SVC").
- Connected near large industrial loads, to improve power quality ("Industrial SVC").

In transmission applications, the SVC is used to regulate the grid voltage [3]. If the power system's reactive load is capacitive (leading), the SVC will use thyristor controlled reactors to consume VARs from the system, lowering the system voltage. Under inductive (lagging) conditions, the capacitor banks are automatically switched in, thus providing a higher system voltage. By connecting the thyristor-controlled reactor, which is continuously variable, along with a capacitor bank step, the net result is continuously-variable leading or lagging power. In industrial applications, SVCs are typically placed near high and rapidly varying loads, such as arc furnaces, where they can smooth flicker voltage [4].

A) Power Quality Problems Definition:-

Power distribution systems, ideally, should provide their customers with an uninterrupted flow of energy at smooth sinusoidal voltage at the contracted magnitude level and frequency however, in practice, power systems, especially the distribution system, have numerous nonlinear loads, which significantly affect the quality of power supplies [5]. As a result of the nonlinear loads, the purity of the waveform of supplies is lost. This ends up producing many power quality problems. While power disturbances occur on all electrical systems, the sensitivity of today's sophisticated electronic devices makes them more susceptible to the quality of power supply. For some sensitive devices, a momentary disturbance can cause This work is supported by institute Arvind Gavali College of Engineering, Satara, India under R & D activity for the award of Post Graduate Degree of Sameer U. Bagwan under the guidance of Dr. Anwar M. Mulla. scrambled data, interrupted communications, a frozen mouse, system crashes and equipment failure etc. A power voltage spike can damage valuable components. Power Quality problems encompass a wide range of disturbances such as voltage sags/swells, flicker, harmonics distortion, impulse transient, and interruptions [7][8].

- Voltage dip: A voltage dip is used to refer to short-term reduction in voltage of less than half a second.
- Voltage sag: Voltage sags can occur at any instant of time, with amplitudes ranging from 10 – 90% and a duration lasting for half a cycle to one minute.
- Voltage swell: Voltage swell is defined as an increase in rms voltage or current at the power frequency for durations from 0.5 cycles to 1 min.
- Voltage 'spikes', 'impulses' or 'surges': These are terms used to describe abrupt, very brief increases in voltage value.

- Voltage transients: They are temporary, undesirable voltages that appear on the power supply line. Transients are high over-voltage disturbances (up to 20KV) that last for a very short time.
- Harmonics: The fundamental frequency of the AC electric power distribution system is 50 Hz. A harmonic frequency is any sinusoidal frequency, which is a multiple of the fundamental frequency. Harmonic frequencies can be even or odd multiples of the sinusoidal fundamental frequency.
- Flickers: Visual irritation and introduction of many harmonic components in the supply power and their associated ill effects.

B) SVC With Binary Sequential Switched Capacitors:-

In the proposed paper capacitor bank step values are chosen in binary sequence weights to make the resolution small. An analysis of switching transients indicates that transient free switching can occur if the following two conditions are met [9].

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

The first condition can be met accurately by timing the control circuitry and the second condition is only met immediately after switching off thyristor. The configuration for five capacitor bank steps in binary sequence weight with thyristors switch is shown in Fig.1.

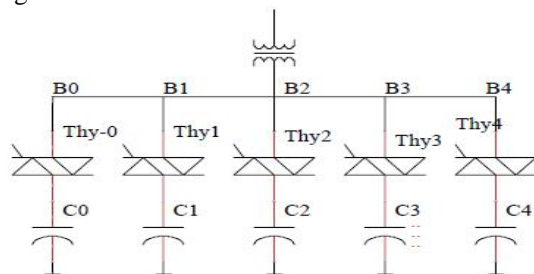


Fig. 1:-Thyristor Binary Compensation (TBC)

At the distribution transformer requiring total reactive power Q for improving the power factor from some initial value Pf1 to the desired value Pf2 at the load. This Q can be arranged in binary sequential 'n' steps, satisfying the following equation [6];

$$Q = 2^n C + 2^{n-1} C + \dots + 2^2 C + 2^1 C + 2^0 C$$

II. DEVELOPMENT OF HARDWARE CIRCUIT MODEL OF SVC

Single Phase Hardware System:-

The Fig.2 shows block diagram of single phase hardware system in which the single phase supply of 230V, 50Hz is given to 3 stages TSC's bank and R-L load up to 2 kW. The switch on and switch off operation of TSC's bank are controlled through

PIC18F458 microcontroller but microcontroller system is operating 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.

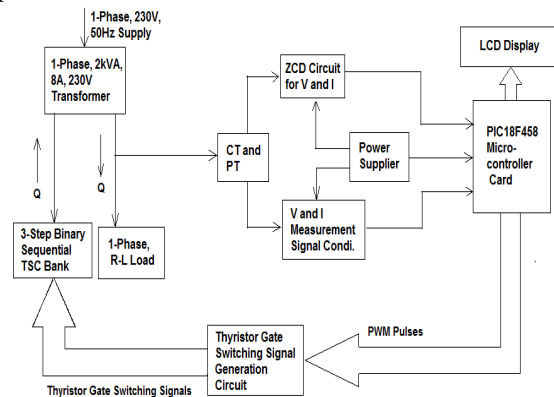


Fig.2:- Proposed Block Diagram of Single Phase Hardware System

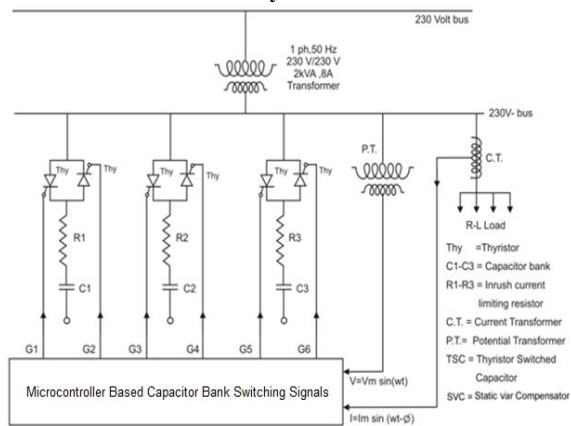


Fig.3:- Proposed Circuit Diagram of Single Phase Hardware System

PIC controller performs following steps;

- Detect rising edge of V and start timer 0.
- Detect rising edge of I and stop timer 0.
- Calculate $\Delta t = T_{start} - T_{stop}$
- If $\Delta t \leq 90$ then
 - Convert Δt into degrees and store it.
 - Store positive sign.
- If $\Delta t > 90$ then
 - Calculate
 - $\Delta t_a = T_{360degrees} - \Delta t$
 - Convert Δt_a into degrees and store.
 - Store negative sign.
- Process V sample.
- Process I sample.
- Process Φ sample.
- The PIC controller process each and every samples of V, I and Φ ; accordingly it display the value of V, I, phase angle (Φ), power factor ($\cos\Phi$), $\sin\Phi$, active power ($VI\cos\Phi$), reactive power ($VI\sin\Phi$).
- After reading the each sample of reactive power, PIC controller takes the further control action as per following instructions;

- If the reactive power varies between (0-300VAr) then TSC1 must be turn on that means PIC sends PWM pulses G1 and G2.
- If the reactive power varies between (301-600VAr) then TSC2 must be turn on that means PIC sends PWM pulses G3 and G4.
- If the reactive power varies between (601-1500VAr) then TSC3 must be turn on that means PIC sends PWM pulses G5 and G6.



Fig.4:- Actual Hardware Circuit Model of SVC

RESULTS OF HARDWARE CIRCUIT MODEL OF SVC

Sr.No.	Load Current (A)	Receiving End Voltage (V)	Power Factor	Real Power (W)	Reactive Power (VAr)	Apparent Power (VA)
1	1.52	228	0.94	325.76	118.23	346.55
2	1.82	226	0.79	324.94	252.18	411.31
3	2.35	225	0.65	343.68	401.81	528.74
4	3.05	224	0.55	375.76	570.58	683.20
5	3.82	223	0.45	383.33	760.73	851.85
6	4.55	222	0.40	404.04	925.77	1010.10

Table No.1:- 2 kVA Transformer Performance without Compensator

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After the observation it is to be clear that

- The receiving end voltage gets decreased.
- The load current gets increased.
- More reactive power consumed by load.
- Poor active power consumed by the load tends to poor power factor.
- Because of the above results the efficiency gets decreased.
- Ineffective utilization of transformer capacity.
- The monthly bill increased on account of poor power factor, and results in maximum demand charges.

Sr.No.	Compensated Reactive Power VAr in Binary Sequential Steps			Reduced Load Current Amp(A)	Receiving End Voltage (V)	Power Factor	Inrush Current Limiting Resistor Ω (100 Ω/5A)	Voltage Across Capacitor Bank (V)	Increased Load Current Capability Amp (A)	Relief in (VA)
	TSC-3 Q1=1330 (VAr)	TSC-2 Q2=665 (VAr)	TSC-1 Q1=332 (VAr)							
1	OFF	OFF	ON	1.45	229	Unity	32.18	156	0.07	16.10
2	OFF	OFF	ON	1.80	227	Unity	18.70	187	0.02	4.60
3	OFF	ON	OFF	2.32	226	Unity	12.61	201	0.03	6.90
4	ON	OFF	OFF	3.91	225	Unity	22.61	178	0.14	32.20
5	ON	OFF	OFF	3.71	225	Unity	17.40	190	0.11	25.30
6	ON	OFF	OFF	4.40	224	Unity	8.70	210	0.13	34.30

Table No.2:- kVAr Compensation In Binary Sequential Steps with SVC For The Cases Referred In Table Above

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CONCLUSION

After the observation 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 Fig.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.

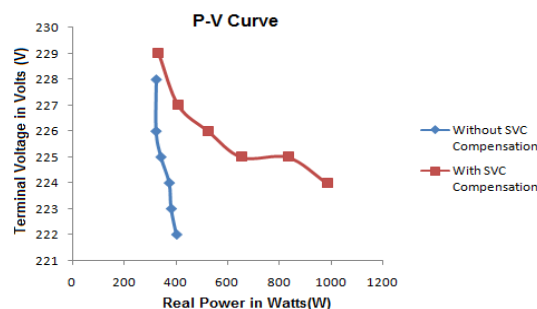


Fig.10:- P-V Curve with and without SVC Compensation

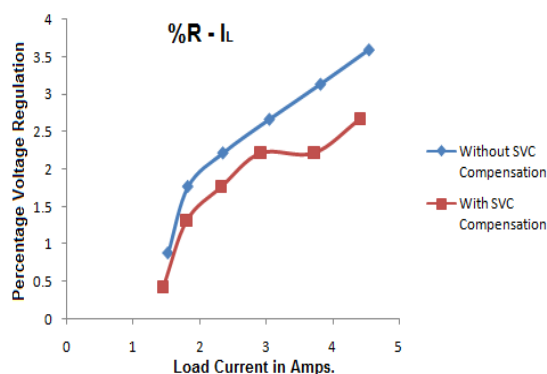


Fig.11:- % Voltage Regulation- I_L with and without SVC Compensation

FUTURE SCOPE

The variable shunt compensation using SVC can be extended to the large rating machines and Large Interconnected Power Systems. The SVC can also be fabricated by using IGBT's and testing can also be performed using DSP. TSC-TCR based SVC can also be implemented for SMSL Test System.

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