PERFORMANCE INVESTIGATION OF STATIC VAR COMPENSATOR (SVC) WITH THYRISTOR BINARY COMPENSATOR AT 500 KVA DISTRIBUTION TRANSFORMER

SAMEER U. BAGWAN, ANWAR M. MULLA, U. GUDARU

Abstract—The electrical distribution systems are consists of large losses as the loads are wide spread, less effective reactive power compensation facilities and their improper control which results in ineffective utilization of electrical energy. In solution of that the investigation is carried on static VAR compensator (SVC) with thyristor binary compensator. The work deals with the analytical studies and implementation of simulation model of static VAR compensator (SVC) at 3Φ, 50Hz, 11kV/440V, DY-11, 500 kVA distribution transformer. The SVC consisting of thyristor switched capacitor bank in binary sequential steps in conjunction with smallest step size thyristor controlled reactor. 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, thyristor switched capacitor, thyristor controlled reactor, 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 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.

a) The thyristor is fired at the negative/positive peak of voltage, and/or
b) 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.

At the distribution transformer requiring total reactive power \( Q \) for improving the power factor from some initial value \( P_1 \) to the desired value \( P_2 \) at the load. This \( Q \) can be arranged in binary sequential ‘n’ steps, satisfying the following equation [6]: This work is supported by company Vsoft Embedded Technology, Pune, India under R & D activity for the award of Post Graduate Degree of Sameer U. Bagwan under the guidance of Dr. Anwar M. Mulla.

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Q = 2^{n-1}C + 2^{n-2}C + \ldots + 2^2C + 2^1C + 2^0C
\]

II. DEVELOPMENT OF SIMULATION MODEL

The SVC system consists of 4 binary sequential TSC’s bank and TCR as shown in Fig.2. Here, measurement and control block is provided in which measurement block continuously measures system parameters while in control block logic is provided for controlling system parameters by turning on and turning off TSC’s and TCR of SVC model through gate terminal switching as shown in Fig.3. The TSC’s are designed in binary sequential steps as,

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>TSC’s No.</th>
<th>TSC’s rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>TSC-1</td>
<td>20 kVAR</td>
</tr>
<tr>
<td>2</td>
<td>TSC-2</td>
<td>40 kVAR</td>
</tr>
<tr>
<td>3</td>
<td>TSC-3</td>
<td>80 kVAR</td>
</tr>
<tr>
<td>4</td>
<td>TSC-4</td>
<td>160 kVAR</td>
</tr>
</tbody>
</table>

Table No.1: Power rating of TSC’s bank used in compensated simulation model and TCR is provided with rating of 75 kVAR.

Fig.4:- Circuit Diagram of TSC-TCR type SVC
The Fig.4 shows the circuit diagram of TSC-TCR type SVC in which the TSC’s and TCR are arranged in delta connection. In TSC’s connection an inductor is provided in series for limiting inrush current. The sequence of TSC designing is firstly three capacitors are connected in delta followed by inrush current limiting reactor connected in series with each phase which is followed by anti-parallel thyristors connected in series for switching on and switching off the capacitor bank after getting gate switching signals from control block, in short anti-parallel thyristors are playing the role of switch. While in case of TCR anti-parallel thyristors are connected in series with each inductor forms a branch consists of inductor in series with anti-parallel thyristors similarly other two branches are formed and then connected in delta.

The Fig.11 shows the complete simulation model for TSC-TCR type SVC at 500 kVA distribution transformer. This model consists of three phase source energizes transformer which forms 440V bus at secondary side. The three phase R-L load, SVC system consisting of four binary sequential tages of TSC’s and single TCR are connected to 440V bus. Measurement and control block is provided for continuous monitoring of circuit parameters of and to take further control action to maintain the system efficient.

RESULTS OF SIMULATION MODEL OF SVC

<table>
<thead>
<tr>
<th>Sl.No</th>
<th>Load Current (A)</th>
<th>Receiving End Voltage (V)</th>
<th>Power Factor</th>
<th>Real Power (%</th>
<th>Reactive Power (%)</th>
<th>Apparent Power (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>214.3</td>
<td>450.4</td>
<td>0.78</td>
<td>98.7</td>
<td>96.0</td>
<td>852</td>
</tr>
<tr>
<td>2</td>
<td>231.6</td>
<td>421.7</td>
<td>0.72</td>
<td>117.2</td>
<td>113.3</td>
<td>96.2</td>
</tr>
<tr>
<td>3</td>
<td>208.6</td>
<td>412.7</td>
<td>0.74</td>
<td>127.9</td>
<td>123.3</td>
<td>95.3</td>
</tr>
<tr>
<td>4</td>
<td>282.3</td>
<td>408.1</td>
<td>0.76</td>
<td>136.1</td>
<td>131.8</td>
<td>97.3</td>
</tr>
<tr>
<td>5</td>
<td>473.5</td>
<td>403.6</td>
<td>0.78</td>
<td>281.1</td>
<td>286.9</td>
<td>307.3</td>
</tr>
<tr>
<td>6</td>
<td>586.1</td>
<td>397.4</td>
<td>0.80</td>
<td>321.6</td>
<td>326.0</td>
<td>396.4</td>
</tr>
</tbody>
</table>

Table No.3: Distribution Feeds Performance without Compensator at 500 kVA Transformer

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.

CONCLUSION

After the observation it is to be clear that
- The receiving end voltage gets improved.
- The load current gets decreased as shown in Fig.12.
- Less reactive power consumed by load as shown in Fig.13.
- 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.
FUTURE SCOPE

The hardware circuit implementation of static VAR compensator (SVC) at 500 kVA distribution transformer of ADCET, Ashta is being planned in future. So before going for it, for realization of SVC performance the systematic experimental studies and investigation of static VAR compensator (SVC) with thyristor binary compensator is carried out. 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.

REFERENCES


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