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Design of a Low Cost Microprocessor-aided Voltage Stabilizer by using SVS (Static Var System)

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Abstract— *In power transmission line voltage fluctuation is a very common problem. When the voltage at the receiving end is either high or low but not equal to the expected value then it is called voltage fluctuation. Voltage fluctuation creates various types of problems at the receiving end side. For example if the voltage becomes too high it may damage the electrical machines and devices connected with the system or if the voltages goes down too low then the electrical machines and devices cannot run properly. To eliminate this voltage fluctuation problem we have to make arrangements so that voltage maintains a stable value. Voltage stabilizer can be used to handle the voltage fluctuation problem. This paper will discuss about the design of a low cost microprocessor-aided voltage stabilizer which can maintain the voltage at a prescribe value. Here, in this voltage stabilizer we can set the value of the voltage as per our requirement around which we need to maintain the system voltage.*

Keywords— *Voltage stabilizer, SVS (Static Var System), Thyristor controlled reactor (TCR), Thyristor switched capacitor (TSC).*

I. INTRODUCTION

In power system voltage control and reactive power control are interrelated. There are different kinds of loads are connected in a power system. Some loads absorb reactive power and some generates it. Any mismatch in the reactive power balance affects the bus voltage magnitudes. So, in order to maintain the voltages at their prescribed values at all times, it is necessary to maintain the balance of reactive power in the system. In other words, the reactive power generation should be exactly equal to the reactive power consumed (absorbed). This paper will discuss the design of a low cost voltage stabilizer. Here we use SVS (Static Var System) for absorption or generation of reactive power. The thyristors of the SVS are triggered as per the nature of requirement of the reactive power to the system. Here by absorbing or generating the reactive power we can control the voltage of the system.

II. RELATION BETWEEN VOLTAGE AND REACTIVE POWER

Let a transmission line shown in the figure 1 below

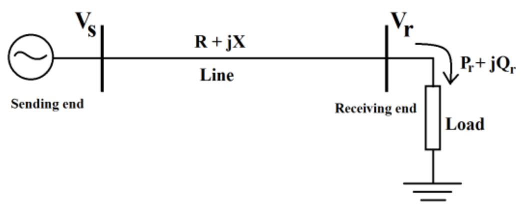

Fig. 1. Single line diagram of a transmission line.

For a transmission line, the magnitude of voltage drop in the line is,

$$|\triangle V| = |V_s| - |V_r| \quad (1)$$

Where, $\triangle V$ = voltage drop, V_s = sending end voltage, V_r = receiving end voltage.

We can also represent $|\triangle V|$ as follows,

$$|\triangle V| = I R \cos\Phi_r + I X \sin\Phi_r$$
$$= [(V_r I \cos\Phi_r)R + (V_r I\sin\Phi_r)X] / V_r$$
$$= (RP_r + XQ_r) / V_r \quad (2)$$

Where, I = transmission current, R = line resistance, X = line impedance, P_r = active power at receiving end, Q_r = reactive power at receiving end, Φ_r = angle between V_r and I at receiving end.

For a transmission line X >> R and R is negligibly small.

Therefore, $|\triangle V| = XQ_r / V_r$

or, $Q_r = (X/V_r)*|\triangle V|$ (3)

So, Q_r (reactive power) is proportional to the magnitude of the voltage drop $|\triangle V|$ in the line.

A. *Why voltage is fluctuating?*

An overexcited synchronous machine (generator or motor) produces reactive power and acts as a shunt capacitor. Similarly, an underexcited synchronous machine consumes reactive power and acts as a shunt inductor. Lightly loaded transmission line or lines under no-load conditions supply reactive power because of their shunt capacitance. When the lines are fully loaded, they operate beyond their 'natural load' and absorb reactive power. Underground cables supply reactive power under all conditions of loading. Transformers absorb low reactive power under no-load conditions. When the transformers are fully loaded, they absorb high values reactive power. Due to these absorptions or generations of reactive power voltage is fluctuating.

B. *How can we control the voltage?*

In order to maintain the voltages at their prescribed values at all times, it is necessary to maintain the balance of reactive power in the system. In other words, the reactive power generation or absorption should be exactly equal to the reactive power consumed or produced respectively in order to maintain the system voltage at a stable value. The following methods are used for voltage control in a power system:

1) Tap-changing transformers
2) Shunt reactors
3) Synchronous phase modifiers
4) Shunt capacitors
5) Series capacitors
6) Static VAR system (SVS) etc.

Among all these methods, now-a-days Static VAR System (SVS) becomes superior because first of all it is a static device

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so here operational losses are very small and also SVS is a thyristors-aided device which enables it for fast-switching operation. Static VAR Systems (SVS) offer the following advantages:

a) The power transfer capability of the lines is increased.
b) Transient stability of the system is improved.
c) The dynamic system stability is also improved due to increase damping provided.
d) It is possible to damp sub-synchronous resonance frequency oscillations.
e) Steady-state and temporary over-voltages can be controlled.
f) Load power factor is improved. Consequently, line losses are reduced and the system efficiency is improved.
g) The dynamic response of SVS is very fast.
h) Their maintenance is very easy.

III. Static Var System (SVS)

In static var system (SVS) thyristors are used as switching devices. Thyristor switching is faster than mechanical switching and also it is possible to have transient-free operation by controlling the instant of switching. The advent of high-speed high-current switching made possible by thyristors has introduced a new concept is providing reactive compensation for optimum Extra-High voltage (EHV) or Ultra-High voltage (UHV) system performance. The static var compensators (SVC) use shunt reactor and shunt capacitor combinations with high-voltage, high-current thyristor control for obtaining fast and accurate control of reactive power flow. The static var compensator (SVC) is also known as static var system (SVS). The first use of static var compensators in EHV/UHV transmission started in 1960s and was based on saturated reactors. The first thyristor switched compensators were installed in late 1070s. Since that time the use of SVS has become very popular to replace synchronous compensation (using synchronous phase modifiers). In modern time many SVS schemes are in operation, some of the commonly used schemes are as follows:

1) Thyristor controlled reactor (TCR)
2) Thyristor switched capacitor (TSC)
3) Fixed capacitor (FC), thyristor controlled reactor (TCR) scheme.
4) Thyristor controlled reactor (TCR), thyristor switched capacitor (TSC) scheme.

Here, we use thyristor controlled reactor (TCR), thyristor switched capacitor (TSC) scheme for controlling voltage fluctuation.

A. *Thyristor controlled reactor (TCR), thyristor switched capacitor (TSC) scheme:*

A parallel combination of a single-phase thyristor controlled reactor X and a single-phase thyristor switched capacitor C is shown in the figure 2 below.

The currents through the reactor (X) and capacitor (C) can be varied by controlling the firing angles of back to back thyristors connected in series with the reactor (X) and capacitor (C) respectively. The thyristor switched capacitor (TSC) scheme is used in EHV lines for providing leading vars during high loads and thyristor controlled reactor (TCR) scheme is used for providing lagging vars during low loads and load rejections. We can also design TCR-TSC scheme for a three-phase transmission line system in either star or delta connection as per our requirement. A three-phase star connected TCR-TSC scheme is shown in the figure 3 below.

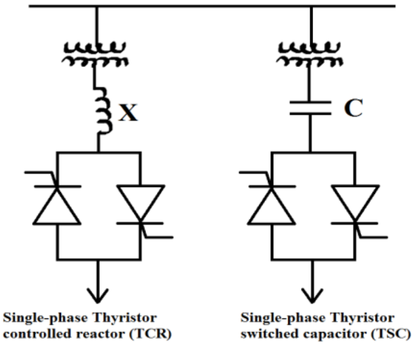

Fig. 2. Thyristor controlled reactor (TCR), thyristor switched capacitor (TSC) scheme.

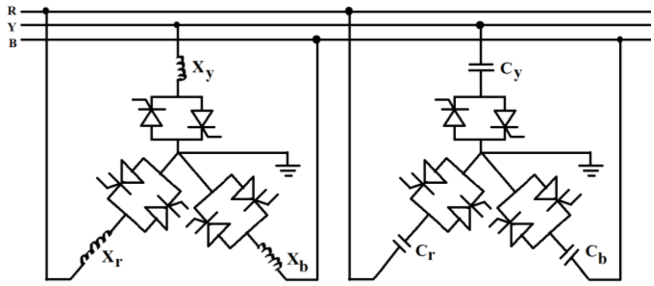

Fig. 3. Three-phase star connected TCR-TSC scheme.

After that the real challenge is triggering the thyristors properly according to the voltage situation of the system. Here we can use microprocessor for proper control of triggering of the thyristors.

B. *How does this system work?*

In this system we set a suitable value of the voltage which we wish to maintain. And we also set a tolerance value (say ϵ) in such a way that the voltage variation (ΔV) should be within this value. So, $-\epsilon < \Delta V < \epsilon$.

A schematic diagram of microprocessor-aided triggering control arrangement for thyristors of TCR-TSC scheme shown in the figure 4 below.

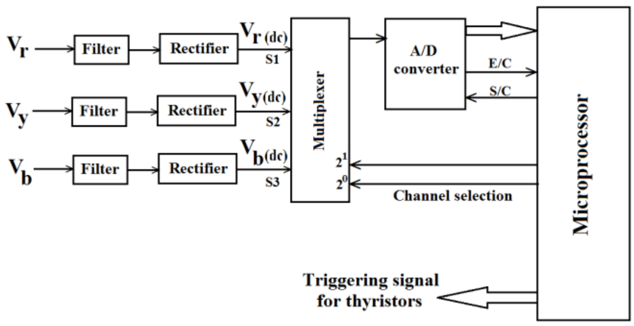

Fig. 4. A schematic diagram of the microprocessor-aided triggering control arrangement for thyristors of TCR-TSC scheme.

Here, instrumental-transformers generate proportional voltage of the each phase and then send them to the rectifier through filter shown in the above figure (Figure 4). The rectifier circuit converts these voltages into equivalent DC voltages. Then these DC voltages are send to the multiplexer. The multiplexer sent these DC voltages one by one to the analog-to-digital converter (ADC). The analog-to-digital converter (ADC) converts the analog voltage signals into digital signals and send these digital signals to the microprocessor. Then the microprocessor reads these signals and compares them with the value of sending end voltage (say V_s) which is pre-stored in the memory of the computer. But here the comparison is not absolute the microprocessor checks that whether the difference between the receiving end voltage (say V_r) and the sending end voltage (V_s) is within the tolerance value or not. The tolerance value (say ϵ) is also pre-stored in the computer memory. If the voltage difference ($\triangle V$) is not within the tolerance value (ϵ) then the microprocessor checks the nature of this difference either positive or negative. If the difference is positive and higher than tolerance value then the system voltage at receiving end is much higher than the expected value, it means that the receiving end needs lagging var and the thyristor controlled reactor (TCR) can provide lagging var which is already explained earlier.

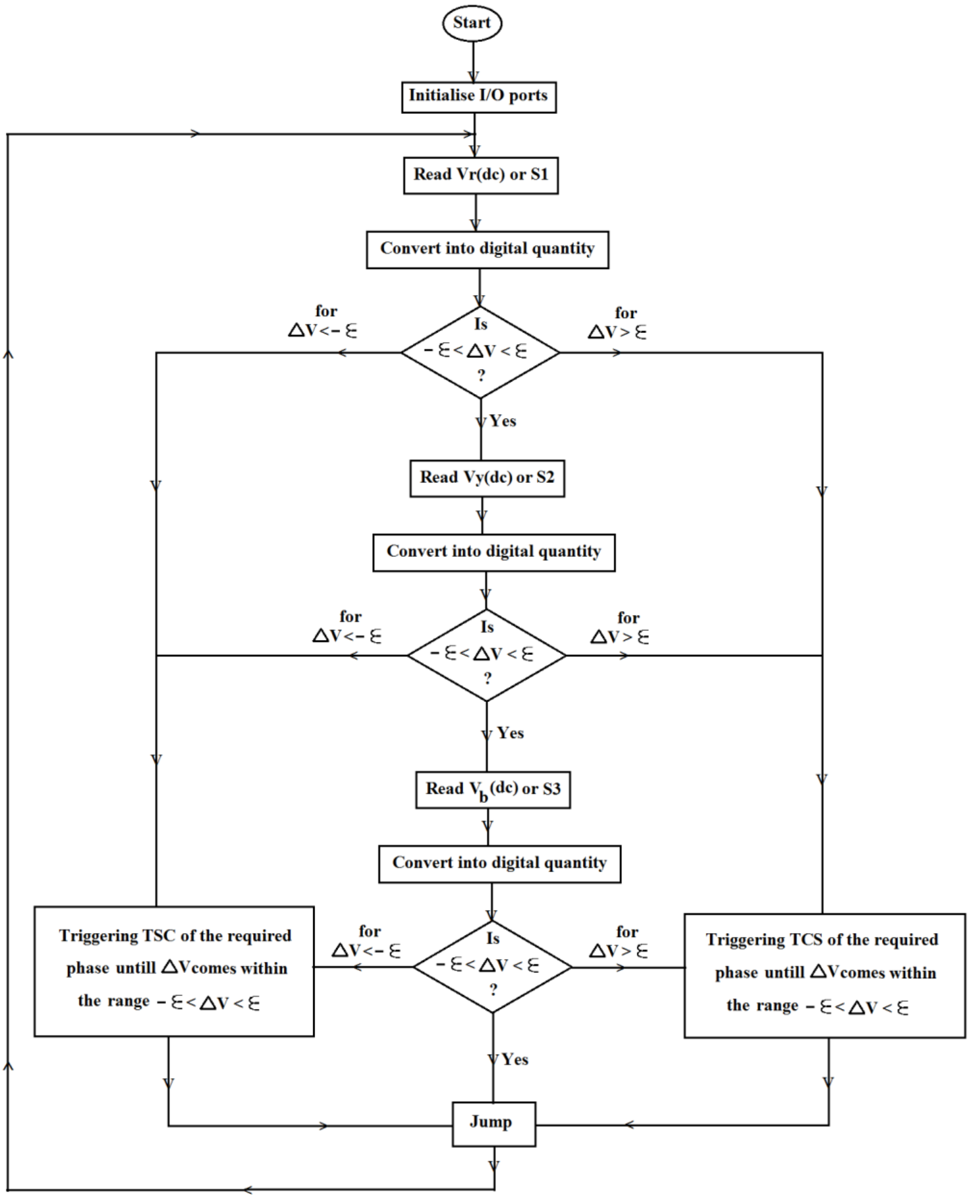

Fig. 5. Flow-chart of the microprocessor-aided voltage stabilizer.

In this case microprocessor generates triggering signals for the back to back thyristors of TCR and triggering thyristors of TCR until the voltage difference ($\triangle V$) comes within the tolerance limit (ϵ). If the difference is negative and lower than the magnitude of tolerance value (ε) then the system voltage at receiving end is much lower than the expected value, it means that the receiving end is heavily loaded and needs leading var and the thyristor switched capacitor (TSC) can provide leading var which is already explained earlier. In this case microprocessor generates triggering signals for the back to back thyristors of TSC and triggering thyristors of TSC until the voltage difference (ΔV) come within the tolerance limit (ε). One more thing here the microprocessor measure the voltage difference and according to which it produces triggering signal with appropriate firing angle. Here, the control of firing angle is very important because depending upon the firing angle the TCR-TSC system generates or absorbs the required reactive power. We can also explain the whole working procedure of this microprocessor-aided voltage stabilizer through the flow-chart shown in the figure 5 below.

IV. Conclusion

So, here we developed the design of a microprocessor aided voltage stabilizer by using Static Var System (SVS). The cost is very low and the voltage stabilizer is suitable for different types of transmission line systems because there is no need to change the reactor (X) and the capacitor (C) or any other part of the system, the only thing which we need to do is to set the reference value of the voltage which we want to maintain and the tolerance value (ε) as per our requirement. The SVS is a static device so here the operational losses are very small as compare to the other conventional methods of voltage control. Moreover, due to the use of thyristors here the switching is very fast and the maintenance is easy. Thus, with this stabilizer we can handle the fast fluctuating voltage easily.

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BIOGRAPHY

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