DESIGN OF VAR COMPENSATION FOR PANNIPITIYA GRID SUB STATION

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Abstract

Reactive Power (var) Planning is the determination of the sizes and locations of shunt var sources (capacitors, reactors, static var systems, synchronous condensers) and their efficient coordination with existing var sources. They improve system properties such as steady-state and dynamic stability, voltage profile, reactive power flow and fault situations (over voltage, load rejections etc.) due to rapid response to voltage deviation. In this project, the data of the Pannipitiya Grid Sub Station and the surrounding bus bars were analysed and the amount of compensation required was found. A suitable compensation method was also selected considering this amount.

1. Introduction

Reactive power compensation has been recognised as a significant factor in the alternating current electric power systems. Since the impedances of the network components are predominantly reactive, and the loads to cater are also somewhat reactive, transmission of active power requires a difference in angular phase between the voltages at the sending and the receiving points. This angular phase difference can be reduced by compensation. That is, by the supply or absorption of an appropriately variable quantity of reactive power. Quality of supply depends on various factors and can be defined in numerical terms as the maximum fluctuation in rms supply voltage averaged over a stated period of time.

1.1 Pannipitiya Grid Sub-Station

Pannipitiya is a Grid Sub-Station in Sri Lanka, where both the incoming and the outgoing lines are at 132 kV. It has four incoming lines coming two each from Biyagama and Kolonnawa and four out going lines to Ratmalana and Panandura. It has three transformers, These three are used to transform 132 kV into 33kV for its 10 feeders.

1.2 Objectives

Reactive power compensation can be used to obtain the following objectives for the betterment of the power system:

Stabilisation of voltage in a weak system.
Reduction of Transmission losses.
Improvement of voltage control and dynamic stability.
Damping of power swings.
Accommodation of maximum demand of a transmission line.

2. Theoretical Background

2.1 Reactive Power

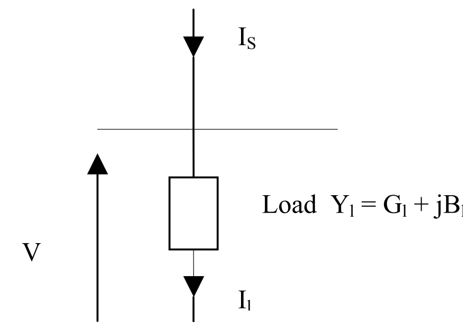

Figure 2.1

Figure 2.1 shows a load of admittance $Y_l = G_l + jB_l$ supplied from a voltage V. The load current I_l is,

$$
\begin{aligned}
I_l &= V\,(G_l + jB_l) \\
&= VG_l + jVB_l \\
&= I_R + jI_X
\end{aligned}
$$

This equation can be represented by figure 2.2 in which V is the reference phasor.

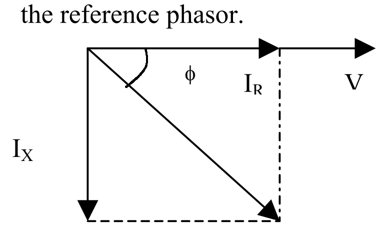

Figure 2.2

The apparent power supplied to the load is,

$$
\begin{aligned}
S &= VI_l^* \\
&= V^2G_l - j\,V^2B_l \\
&= P_l + jQ_l
\end{aligned}
$$

The apparent power thus has a real component P_l and a reactive component Q_l.

The current supplied by the power system is larger than is necessary to supply the active power alone, by the factor

$$I_l / I_R = 1 / \cos\phi$$

Here, $\cos\phi$ is the power factor.

The principle of power-factor correction is to compensate for the reactive power by providing locally a compensator having a purely reactive admittance $-jB_l$ connected in parallel with the load. The current supplied by the power system to the combined installation of load and compensator now becomes,

$$\begin{aligned} I_S &= I_l + I_C \\ &= V(G_l + jB_l) - V(jB_l) \\ &= VG_l \\ &= I_R \end{aligned}$$

which is in phase with V, making the overall power-factor unity. Figure 2.3 shows the phasor relationships.

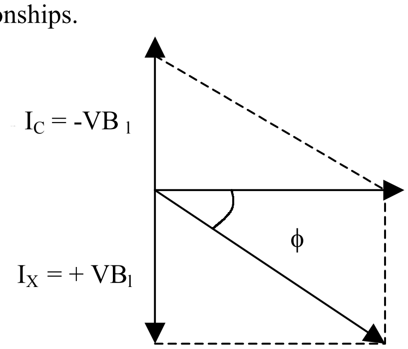

Figure 2.3

The supply current I_S now has the smallest value capable of supplying full power P_l at the voltage V, and all the reactive power required by the load is supplied locally by the compensator: thus the load is totally compensated.

2.2 Need for Compensation

A compensator can be a bank of capacitors (or inductors) that can be divided into parallel sections, each switched separately, so that discrete changes in the compensating reactive power may be made.

The need for adjustable reactive power compensation can be analysed in three different classes.

The need to maintain the stability of synchronous machines.

The need to control voltage within acceptable bounds about the desired steady-state value to provide quality service to consumer loads.

The need to regulate voltage profiles in the network to prevent unnecessary flows of reactive power on transmission lines.

2.3 Methods of Compensation

When a compensation system is used, it can have reactors and capacitors both according to the requirement. Instead of using capacitors individually we can have capacitors and small reactor in series which can be tuned to suppress some particular harmonics according to the total impedance of the path we have tuned. This helps to the system generators to run smoothly. If the amount of harmonics is large in supply current it is not allowed to the system generators to run smoothly.

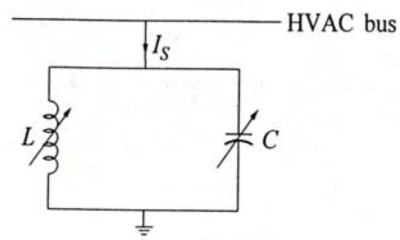

Figure 2.4 : Idealised Static var System

Method of Compensation	**Advantages**	**Disadvantages**
Synchronous Condensor	Has useful overload capability. Fully Controllable. Low Harmonics.	High maintenance requirement. Slow control response. Performance sensitive to location. Requires strong foundations.
Switched Shunt Reactors	Simple in principle and construction	Fixed in value
Series Capacitors	Simple in principle. Performance relatively insensitive to location .	Requires overvoltage protection and subharmonic filters. Limited overload capability.
Switched Shunt Capacitors	Simple in principle and construction	Fixed in value. Switching Transients.
Thyristor Controlled Reactor (TCR)	Fast response. Fully controllable. No effect on fault level. Can be rapidly repaired after failures.	Generates harmonics. Performance sensitive to location.

Thyristor Switched Capacitors (TSC)	Can be rapidly repaired after failures. No harmonics.	No inherent absorbing capability to limit overvoltages. Complex buswork and controls. Low frequency resonances with system Performance sensitive to Location
Mechanical-ly Switched Capacitors (MSC)	Cheaper. Can be easily repaired after failures.	Harmonics. Switching transients.

Table 2.1: Advantages and Disadvantages of different types of Compensators

2.4 Stability

The stability of an interconnected power system is the ability to maintain acceptable operating conditions under normal operations and after being subjected to a disturbance. Stability can be classified in two ways.

- Synchronous Stability and Voltage Stability
- Transient Stability and Small signal Stability

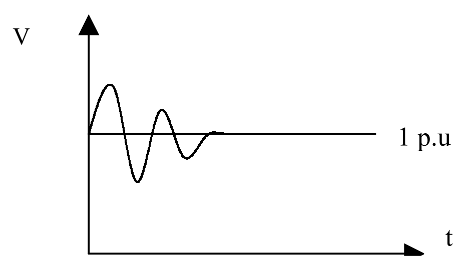

Figure 2.5 : Bus Voltage representation

Voltage Stability

Voltage stability is the ability of a power system to maintain steady-state acceptable voltages at all buses in the system under normal operating conditions and after being subjected to a disturbance. After a disturbance, if the voltage comes to 1 p.u (as shown in Figure 2.5), the system is said to be stable. If it diverges from that value, it is said to be unstable.

A system enters voltage instability when a disturbance causes a progressive and uncontrollable drop in voltages.

These disturbances may be due to,

increase in loading
line tripping/ faults
generator outages
generators or SVCs reaching reactive power limits
action of tap changing transformers
load recovery dynamics

3. Study Methodology

For our study, a network was taken with bus bars connected with the Pannipitiya Grid Sub Station. The amount of reactive power needed for this particular sub station was analysed. This wider network was reduced to have only 5 sub stations.

The study was done using a software called 'Power World Simulator'(PWS). This is a power system simulation package. It is an interactive and graphical software that can be used to explain power system operation.

All the required data were collected from the Systems Control Centre of the Ceylon Electricity Board. Data was collected from 00.00 hours to 24.00 hours on the 25th of September 2001 in steps of one hour.

The assumptions made during the analysis were as follows:

All the Transformers are at nominal tap position.

Incoming feeder lines, which we could not include, were taken as Generators connected to the appropriate Bus bars.

Kelanitissa Power Station was taken as the slack Bus bar.

4. Analysis and Conclusion

According to the data received, the following analysis was done using PWS.

The amount of reactive power that should be injected to the system at a particular time was obtained. To obtain this, the voltage at the 33 kV bus bar was kept as close as possible to 1 p.u.

According to the results obtained, it was seen that the Pannipitiya Grid Sub Station needs only leading reactive power. Therefore, it was decided to consider capacitor banks, which inject leading reactive power to the system.

Among the type of switching that were available it had to be either Thyristor Switched Capacitor (TSC) or Mechanically Switched Capacitors (MSC).

The rating of the capacitor banks also had to be carefully selected considering the cost and the operation of the type of compensator. Another aspect that had to be considered was the reliability to the power system.

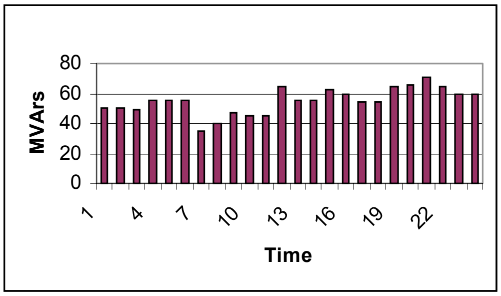

Figure 4.1: Graph of Reactive Power Vs Time

After the analysis of data, it was seen that the maximum requirement to the 33kV bus bar would be slightly higher than 70 Mvar to keep the bus bar voltage in the range of 0.99 to 1.01. Therefore, the capacitor bank with capacity would be of 75 Mvar.

The areas fed by Pannipitiya Grid Sub Station are mostly industrialised.

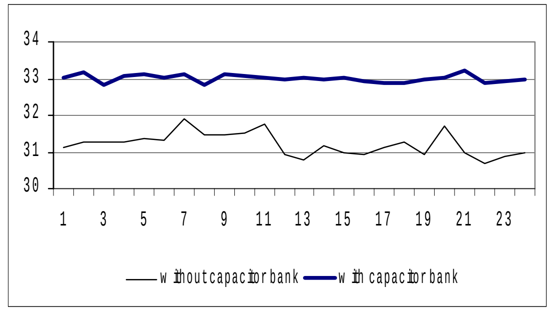

Figure 4.2: The 33 kV bus Voltage with and without Capacitor Bank

Thus, considering the annual growth rate of electricity demand, future loads are expected to grow largely. This will result in the need for more reactive power in near future. Therefore it is desirable to install 100 MVAr capacity capacitor bank when consider about the future loads to be fed.

5. Bibliography

T.J.E.Miller, "Reactive Power Control in Electric Systems".

P.Kundur, " Power System Stability and Control ".

" Optimal Power System var Planning", IEEE Transaction on Power Systems, Vol.5, No.1, Feb 1990.

" Power World Simulator" - Help Menu