Transient Overvoltages And Its Prevention And Protection

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ABSTRACT

Overvoltage causes hazardous effect in the power system. There are two main sources of transient overvoltages on utility side one is capacitor switching and another one is lightning. These are the sources of transient overvoltages as well as a countless of other switching phenomena in the distribution system .The overvoltage occur in power system due to lightning is very high when compared with transient due to power electronic devices under switching phenomenon. Over voltage protection should be provided to the power system, to avoid damages and uninterrupted power. This paper presents various causes and its prevention methods of transient overvoltages

Keywords: *Capacitor Switching, Ferroresonance, Lightning Transients, Preinsertion resistors ,Surge arrestors.*

Capacitor switching

Capacitors are used to provide reactive power to correct the power factor, which reduces losses and supports the voltage on the system. It is very economical and generally trouble-free means to accomplishing the goals. Disadvantage of capacitor switching is that they yield oscillatory transients. Some capacitors are switched all the time while others are switched according to reactive power consumption. Figure 1 shows the single-line diagram of a typical utility feeder capacitor-switching. When the switch is closed, a transient similar in Figure 2 may be observed at the monitor location.

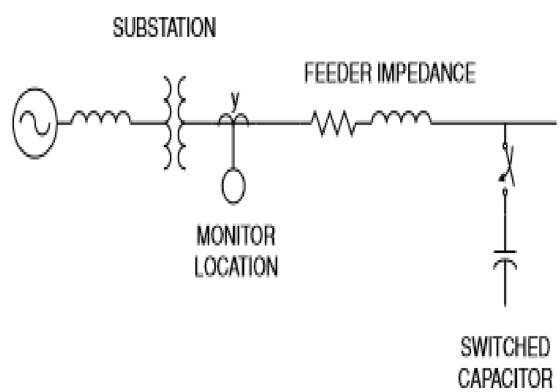

Figure 1 single line diagram of a capacitor-switching operation

.AC Drives and solid-state motor controllers are quite sensitive to voltage rises resulting from capacitor bank switching operations. When voltage of the system is rising beyond the maximum tolerance the motor will be shut down by AC drives. Capacitor switching causes the voltage oscillations and results in spikes in the waveform which leads to change in zero crossing of time axis. In order to have smooth operation and better performance of drives zero crossing is essential.

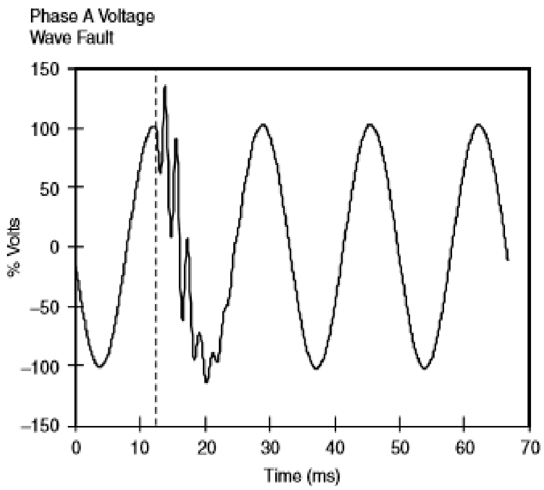

Figure 2 utility capacitor-switching transient reaching

Ferroresonance

Ferroresonance is a kind of resonance that occurs between capacitance and inductance. It normally occurs when the magnetizing impedance of a working transformer is positioned in series with a capacitor bank

Lightning overvoltage

Lightning is a electrical discharge between clouds or between clouds and earth surface. Inside the clouds there may have separate charge center. The damage and economic losses are caused by the destructive transients which is randomly injected by lightning's in the power system. These destructive natural forces are in the form of cloud-to-ground (CG) flashes and their subsequent return strokes. Globally, about 100 lightning flashes occur every second. Different regions of the world receive various levels of lightning activity and flash intensity.In Figure 3 shows the illustration of the time parameter of full standard lightning impulse

Table 1.

Typical characteristics of a lightning

Stroke diameter	1 cm
Subsequent return strokes	2-3
Peak current	5-300kA
Stroke voltage	Uptill 1 billion volts
Stroke temperature	50,000 °F
Nominal duration	20-50 microseconds
Polarity	Negative or positive

In a typical lightning impulse wave, there are two important parameters which are front time (t_f) and tail time (t_t). Front time is the time taken for the lightning impulse at 10% of its peak value to reach 90% of its peak value and tail time is the time taken for the lightning impulse to reach 50% of its peak value. A typical lightning impulse wave will have front time (t_f) of 1.2µs and tail time (t_t) of 50µs.

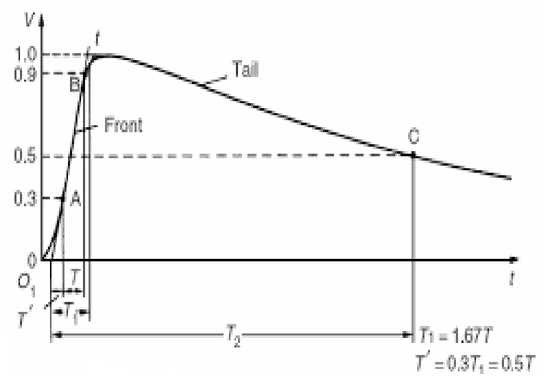

Figure 3 Illustration of the time parameters of a full standard Lightning Impulse

Prevention of Overvoltage Surges

Preinsertion resistors

Preinsertion resistors is used to reduce the capacitor-switching transient. The first peak of the transient is usually the most vulnerable. The plan is to insert a resistor into the circuit so that the first peak is damped significantly

Synchronous closing

For switching overvoltage surges, synchronous closing control can be used. The overvoltage surges can be prevented by switching the capacitor contact when the voltage of the system matches the capacitor voltage which is normal during the change of positive to negative cycle of the phase voltage. It avoids the sudden change in voltage when capacitor banks are switched on. The timing required for synchronous closing control is determined by forecasting the upcoming system voltage when it reaches zero. Due to the requirement of anticipating and forecasting, each of the switches requires microprocessor to process and provide the closing signal. Figure 4 shows the overvoltage switching surges waveform when the switches are not closed synchronously.

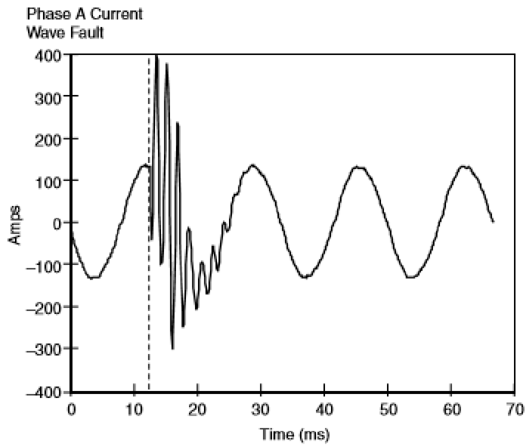

Figure 4 Overvoltage Surges without Synchronous Closing Control

Figure 5 shows the overvoltage switching surges waveform when the switches are closed synchronously. From the waveform we can able to interpret that when the switches are closed synchronously the surge value of the first peak will reduce drastically.

Figure 5 Overvoltage Surges with Synchronous Closing Control

In order to prevent the capacitor switching restrike, regular checking and maintenance should be carried out to make sure that contact should not be contaminated and insulation should not fail.

Shielding

The lightning strikes in the transmission line can be reduced by installing a grounded neutral wire over the phase wires. Figure 6 shows the shielding provided for the transmission line and for the substation. This method will reduce lightning strokes before they strike the phase wires

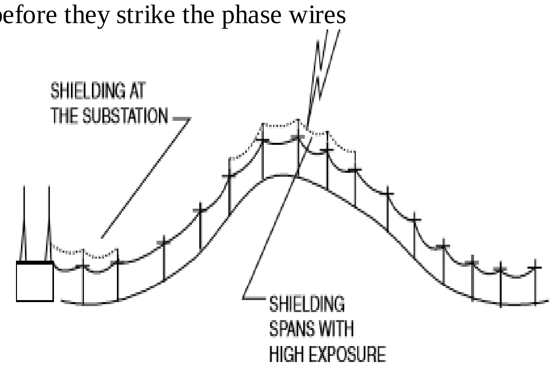

Figure 6 Shielding of transmission line and substation

Line arresters

A surge arrester is used to protect electrical components from over-voltage transients due to external or internal interference. Surge arresters are not designed to protect against a direct lightning strike in a conductor, but also used to reduce electrical transients from lightning strikes occurring in the vicinity of the conductor. Lightning strikes the earth surface which results in ground currents which passes over buried conductors and induce a transient that propagates over the edge of the conductor. Figure 7 shows the surge arrester which is used at the end of the substation

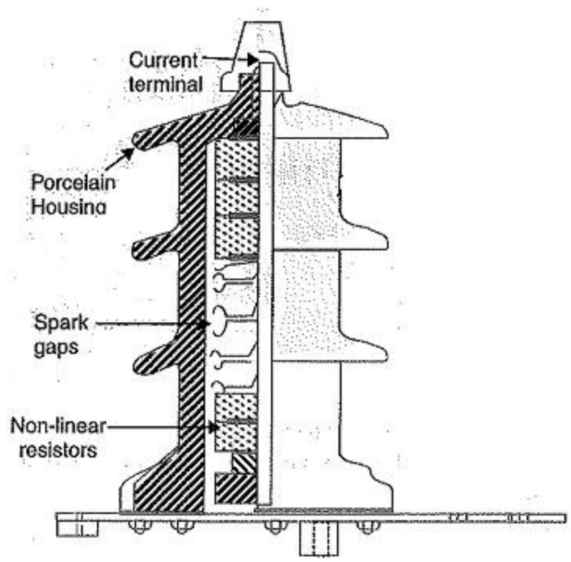

Figure 7 Valve type surge arrester

The spark gap inside the surge arrester acts as a switch while the non-linear resistors provide the low impedance to the ground path. The overvoltage surge causes an arc to form across the air gap just like the switch is turned on. The surge current is then discharge to the ground through the arc and non-linear resistors. There are different types of surge arrester. All of them have resistive element and may or may not have spark gap. They differ only in mechanical construction and by the type of resistive element employed. Although there are different types of surge arresters such as silicon carbide (SiC) arresters with spark gaps, silicon carbine (SiC) arresters with current limiting gaps, gapless metal oxide (zinc oxide) varistor (MOV) arresters and hybrid of metal oxide varistor and silicon carbine (SiC), the surge arresters normally divided into two major types which are the surge arresters with spark gap and the metal oxide varistor (MOV) surge arrester without spark gap.Figure 8 shows the volt ampere charactertics of a non linear resistor which is used inside the surge arrester.Figure 9 shows the operation of surge arrester

$$I=KV^{\alpha}$$

where,

I = discharge current,

V = applied voltage across the element, and
k, α = constant depending on the material and dimensions of element

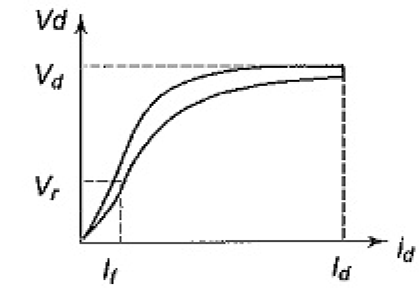

Figure 8 Volt-ampere charactertics of a non-linear resistor

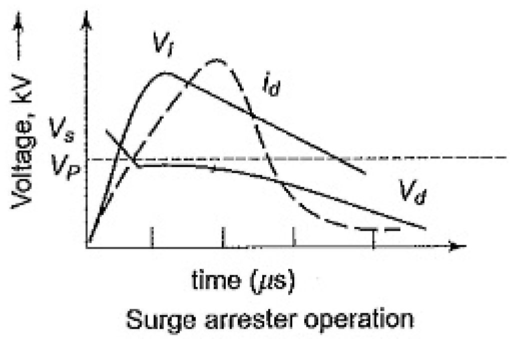

Figure 9 surge arrester operation

Conclusion

In this paper we discussed the major causes of overvoltages in the power system and prevention and protection techniques like Preinsertion resistors, Synchronous closing of capacitor for switching overvoltage, shielding, surge arrester can be implemented to protect power system equipment against lightning overvoltage surges.

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