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Study of Temporary Overvoltages in 110/13.8/6.6 Kv Power Substation

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Abstract
Over voltages, be it of any magnitude, shape or amplitude adversely affect the smooth working of power substation and may prove to be fatal in many cases. In this paper study of insulation coordination of temporary over voltages (TOV) has been carried out in 110/13.8/6.6 kV substations. The factors determining the calculation of over voltages are considered in details and results are presented for over voltages induced in transformers, Gas Insulated Substations, surge reactors and surge arresters. These observed over voltages can be further used to determine the overall overvoltage rating of the station. Determining over voltages in the system help us to ensure whether the existing protection devices are sufficient to handle extreme situations without overshooting their energy ratings or some changes are required.

1. Introduction

The study of overvoltages on power system includes examination of their shapes, magnitudes, durations, and frequency of occurrence. This study should be performed at the point where an overvoltage may originates and also at points along the network to which surges may travel. With the steady increase in transmission voltages need to fulfill required rise in transmitted powers, switching surges serve as a governing factor in designing insulation for Extra High Voltage and Ultra High Voltage systems [3, 9].

2. Origin of Over voltages

Overvoltages affecting the power system are grouped into two main types [1,9]:
External overvoltages: Generated by atmospheric disturbances, such as lightning.
Internal overvoltages: Generated by changes in the operating conditions of the network such as switching actions [4].
Internal overvoltages can be further divided into groups [9,10] :
(a) Temporary overvoltages.
(b) Switching overvoltages
This paper of the insulation coordination study the Temporary Overvoltages (TOV) in 110/13.8kV BSP due to various power system operations and switching actions. Factors such as Cable / line or transformer energisation, phase and ground faults, load rejection and ferroresonance also major factors which initiates the production of Temporary Overvoltages (TOVs) [6].
Frequency of TOV is close to harmonic frequency of power, hence they are also termed as Power Frequency Overvoltage [5]. Fault in high-voltage (HV) power distribution system, medium-voltage (MV) or Low-voltage (LV) power distribution systems give rise to TOVs at power frequencies.
Recent studies shows that TOV are more perpetual and potentially more devastating than other overvoltages.[1,3,5] They have high frequency and may last for about 100 cycles and its amplitude decay slowly[6]. The temporary overvoltages on healthy phases can be very large, much higher than $\sqrt{3}$ p.u. (up to 3.5 p.u.) [2,3].
Their amplitude and shape differ with system variables and network design in many cases. However inspite of having same system variables and network design TOVs depend highly on Circuit breaker operation characteristics and the instant where switching action is initiated [4,6,11].
TOVs are plays critical role in Proper insulation coordination of a power plant. shunt reactor, surge arresters, Pre-insertion resistor (PIR) and controlled switching of circuit breaker may be used as protective devices to counter TOVs under various operation conditions of symmetrical or unsymmetrical circuit breaker switching [7,8].

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The simulations focused on such overvoltages induced in transformers, GIS Components and Reactors in the power system. In this study results are presented to confirm the acceptability of surge arresters to sustain the overvoltage levels below the 'Maximum Protection Level' and also to uphold the potential of the arresters to absorb the energy without exceeding their energy ratings.
The following types of temporary overvoltage effects were studied in the
110/13.8/6/6kV GIS:

- All types of phase to earth faults
- Load rejection
- Earth fault with load rejection

The above studies are carried out to govern proper insulation levels of several components of substation. The study shall deduce whether the present insulation level is adequate or some changes (such as surge arrester installation) would be proposed. Various Configurations were taken into consideration to identify conditions under the 'worst case'.

3. TOV Case Scenarios

3.1. 110 Kv

3.1.1 Earth faults

For earth fault simulation, the double circuit line from substation is considered as Circuit 1 to Circuit 2 line. All the transformers and lines are assumed to be disconnected during simulations except the source at circuit.
Earth faults are considered at various fourth distances from the substation to circuit 2. Line shunt reactors for circuit 1 and 2 at substation are considered connected during the study. Also Substation is in unloaded condition throughout case simulation. Both LG (single line ground fault) and LLG (double line to ground fault) are considered while determining overvoltages due to earth faults.

3.1.2 Load Rejection

Maximum of 1200 MW (1500MVA x 0.8p.f = 1200MW) of load at substation is considered to carry out the study for load rejection and the same load can be provided by double circuit lines 1& 2 connected to 110 kV substation. Shunt reactor for both the circuits are considered to be isolated during simulation to derive the worst results.

3.1.3 Load Rejection with earth fault

The worst case results from above two cases are combined in order to drive load rejection with earth faults

3.2 13.8Kv

3.2.1 over voltages at 13.8kV Switchgear

In order to get the worst over voltages at 13.8kV level, simulations cases have been performed similar to 110kV.

3.2.2 Over voltages at Tertiary (13.8kV level) of 502MVA Transformer

All the 502 MVA Transformers are with unloaded tertiary. Hence to get the worst over voltages at 13.8kV tertiary, various load rejection and earth fault cases at 110kV has been considered.

3.3 6.6kV

3.1.1 over voltages at Tertiary (6.6kV level) of 67MVA Transformer

In order to get the worst over voltages at 6.6kV level, various load rejection and earth fault cases at 13.8kV has been considered.

4. Acceptance Criteria

The allowable phase to earth temporary overvoltage limits for 110kV system as per GIS details is considered as 275kV RMS (388.9kVpeak).

4.1 . Simulation Results

For the Temporary Overvoltages (TOV) study simulations, the simulation results based on the study of case scenario are presented in the succeeding sections. Some simulation graphs for peak overvoltages are incorporated for TOV studies. Observed peak overvoltages for each case scenario are summed up in Tables from 1-4

4.2- 110 kV Level

Overvoltages observed from various TOV case studies for 110kV system is summarized in Table 1. Load rejection followed by LLG fault at 110kV Substation gives maximum overvoltage. Maximum phase over voltage observed in this case is 154.98 kVp (1.73 PU), which is within the acceptable limit. 110kV overvoltages at substation after load rejection and LLG fault are shown in Figure 1.

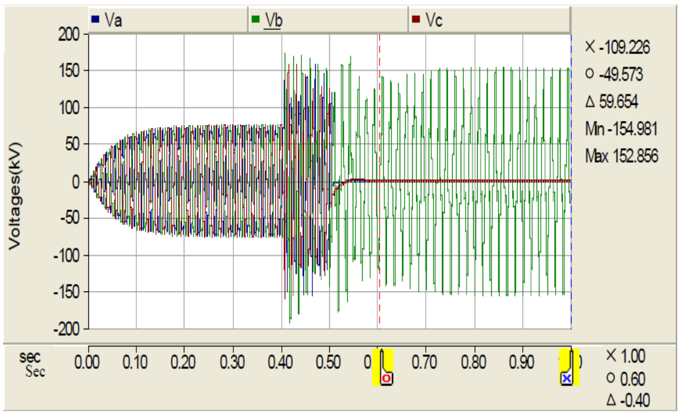

Fig.1: 110kV Phase voltages for load rejection and LLG fault at 110kV substation

S. No	Case Considered	Description	Max.Voltage (ph-G)
1	Two lines from Substation 1 to Substation 2	LG fault applied at 110kV Substation end at 0.4042 sec.	106.72 kVp
2	Two lines from Substation 1 to Substation 2	LLG fault applied at 110kV Substation end at 0.4042 sec.	152.95 kVp
3	Two lines from Substation 1 to Substation 2	Load rejection at 110kV Substation end at 0.4042 sec.	129.25 kVp
4	Two lines from Substation 1 to Substation 2	Load rejection at 110kV Substation end at 0.4042 sec. + LLG fault applied at 110kV Substation end at 0.5042 sec.	154.98 kVp

4.3 -- 13.8kV level

4.3.1 Overvoltages at 13.8kV Switchgear

Overvoltages observed from various TOV case studies for 13.8kV system is summarized in Table 2. LG fault at 13.8kV Switchgear substation in this case gives the maximum overvoltage. Maximum phase over voltage observed in this case is 22.29 kVp (1.98 PU), which is within the acceptable limit. 13.8kV overvoltages at substation after LG fault is shown in Figure 2.

Table 2: Summary of Temporary phase overvoltages at 13.8Kv Switchgear System

S.No	Case Considered	Description	Max.Voltage (ph-G)
1	Two 73MVA transformer connected to 110kV equivalent source through Cable	LG fault applied at 13.8kV S/S end at 0.4042 sec.	22.29 kVp
2	Two 73MVA transformer connected to 110kV equivalent source through Cable	LLG fault applied at 13.8kV S/S end at 0.4042 sec.	18.56 kVp
3	Two 73MVA transformer connected to 110kV equivalent source through Cable	Load rejection at 13.8kV S/S end at 0.4042 sec.	12.38 kVp
4	Two 73MVA transformer connected to 110kV equivalent source through Cable	Load rejection at 13.8kV S/S end at 0.4042 sec. + LLG fault applied at 13.8kV S/S end at 0.5042 sec.	18.56 kVp

4.3.2 Overvoltages at Tertiary(13.8kV level) of 502MVA Transformer

Overvoltages observed from various TOV case studies for overvoltages at tertiary of the transformer are summarized in Table 3. Load rejection at 110kV gives the worst overvoltages. Maximum over voltage observed in this case is 26.25 kVp (1.34 PU), which is within the acceptable limit. Overvoltages at the tertiary winding are shown in Figure 3.

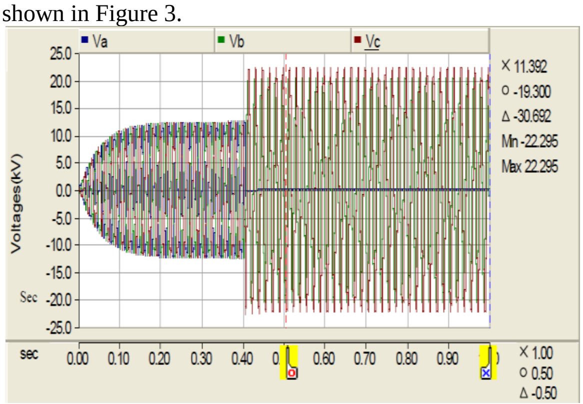

Fig.2 13.8kV Phase voltages at Al-Adel S/S for LG fault at Al-Adel 13.8kV Switchgear

4.4 -- 6.6kV Level

4.4.1 Overvoltages at Tertiary (6.6kV level) of 73 MVA Transformer

Overvoltages observed from various TOV case studies for overvoltages at tertiary of the transformer are summarized in Table 4. In order to get the worst overvoltages at the tertiary winding of the 73 MVA Transformer, LG fault at 13.8kV Switchgear has been considered.

Maximum over voltage observed in this case is 10.76 kVp (1.09 PU), which is within the acceptable limit. Overvoltages at the tertiary winding are shown in Figures 4.

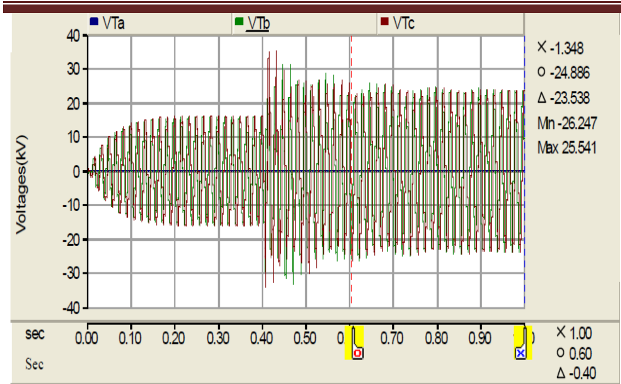

Fig. 3 13.8kV phase voltages of unloaded tertiary winding of 502 MVA Transformer with load rejection at 110kV Substation.

Table 3: Summary of Temporary overvoltages at Tertiary (13.8kV level) of 502MVA Transformer

SNo	Case Considered	Description	Max. Voltage(ph-G)
1	Two lines from Substation 1 to Substation 2	LG fault applied at 110kV Substation end at 0.4042 sec.	20.39 kVp
2	Two lines from Substation 1 to Substation 2	LLG fault applied at 110Kv Substation end at 0.4042 sec.	11.15 kVp
3	Two lines from Substation 1 to Substation 2	Load rejection at 110kV Substation end at 0.4042 sec.	26.25 kVp
4	Two lines from Substation 1 to Substation 2	Load rejection at 110kV Substation end at 0.4042 sec. + LLG fault applied at 110kV Substation end at 0.5042 sec.	11.62 kVp

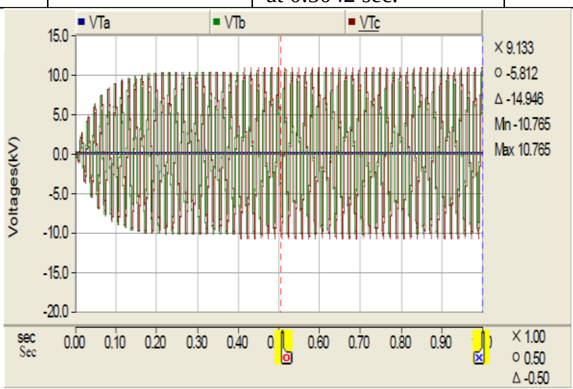

Fig.4 6.6kV phase voltages of unloaded tertiary winding of 73 MVA Transformer with LG fault at 13.8kV Switchgear.

Table 4: Summary of Temporary overvoltages at Tertiary (6.6kV level) of 73MVA Transformer

S. No	Case Considered	Description Max.	Max.Voltage (ph-G)
1	Two 73MVA transformer connected to 110kV equivalent source through Cable	Single line to ground fault applied at 13.8kV Substation end at 0.4042 sec.	10.76 kVp
2	Two 73MVA transformer connected to 110kV equivalent source through Cable	Double line to ground fault applied at 13.8kV Substation end at 0.4042 sec.	5.36 kVp
3	Two 73MVA transformer connected to 110kV equivalent source through Cable	Load rejection at 13.8kV Substation end at 0.4042 sec.	10.26 kVp
4	Two 73MVA Transformer connected to 110kV equivalent source through Cable	Load rejection at 13.8kV Substation end at 0.4042 sec. + Double line to ground fault applied at 13.8kV Substation end at 0.5042 sec.	5.36 kVp

6. Conclusions

In this paper, the inssulation coordination study for TOV has been performed for 110/13.8/6.6Kv substation. The substation is equipped with surge arresters and shunt reactors. Basic Switching Impulse withstand level (BSL) of the substation equipments, shunt reactors and Transformers is 1050kVp. The substation is provided with the 360kV surge arresters at cable/line entrance. In addition to that 360kV surge arresters are also connected to protect line and bus shunt reactors and 18kV surge arrester is connected to protect the 13.8kV shunt capacitor bank. 100kV & 21kV surge arresters are connected at the 502MVA auto transformer 110kV & 13.8kV terminals respectively. Similarly, 100kV, 15kV & 10kV surge arresters are connected to the 73MVA power transformer 110kV, 13.8kV & 6.6kV terminals respectively.

References

[1] Flore Chiang, Implications of Temporary Overvoltages for Insulation Coordination for Equipment Within Low-Voltage Systems, IEEE Symposium on Product Compliance Engineering (Pses), 2011

[2] A Cerretti, FM Gatta, A Geri, S Lauria, M Maccioni, G Valtorta. Temporary Overvoltages Due to Ground Faults in Mv Networks, Powertech, 2009 Ieee Bucharest, 2009, 1-8

[3] Temporary overvoltages: causes, effects, and evaluation, IEEE power engineering review, 10, 1990, 14 – 15

[4] D Thukaram, H Khincha, S Khandelwa. Estimation of Switching Transient Peak Overvoltages During Transmission Line Energization Using Artificial Neural Network, Electric Power Systems Research, 76, 2006, 259–269.

[5] Cigre Working Group, Switching Overvoltage in Ehv and Uhv Systems with Special Reference to Closing and Reclosing Transmission Lines, Electra, 30, 1973, 70-122.

[6] R King, F Moore, N Jenkins, A Haddad, H Griffiths, M Osborne, Switching Transients in Offshore Wind Farms – Impact on The Offshore and Onshore Networks, International Conference on Power Systems Transients, Ipst, Delft, The Netherlands, June 14-17, 2011.

[7] P Mestas, M Tavares. Comparative Analysis of Techniques For Control Of Switching Overvoltage During Transmission Lines Energization, International Conference On Power System Transients, Ipst'07, Lyon, France, June 4-6, 2007, Paper No.116

[8] H Seyedi, M Sanaye-Pasand, MR Dadashzadeh. Application of Transmission Line Surge Arresters to Reduce Switching Overvoltages, International Conference on Power System Transients, Ipst'05, Montreal, Canada, June 19-23, 2005, Paper No. 082

[9] IEC 60071-1. Insulation Coordination-Part 1: Definitions, Principles And Rules, International Electrotechnical Commission, (IEC) 2006.

[10] IEC 60071-2. Insulation Coordination–Part 2: Application Guide, International Electrotechnical Commission, (IEC) 1996.

[11] IEEE Std. C62.22-1997, IEEE Guide for the Application of Metal-Oxide Surge Arresters for Alternating-Current Systems, IEEE Power & Energy Society, 2009