Switching overvoltage calculations and reduction, for 400 KV-line connecting Khoms and Gmmra substations

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Abstract

Transient overvoltage in power systems is one of the most important issues to be considered for system stability. Switching surges is one of the most important reasons that cause Transient overvoltage. This paper presents a full study of the high-voltage line connecting KHOMS and GMMRA substations. The study utilizes the Alternative Transient Program (ATP) to compute the transient overvoltage due to switching surges (line closing and re-closing); as well as presenting the usage of surge arrester with pre-insertion resistor to reduce the upper limit of transient overvoltage. The results present the positive effect of using surge arrester and resistor switching element to limit transient overvoltage and keep it at certain level; as well as damping the isolation in the voltage waveform.

Keywords: Transient overvoltage; Switching surges; Stability.

1. Introduction

It is essential for electrical power engineers to reduce the number of outages and preserve the continuity of service and electric supply. Therefore, it is necessary to direct special attention towards transient overvoltage in electric systems. Transient overvoltage in power systems has been covered in many publications. In [1], the author classified the overvoltage into two types. The first one is the Internal overvoltage which generated by the changes in operating conditions (mainly by switching surges). The second type is External overvoltage which generated by lightning storks.

Transient high voltage impulses and travelling waves in power systems are covered in many publications such as in [1, 2]. Other publications cover different topics in this sector. In [3, 4] the negative impact of transient overvoltage on the insulators as well as classification of dielectric stresses have been covered. In [5-9], the insulators, insulation level and transient high voltage limits for overhead lines are presented.

Lightning surges are less important for Extra High Voltage (EHV) transmission systems above 345kV as well as for Ultra High Voltage (UHV) transmission systems, which have improved insulations. Switching surges became the limiting factor in insulations coordination for system voltages above 345kV [5]. Some important switching operations which can lead to switching overvoltage are presented in [1]. In [4] Factors affecting switching overvoltage are presented in details. Some common methods for controlling switching surges and reducing transient overvoltage have been well covered in many publications such as in [1,3,4,6]. These methods of controlling switching surges to limit the transient overvoltage include Resistor switching, Phase controlled switching, Drainage of trapped charge, Shunt reactors, and Surge...
arrester. Some other publications represent Measurement methods of transient overvoltage such as in [10,11]. In [12], the authors concentrated on transient overvoltage waveshapes in a 500-kV gas insulated switchgear. This paper utilizes surge arrester and pre-insertion resistor technique to reduce the upper limit of transient overvoltage due to switching surges.

2. Pre-Insertion Resistor (PIR).

Switching overvoltage mainly occur when a line is energized or re-energized. Energization and re-energization surges are done typically for fault recovery or for maintenance services. Different switching operations which can lead to switching overvoltage are presented in [1]. Using a resistor in series at the instant of energization/re-energization limits the overvoltage to an acceptable value.

The technique used in this paper uses two switches at the sending end of the line as well as at the end of the line. One switch is connected directly to the line and the other is connected via series resistor to limit the transient overvoltage. The line between the two ends is divided into several segments each segment is 10% of the line length.

The technique used in this paper can be summarized in the following steps.

- Energization/re-energization is done by initially applying the supply voltage to the line through a resistor.
- After a suitable period of time, the pre inserted resistor is shorted circuit.
- By the end of the pre insertion period, the magnitude of the energization surge is usually reduced by the effected of the system damping.
- The initial amplitude of the energization surge when the pre insertion resistor of value R is used will be only $\frac{Z_0}{(R + Z_0)}$ where $Z_0$ is the surge impedance of the line.
- When the resistor is shorted at the end of the pre insertion period, another surge will develop.
- If $R$ is too small, control of the first surge becomes ineffective, if it is too large, the second surge becomes dangerous.
- The optimum resistor value varies with different system conditions but is typically in the range 300-500 ohms [4].


A surge arrester is a device designed to protect electrical equipment from transient overvoltage due to lightning or switching surges. Switching overvoltage mainly occur when a line is energized or re-energized. Energization and re-energization surges are done typically for fault recovery or for maintenance services. Different switching operations which can lead to switching overvoltage are presented in [1]. Using a surge arrester limits the overvoltage to an acceptable value.

The electrical characteristics of an ideal surge diverter are:

a) Under normal operating voltage, it should draw zero current (has very high impedance).
b) It should breakdown very quickly under abnormal transient voltage [1].

c) Dissipate or store the energy in the surge without damage, and return to open-circuit conditions after the passage of a surge [6].

Selection of surge arrester rating is very important issue. The temporary overvoltage level and duration must be carefully considered before selecting the rating of the surge arrester to be used. From the rated value stems the protective or voltage limiting characteristic of the surge arrester: the higher the rating, the higher the limiting or residual voltage the arrester will have.

Thermal constraints are very important since if the rating is too low, temporary overvoltage may cause excessive heating resulting in thermal instability and subsequently failure of the system [4].

The technique used in this paper uses two switches at both line ends as well as two other switches (SWa, SWb), for reclosing case, in parallel at line ends. The line between the two ends is divided into several segments each segment is 10% of the line length as shown in figure. 1.

![Figure 1](image)

Figure. 1: Circuit re-closing case model with surge arrester and PIR (ATP circuit).

A measure of the overvoltage is done at each segment of the line. The point of interest is the overvoltage at both ends of the line. Hence, overvoltage results at other segments will not be published.

4. Simulation Results and Discussion

The case study used to present the effectiveness of using surge arrester and PIR to limit the overvoltage values at satisfying level is the 400KV line connecting KHOMS and GMMRA substations in the Libyan power network. Figure. 2 represents the 400KV Libyan network [13] including our case study.

The Alternative Transient Program (ATP) is used represent the chosen case. Line data and tower configurations for the line under study was taken from [10], as well as the maximum overvoltage limit. Transient overvoltage analysis will be done for Closing and Re-closing cases.
A. Closing Case

Figures 3 and 4 represent the closing circuit diagrams from KHOMS and GMMRA sides respectively with surge arrester and pre-insertion resistor.

When the line is energized without using SA and PIR, the overvoltage value exceeds the maximum level. Figures 4 and 5 represent the overvoltage waves at GMMRA and KHOMS sides respectively without SA and PIR.
The numerical results for the overvoltage values for both sides are presented in table 1.

<table>
<thead>
<tr>
<th>The source side</th>
<th>Max overvoltage result at the end of the line (p.u)</th>
<th>Max overvoltage limit (p.u) at the end of the line</th>
</tr>
</thead>
<tbody>
<tr>
<td>KHOMS</td>
<td>2.5</td>
<td>2.3</td>
</tr>
<tr>
<td>GMMRA</td>
<td>2</td>
<td>1.7</td>
</tr>
</tbody>
</table>

It is clear that the value of overvoltage at both ends exceeded the Maximum limit when energizing the line. This large value well negatively affect the system operation as well as may cause damage to some elements in the network such as insulators.

To decrease the overvoltage values at both ends when energizing the line, a SA and PIR is used as shown in figures 3 and 4.
Figures 3 and 4 represent the closing circuit diagrams from KHOMS and GMMRA sides respectively with SA and PIR. Figures 7 and 8 represent the overvoltage waves at GMMRA and KHOMS sides respectively for this case.

![Figure 7: Closing overvoltage waves at GMMRA side with SA and PIR.](image1)

![Figure 8: Closing overvoltage waves at KHOMS side with SA and PIR.](image2)

The numerical results for the max overvoltage results for both sides are presented in table 2. It is clear that when the SA and PIR inserted, the overvoltage value does not exceed the limit.

<table>
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<tr>
<td>KHOMS</td>
<td>1.36</td>
<td>2.3</td>
</tr>
<tr>
<td>GMMRA</td>
<td>1.24</td>
<td>1.7</td>
</tr>
</tbody>
</table>

B. Re-closing Case
Figures 9 and 10 represent the reclosing circuit diagrams from KHOMS and GMMRA sides respectively with surge arrester and pre-insertion resistor.
It is clear from Table 1 that the value of overvoltage at both ends exceeded the Maximum limit when reenergizing the line. To decrease the overvoltage values at both ends when reenergizing the line, a SA and PIR is used as shown in figures 9 and 10.

Figures 9 and 10 represent the reclosing circuit diagrams from KHOMS and GMMRA sides respectively with SA and PIR. Figures 11 and 12 represent the overvoltage waves at GMMRA and KHOMS sides respectively for this case.
The numerical results, without SA and PIR, for the max overvoltage results for both sides are presented in table 3. The overvoltage value exceeds the limit when the line is reenergized without SA and PIR.

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<tr>
<td>KHOMS</td>
<td>4</td>
<td>3.8</td>
</tr>
<tr>
<td>GMMRA</td>
<td>3.5</td>
<td>3.46</td>
</tr>
</tbody>
</table>

Table 4 represents the numerical results when the SA and PIR are inserted. The overvoltage value does not exceed the limit and remains at an acceptable limit.

<table>
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<tr>
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4. Conclusion

This paper presents a full study of the high-voltage transmission line connecting KHOMS and GMMRA substations in the Libyan network. The study utilizes the Alternative Transient Program (ATP) to compute the transient overvoltage due to switching surges (line closing and re-closing); as well as presenting the usage of surge arrester and pre-insertion resistor to reduce the upper limit of transient overvoltage. The results present the positive effect of using surge arrester with resistor switching element to limit transient overvoltage and keep it at certain level; as well as damping the isolation in the voltage waveform. This procedure can be used for all main nodes in the network to keep the system stable and reliable.

References


