Switching Overvoltage Reduction Using Surge Arrester, 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 an 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 to reduce the upper limit of transient overvoltage. The results present the positive effect of using surge arrester switching element to limit transient overvoltage and keep it at certain level; in addition to damping the isolation in the voltage waveform.**

Index Terms: **Transient overvoltage; Surge arrester; Stability**.

I. 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 is generated by the changes in the operating conditions (mainly by switching surges). The second type is an external overvoltage which generated by lightning storms.

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

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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 wave shapes in a 500-kV gas insulated switchgear. This paper utilizes surge arrester technique to reduce the upper limit of transient overvoltage due to switching surges.

II. SURGE ARRESTER (SA)

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

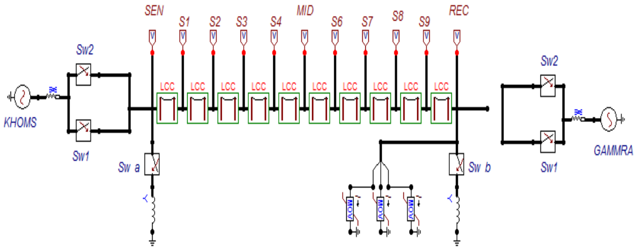

Figure. 1. Circuit Re-Closing Case Model with Surge Arrester (ATP Circuit).

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.

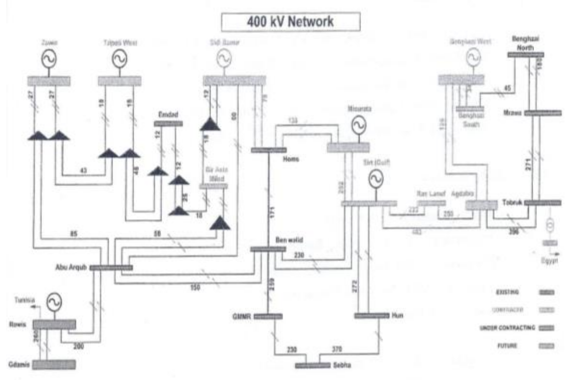

Figure. 2. 400KV Libyan Network

III. Simulation Results and Discussion

The case study used to present the effectiveness of using surge arrester 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 to represent the chosen case. Line data and tower configurations for the line under study was taken from [13]. In addition the maximum overvoltage limit. Transient overvoltage analysis is carried out for Re-closing case only.

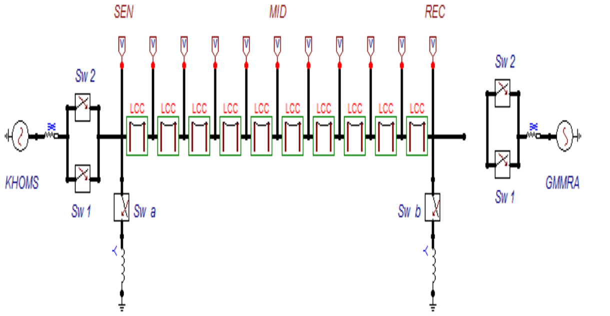

Figure. 3: Re-Closing Case from KHOMS Side without SA.

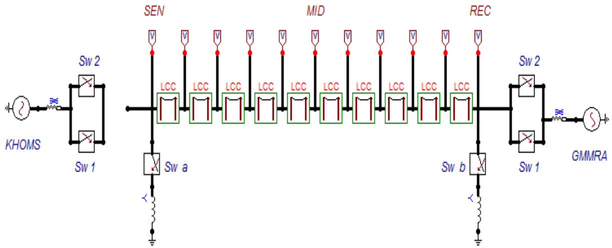

Figure. 4: Re-Closing Case from GMMRA Side without SA.

Figures 3 and 4 represent the re-closing circuit diagrams from KHOMS and GMMRA sides respectively without surge arrester (SA). When the line is reenergized without using surge arrester, the overvoltage value exceeds the maximum level. Figures 5 and 6 represent the overvoltage waves at GMMRA and KHOMS sides respectively.

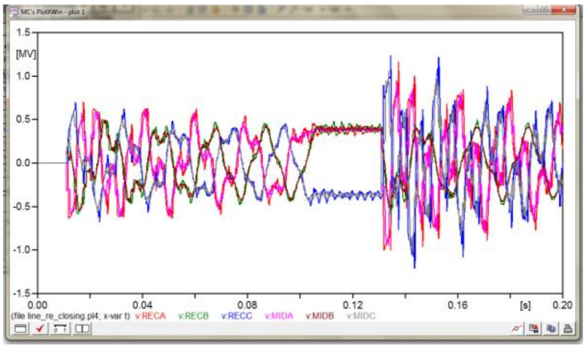

Figure. 5. Overvoltage Waves at GMMRA Side without SA.

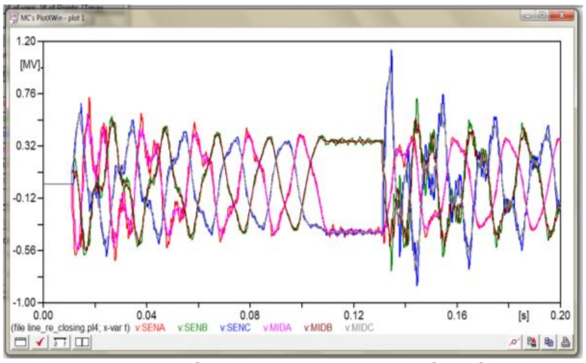

Figure. 6. Overvoltage Waves at KHOMS Side without SA.

The numerical results for the overvoltage values for both sides are presented in table 1.

Table 1. Line Reclosing Overvoltage in (pu) without SA.

The source side	**Max overvoltage result at the end of the line (p.u))**	**Max overvoltage limit (p.u) at the end of the line**
KHOMS	4	3.79
GMMRA	3.5	3.46

It is clear that the value of overvoltage at both ends exceeded the Maximum limit when reenergizing the line. This large value may 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 reenergizing the line, a surge arrester is used as shown in figures 7 and 8.

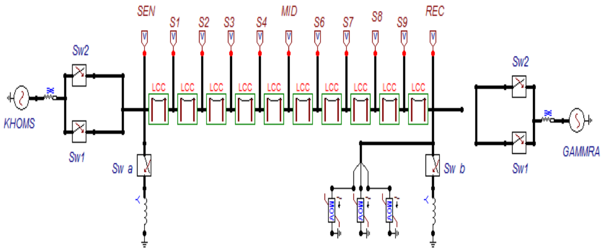

Figure. 7. Re-Closing Case from KHOMS Side with SA at GMMRA.

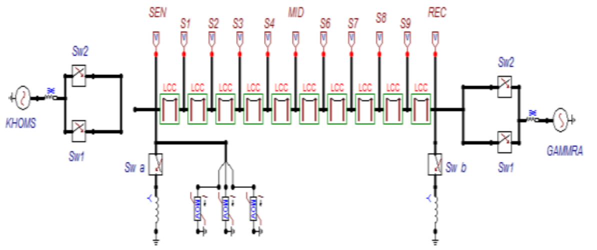

Figure. 8: Re-Closing Case from GMMRA Side with SA at KHOMS.

Figures 7 and 8 represent the re-closing circuit diagrams from KHOMS and GMMRA sides respectively with surge arrester (SA). The surge arrester characteristic of 400kV network are taken from [10]. When the line is reenergized with SA, the overvoltage value remains low and does not exceed the maximum level. Figures 9 and 10 represent the overvoltage waves at GMMRA and KHOMS sides respectively for this case.

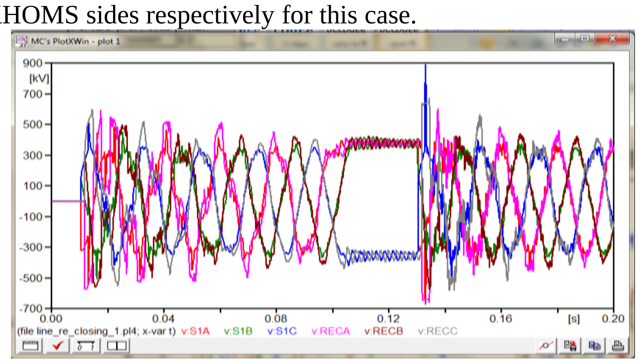

Figure. 9. Overvoltage Waves at GMMRA Side with SA.

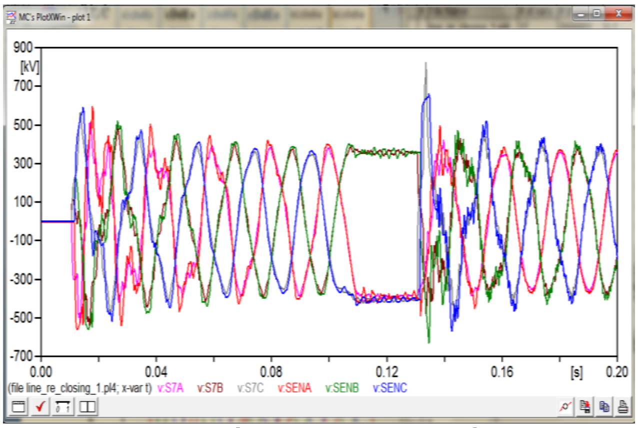

Figure. 10. Overvoltage Waves at KHOMS Side SA.

The numerical results for the max overvoltage results for both sides are presented in table 2 with surge arrester (SA). It is clear that when the SA is used, the overvoltage value does not exceed the limit.

Table 2. Line Reclosing Overvoltage in (pu) with SA.

Source Side	**Max overvoltage result at the end of the line (p.u)**	**Max overvoltage limit (p.u) at the end of the line**
KHOMS	2.72	3.79
GMMRA	2.52	3.46

IV. CONCLUSION

This paper presented 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 re-closing); and to represent the usage of surge arrester (SA) to reduce the upper limit of transient overvoltage. The results confirm the effectiveness of using surge arrester element to limit the transient overvoltage at acceptable level. In addition to damping the isolation in the voltage waveform. This technique can be used for all main nodes in the network to keep the system stable and reliable.

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