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Evaluation Methods of Limiting Switching Overvoltage during Line Energization

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***Abstract*-** The transmission line faces overvoltage problem in the case of energization. There are some methods to have acceptable level of voltage. In this paper, some of the methods to solve the problem are explained and combinations of several of them are presented. A traditional way to limiting switching overvoltage is using the circuit breakers equipped with pre-insertion resistors. It has some advantage same as good effect and disadvantage same costly and complex. One of the other methods is using the surge arrester at the lines. Description of the traditional method and the other ways are presented. At the end the comparison of these methods by using the PSCAD software shows the effect of different methods.

***Keywords*-** *Arrester, Pre-insertion resistors, PSCAD, Reactor.*

I. INTRODUCTION

Switching surges are the transient overvoltages that right away follow the opening or closing of a circuit breaker or other switching apparatus. Those overvoltages caused damage to insulator equipment. Any increase in voltage from the nominal voltage is overvoltages and it is necessary to prevent the occurrence of that in the network. This phenomenon is very important in insulation coordination for extra high voltage (EHV) lines. The main objective of switching overvoltages simulation is to help suitable insulation coordination and have minimal damage and interrupt in the system [1]. The insulation design of power supplies is based on the concepts of stress and strength [2]. According to the IEC-71-1 standard insulation coordination is choice of insulation resistance if equipment and its application that related to the voltage that can appear in system and cause damage on the insulation of equipment and prevent the continuation of system [3]. So by controlling the transient overvoltages amplitude the insulation level is reduced thus its result is cost saving. As a consequence recognizing the fast transient response of system is necessary to design the transmission line. According to the IEC endorsement, all equipment designed for operating voltages above 300 kV should be considered under switching impulses. Switching surges have become to governing factor in the design of insulation for the EHV and UHV systems [4].

In general some of the methods to reduce the switching overvoltages are:

1) Pre-insertion resistors
2) Shunt reactor connected to line
3) Switching in the suitable time
4) surge arrester
5) Connecting the beginning and end of line at the same time

II. METHODS

Some of the methods on above are explained in this part:

A. Pre-insertion resistor

The traditional way to solve the problem is installing the pre-insertion resistors in the line circuit breakers. The method is more common and it's effective to have acceptable levels of the overvoltages that made by switching but it makes the circuit breaker more complex and expensive [5], [6].

In this method at first line energizes through a resistance, the resistance is series with line and source. After a short defined time, resistance will be short circuit and the line reaches full source. Due to it, line is energized in two stages, if the suitable resistance is selected, the voltage amplitude will be reduced to the desired value [7].

B. Shunt reactor is connected to line

The reactor used in line is for controlling the reactive power and voltage in line. With absorption the reactive power from line, it can control the steady state overvoltage. That has been proven if reactor is connected to line when the line is energized, overvoltage is reduced. Usually the reactors are using in one side or both sides of line. Using the reactors especially in long line that has been energized by a source with high inductance is useful. Because in this case natural frequency of source and line is close to the circuit power frequency so in this situation the pre-insulation resistor is useless [8].

Installations the reactor at the end of line is more effective in reduced the overvoltages than the same that installed in the beginning of the line.

C. Surge arrester

One of the methods that used instead of pre-insertion resistors in line circuit breakers is surge arrester in line. One

basic requirement for arresters, in general, is effective protection of other equipment The arresters have enough effect in the case of protection and made acceptable levels of limiting switch overvoltages. Thus it is necessary aid to insulation coordination. It is clear from figure 1 [9]. By using an extra arrester in the middle of the line, reduction of switching can be achieved [10].

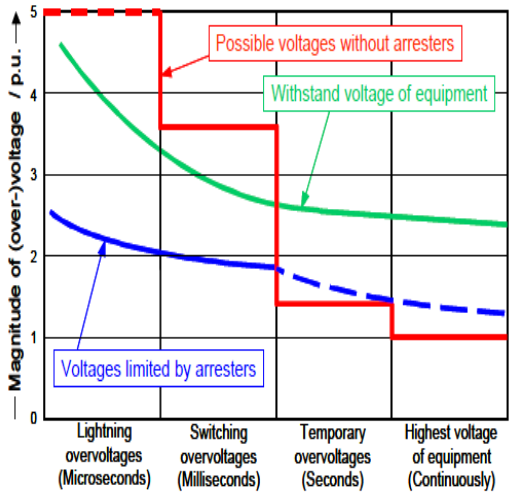


Figure 1. Voltages and overvoltages in high-voltage electrical power systems

The surge arresters use for both lighting and switching but in this paper only the switching are explained.

III. SYSTEM CONFIGURATION

In this part, explanation of the used system in the simulation is presented. PSCAD software is used in this study. The simple scheme of system has been shown in figure 2. Detailed simulation parameters are given in Table 1.

TABLE I. SIMULATION PARAMETERS

Fundamental frequency	50 Hz
Line length	350 Km
pre-insertion resistor	200 ohm & 400 ohm

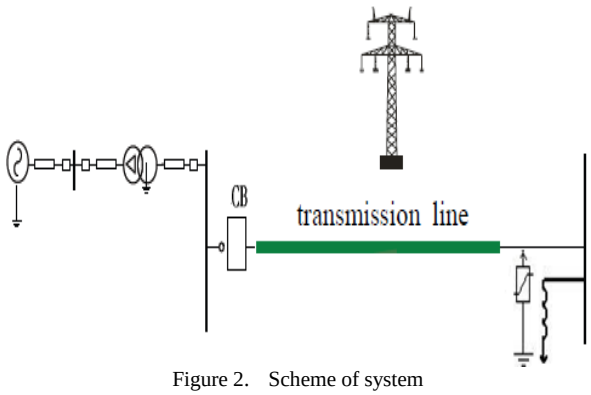
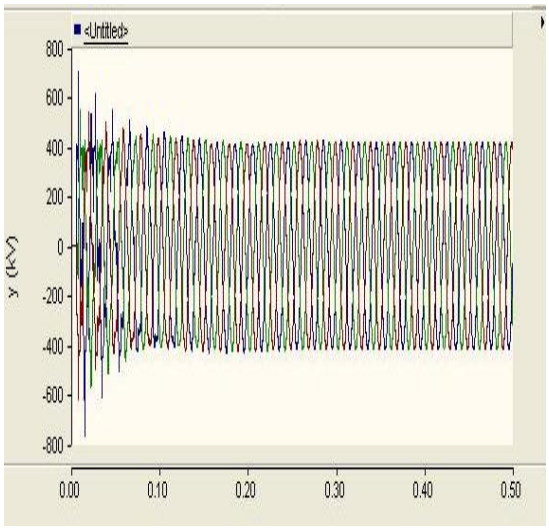


Figure 2. Scheme of system

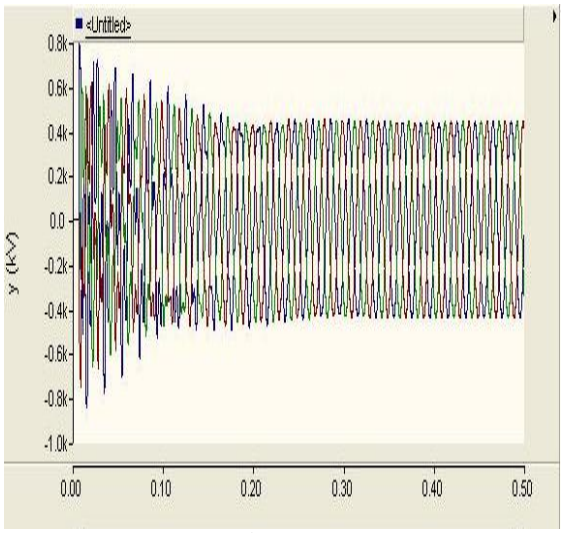
The system includes same segments during line. The surge arrester, circuit breaker and reactor are shown in the figure, those used in the many section of simulation part.

IV. SIMULATION RESULTS

The simulation results are presented in this part. Figure 3 shows the waveform at first point and at end in the line without any overvoltage control.



a) The waveform at the first point



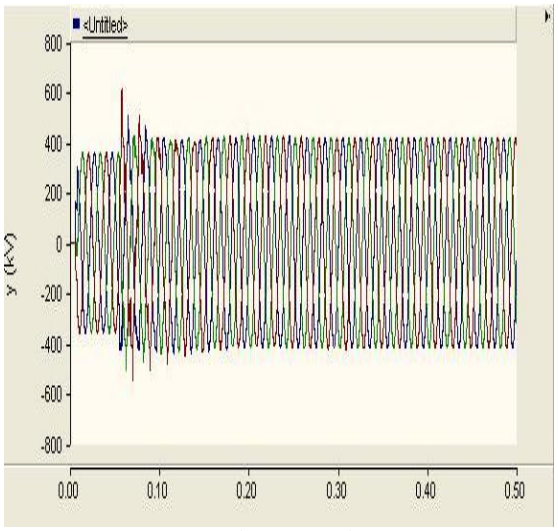
b) The waveform at the end point

Figure 3. The waveform without overvoltage control

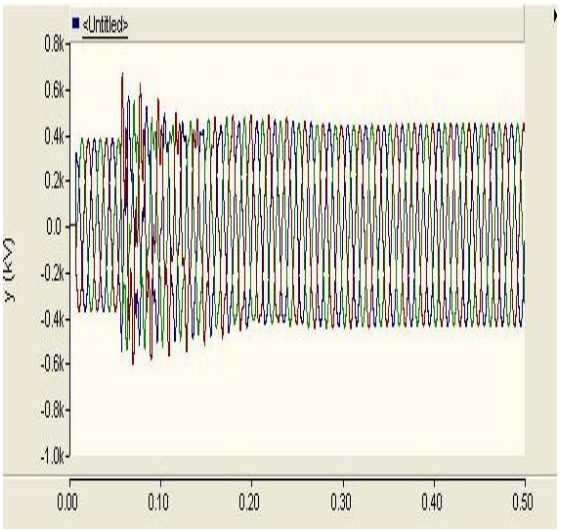
It is specified from Figure 3 that when the line is energized, waveform amplitude is increased about 2-fold at the first point of line and this value is increased more to the end of the line.

So by this waveform showed in figure 3, using the practical method to reduce these overvoltages is specified.

The effects of using pre-insertion resistors with different values of resistor are shows in figure 4 and 5. After 0.05sec the resistor in the circuit will be short circuit, so line is energized in two steps. It is the cause of have acceptable level overvoltages in case of switching. The range of resistors are used in this method is between 200 to 850 ohm. The value of resistor is depended on the structure of network.



a) The waveform ate the first point

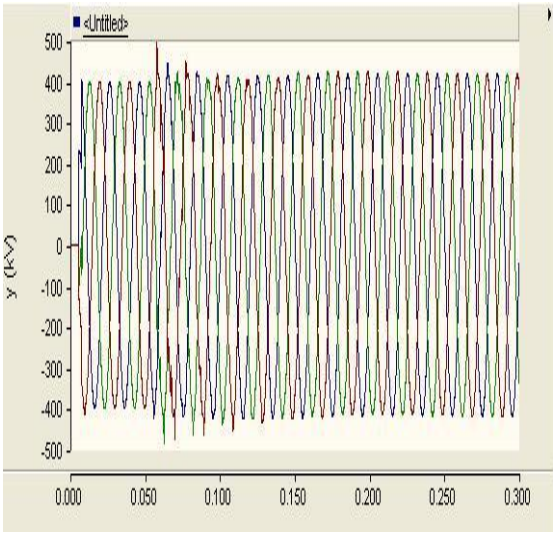


b) The waveform at the end point

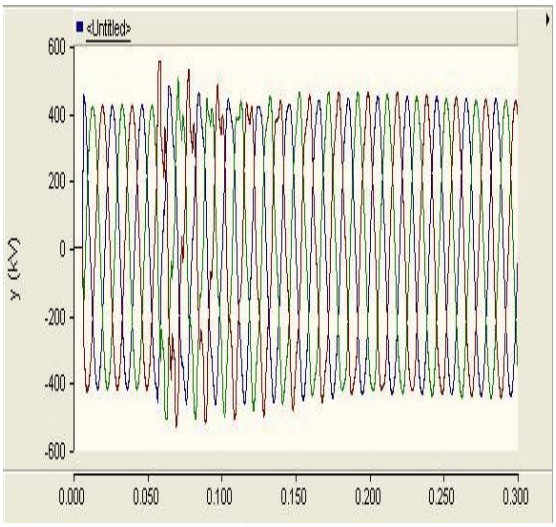
Figure 4. The waveform with pre-insertion resistor (400 ohm)

The overvoltages are reduced. Before the resistor in the circuit be short circuit there is no overvoltages and after that, the overvoltages is appeared but it has smaller amplitude to compare with the case without any controller and it is related to the mechanism of this method by using rector.

If the value of resistor is changed, amplitude of overvoltages has different change. To show that, pre-insertion resistors with 200 ohm resistor is used in next case and the result of that is shown in figure 5.



a) The waveform at the first point

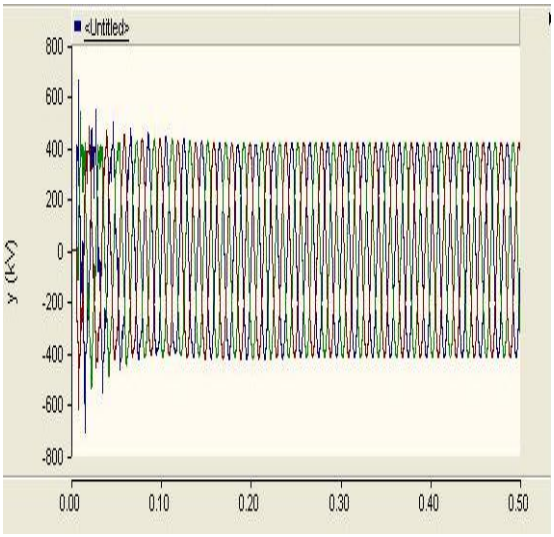


b) The waveform at the end point

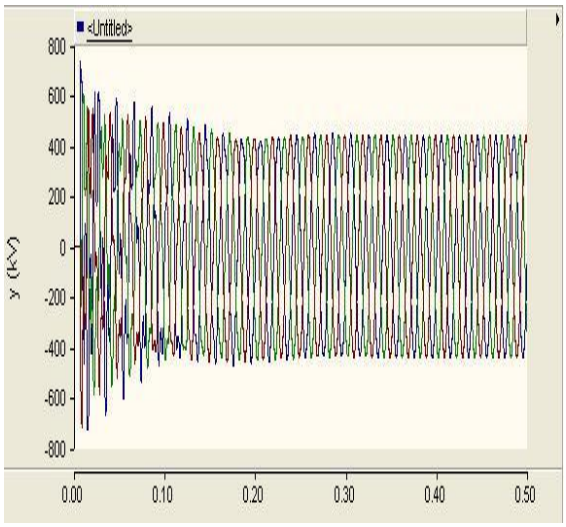
Figure 5. The waveform with pre-insertion resistor (200 ohm)

Figure 4 and 5 shows, the resistors with 200 ohm have better act to limiting the overvoltages to compare the resistor with 400 ohm value. The value of resistor is depended on the network structure.

By using surge arrester in line, overvoltages can be controlled. Effect of it, installing at end has been shown in figure 6 and installing an extra arrester in middle of line has been shown in figure 7.

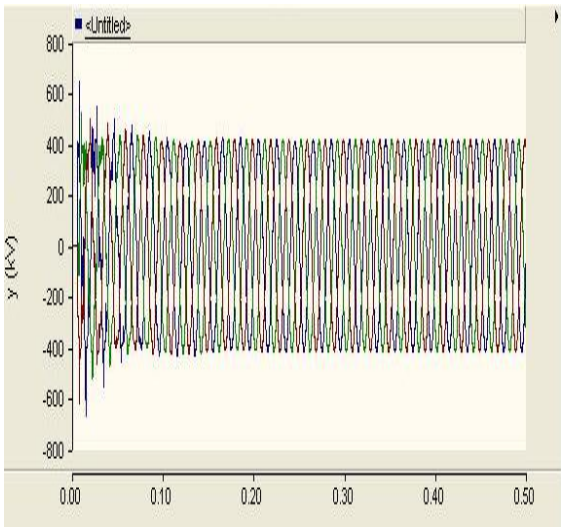


a) The waveform at the first point

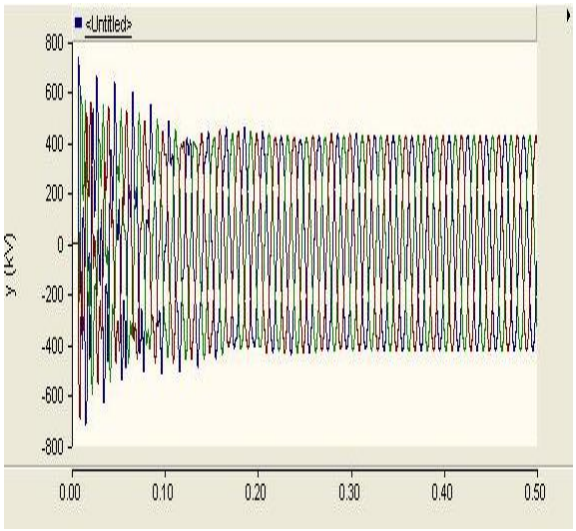


b) The waveform at the end point

Figure 6. The waveform with arrester at the end of line



a) The waveform at the first point



b) The waveform at the end point

Figure 7. The waveform with arrester at the end of line and middle of line

Figure 6 showed the effect of using a surge arrester at the end line. It is clear the overvoltage be controlled at the first point and has good waveform. So by using surge arrester the overvoltages can be controlled and if the extra surge arrester is used in the line, the overvoltages is reduced more. This effect is showed in figure 7.

To have better comparisons between the methods and effect of them, overvoltages during the line by using different method is presented in this part of the paper.

The comparison for overvoltages between the line without control and installing a reactor at end line during the line and is shown in figure 8.

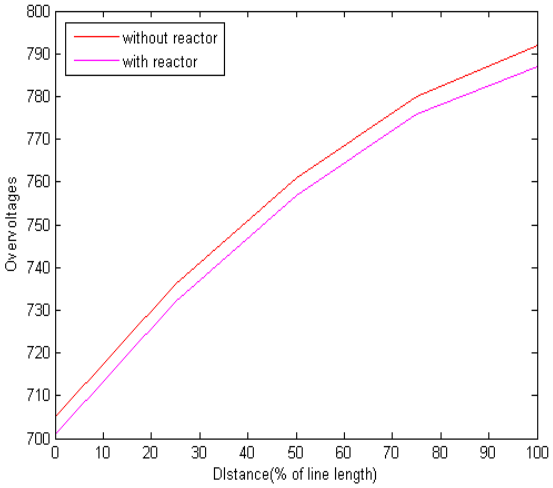


Figure 8. Overvoltage profile during line

In other comparison the line is with reactors at the end and other methods to reduce overvoltages are additives to this line.

Figure 9 shows the effect of different value of resistor that uses as an equipment control in pre-insulation resistor method.

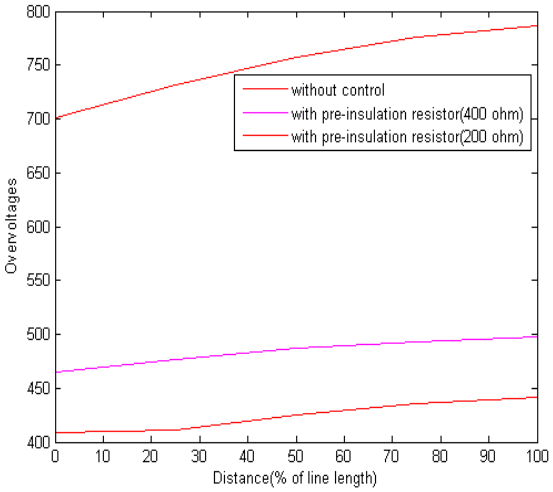


Figure 9. Effect of different values of pre-insulation resistor

The results showed in this network the 200 ohm resistor have better effect to compare with 400 ohm one. Surge arrester have sufficient effect to control the over voltage by installing it at end of line. It is possible to install an additional arrester in middle of line. The comparison between them has been shown in figure 10.

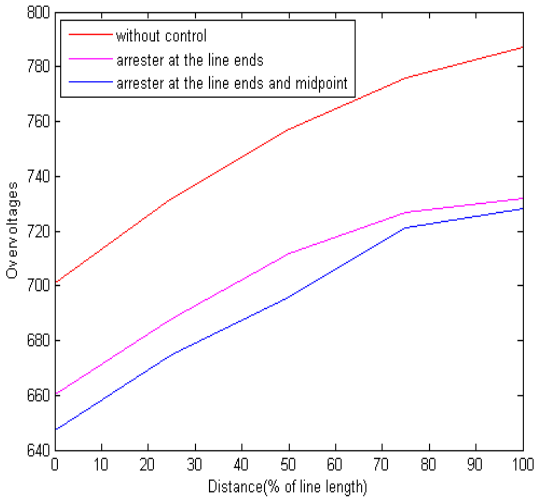


Figure 10. Effect of different numbers of arrester

So by using extra surge arrester at midpoint, the overvoltages is reduced more than using only one surge arrester at ends line. The general comparison between using only reactor and using it with arrester and pre-insulation and their efficient is shows in figure 11.

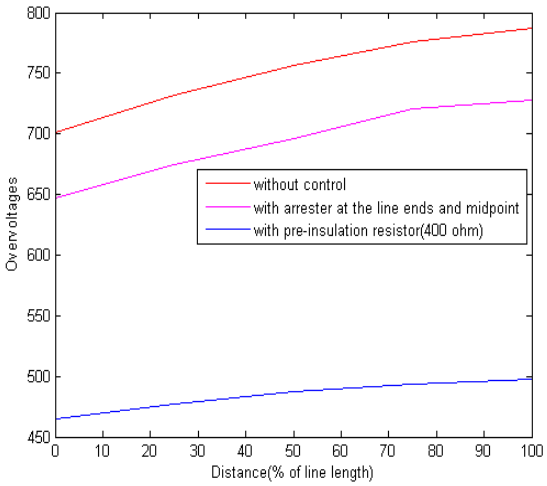


Figure 11. Overvoltages during feeder by using several methods

Figure 11 shows the pre-insulation resistor is an effective device for limiting the over voltages switching but it is more complex and expensive.

V. CONCLUION

Overvoltages caused by Closing and re-closing in the line can be limited by using the different methods such as pre-insulation resistors, shunt reactor and surge arrester. By using the shunt reactor, the overvoltage is reduced but it is not sufficient. This paper shows the traditional solution, pre-insulation resistor is an effective device for limiting the over voltages switching but it is more complex and expensive. Different values of resistor have different result, so to choice the value of resistor knowing the data of the network is necessary. One of other method is using surge arrester. The surge arresters have enough effect on the line and it is reliable and the places of the arrester have effect on its performance.

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