Lightning Protection of A 22kV Distribution Overhead Line- A Case Study

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***Abstract*—The protection of electrical distribution network against lightning with high reliability is a critical aspect for power utilities. Lightning strokes influences the performance of a distribution systems. In this paper, we investigate the option of using streamer to minimize the effect of lightning in the Doulas MMS Coal 22kV plant. The network is modelled using MATLAB. Furthermore, we compared the surge arrestors and streamers and determined a suitable option for the application.**

Keywords— Distribution Systems, Surge arrestors, Steamers, Lightning

I. Introduction

The protection against lightning on power distribution and transmission networks has primarily been carried using equipment such as (surge arrestors, surge capacitors, shield wires and basic insulation earthing systems). The fundamental application of the protection equipment is to attempt to minimize the high induced voltage resulting from lightning strike. Minimizing the high voltages reduces the extent of damage on the system. Overhead electrical systems are mostly exposed to the effect of lightning [1]. Technically lightning induces a rapidly voltage on the power system network, thus this could result in substantial power outages [1].

Lightning has the potential to affect and damage the power system equipment. It is therefore imperative that adequate electrical protection is installed to minimize the extend of the damage [2]. In recent years, most power utilities have adopted a technique based on installing a shield wire to protect the phase conductors whenever there is a direct lightning strike [3, 4]. This shield wire is used to redirect the surge current induces form the lightning into to the ground. It is therefore, important that ground earthing is sufficient.

Surge arrestors have mostly been used to protect electrical equipment against over-voltages from lightning and switching events. The surge arrestor insulates the electrically connected part and the ground. This enables a deviation of surge current which may be induced on the equipment to be directed to the ground. The design of surge arrestors is not meant to eradicate the presence of lightning but rather to minimize the damage against lightning strokes within the vicinity of the conductor [5, 6]. In power distribution medium voltage systems between (6.6 kV -33 kV), lightning protection is achieved by adequate basic insulation level (BIL). The use of streamers for power systems line protection against lightning provides a comprehensive system. Ruling out the possibility of short-circuit faults, these devices are also capable of breaking the high follow current that appears on a line as the result of direct lightning strikes [7, 8] and [9].

II. Lightning Phenomenon

Overhead distribution lines are prone to lightning effects. This may compromise reliability of the system. The increase in lightning protection performance of distribution system depends on the insulation level capacity [10]. The mathematical model of lightning stroke may be defined as a current source I_0 with source impedance Z_0 discharging to ground. If the lightning strikes an object with impedance Z, then the voltage built up across the object is:

$$V = IZ \tag{1}$$

$$= I_0 \frac{ZZ_0}{Z + Z_0} \tag{2}$$

The true value values of the source impedance are not exactly known, but it is estimated to be between 1-3kΩ. The surge impedance may be calculated as:

$$SIL = \sqrt{\frac{L}{C}} \tag{3}$$

where, L and C are the distribution line inductor and capacitor parameters.

A. Case Study

The main in-coming feeder into the Substation (Renoster) which is mostly used by different operations at Wolvekrans Colliery as their source of supply, is currently experiencing lot of breakdown outages due to the current Douglas MMS Coal Plant 22kV network (Line 11) that keep on tripping whenever there is a lightning struck.. The line, load and source parameters are presented in Table I to II respectively. In Table III, the ratings of surge arrestor and lightning streamers are presented. The network representing the study is modeled using MATLAB. The models with surge arrestors and streamers installed on the power system is presented in fig. 1-2 respectively.

TABLE I. Distribution Line Parameters

Description	**Value**
Resistance per unit length (Ohms/km) [r]	0.011
Inductance per unit length (H/km) [I]	0.8674e-4
Capacitance per unit length (F/km) [c]	13.41e-6
Distribution line length (km)	10.5

TABLE II. Load And Source Parameters

Description	**Value**
Nominal voltage (V)	22000
Nominal Frequency (Hz)	50
Active Power P (W)	8MW
Inductive reactive power QL (positive var)	100
Capacitive reactive power Qc (negative var)	100
AC Current Source Peak Amplitude (A)	20kA

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TABLE III. LIGHTNING EQUIPMENT PARAMETERS

Lightning Protection Equipment	Rated Voltage (kV)	Rated fault current (kA)
Surge Arrestor	24	5kA
Lightning streamers	24	5kA

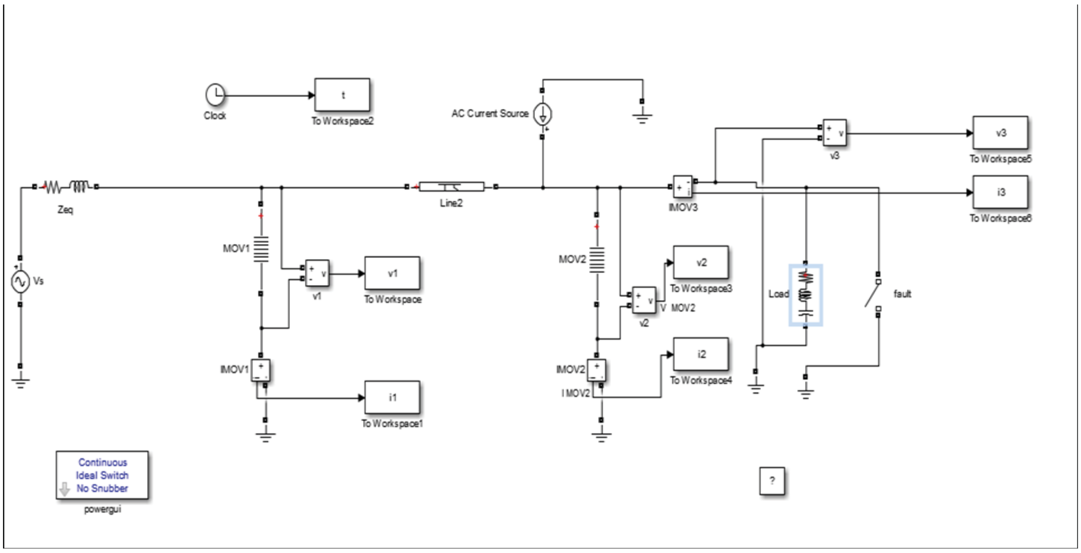

Fig.1: 22kV distribution line with surge arrestors

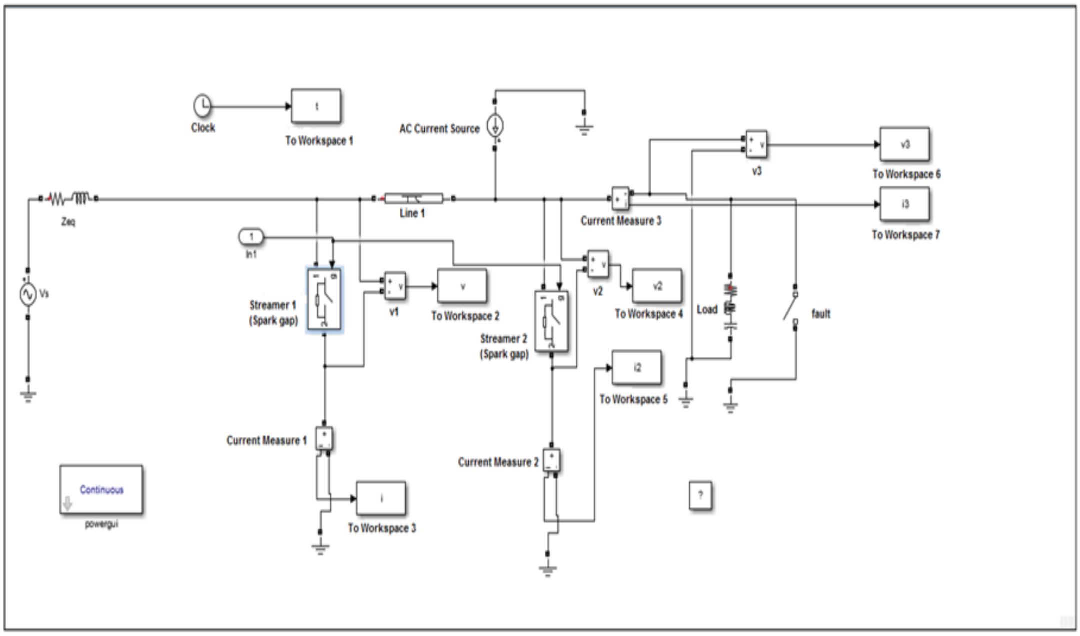

Fig.2: 22kV distribution line with streamers

III. RESULTS AND DISCUSSION

The study performed in this is to demonstrate how effective is surge arrestors and lightning streamers are to clearing the surge faults. The voltage and current waveforms using surge arrestors before clearing the fault is presented in Fig. 3 to 4 respectively. From the figures it may be clearly seen that the surge arrestor attempts to clip the surge voltage after 0.04 sec to return the system to steady state. The same analysis was done using lightning streamers and the results of the voltage and current waveforms are presented in Fig . 5 to 6. From the comparison, lightning streamers clips a the surge voltage of great magnitude with minimum time compared to surge arrestor.

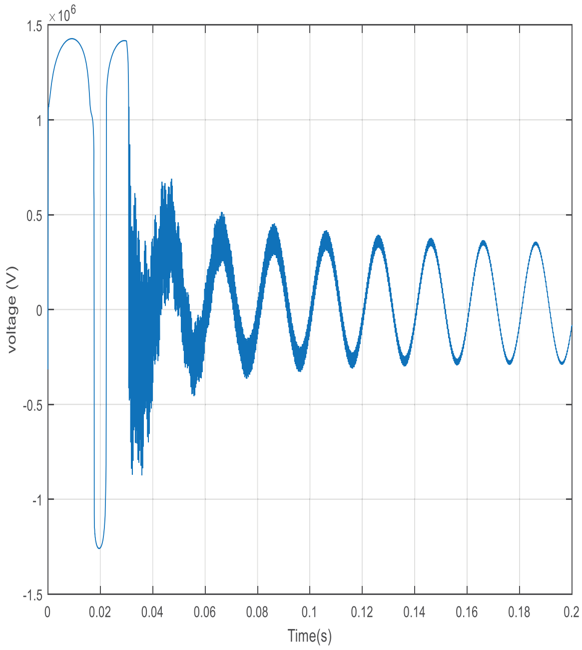

Fig. 3:Voltage waveform using surge arrestor (before clearing the fault)

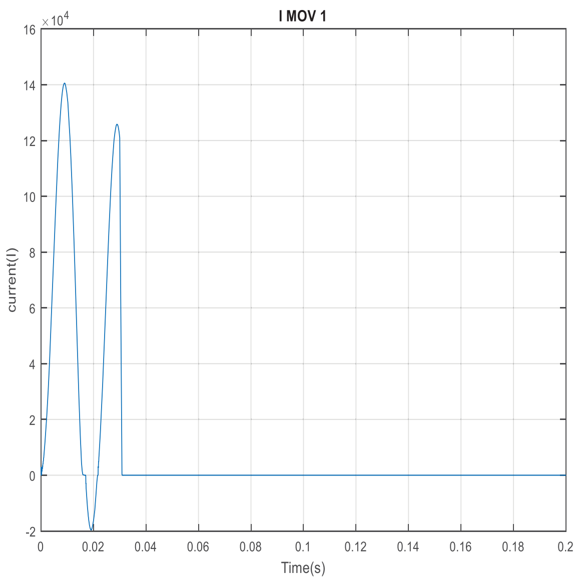

Fig. 4: Current waveform using surge arrestor (before clearing the fault)

Fig. 3: Current waveform using surge arrestor (before clearing the fault)

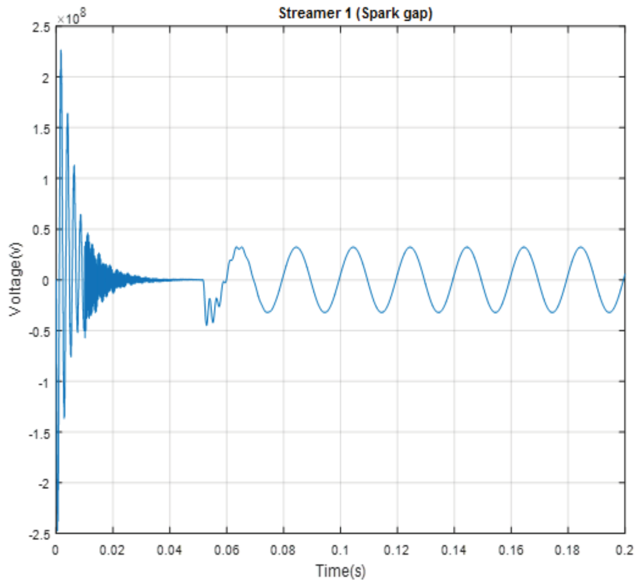

Fig. 5: Voltage waveform using surge arrestor (before clearing the fault)

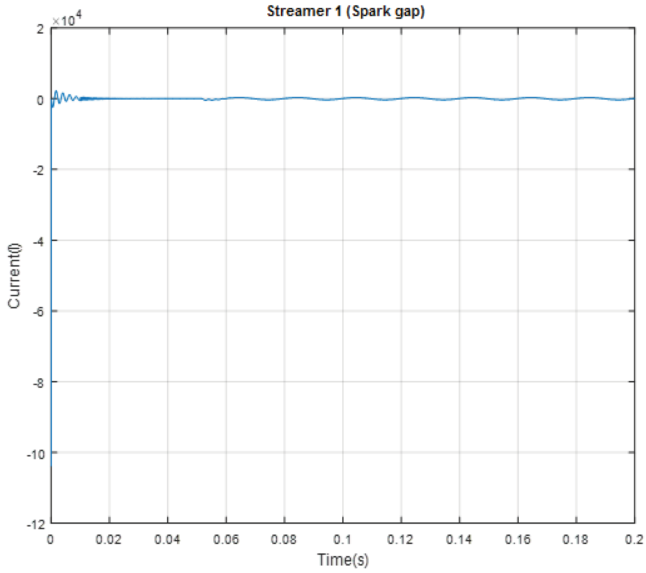

Fig. 6: Current waveform using surge arrestor (before clearing the fault)

To analyze the effect of lightning on a power system, the performance of surge arrestor and lightning streamers after clearing the fault is critical. The voltage and current waveforms using surge arrestors and lightning streamers is presented from Fig. 7 to 10 respectively. From the figures illustrating the performance of streamers and surge arrestor after clearing the fault, it may be seen that the streamers almost clears the fault current to zero compared to the surge arrestor.

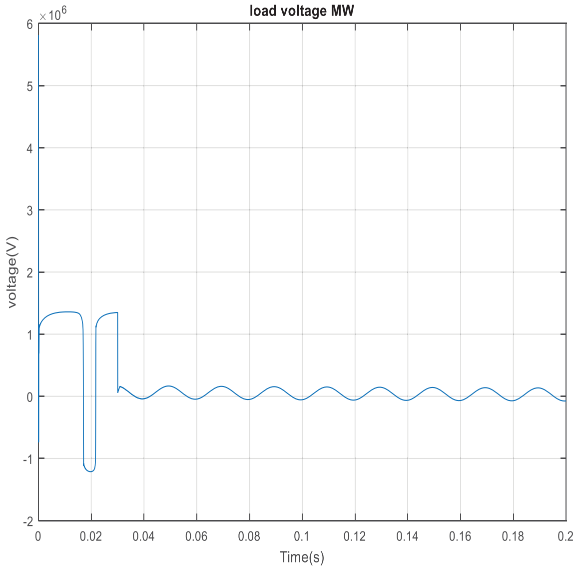

Fig. 7: Voltage waveform using surge arrestor (after clearing the fault)

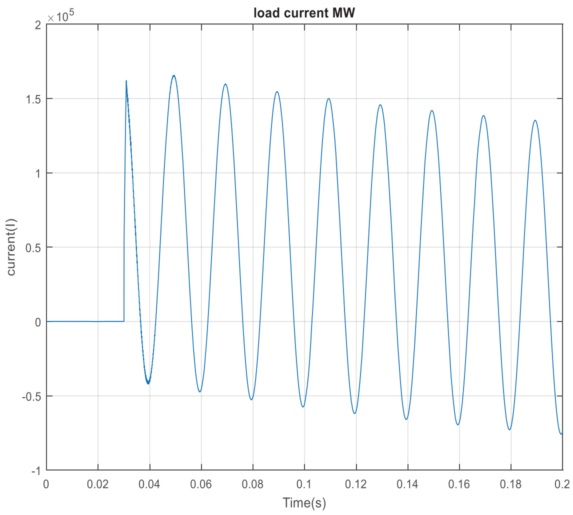

Fig. 8: Current waveform using surge arrestor (before clearing the fault)

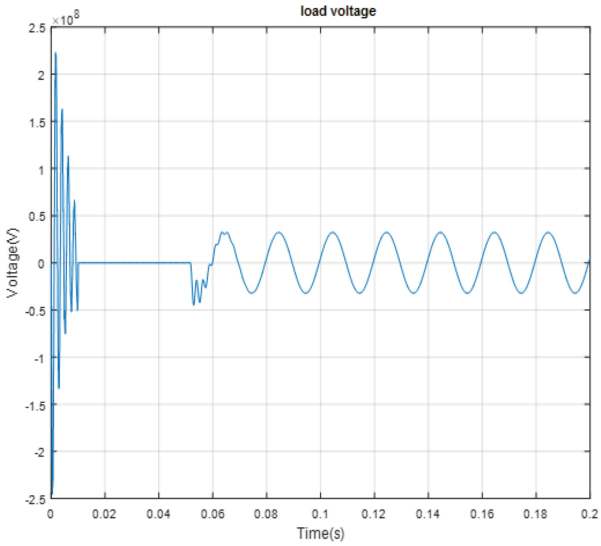

Fig. 9: Voltage waveform using surge arrestor (after clearing the fault)

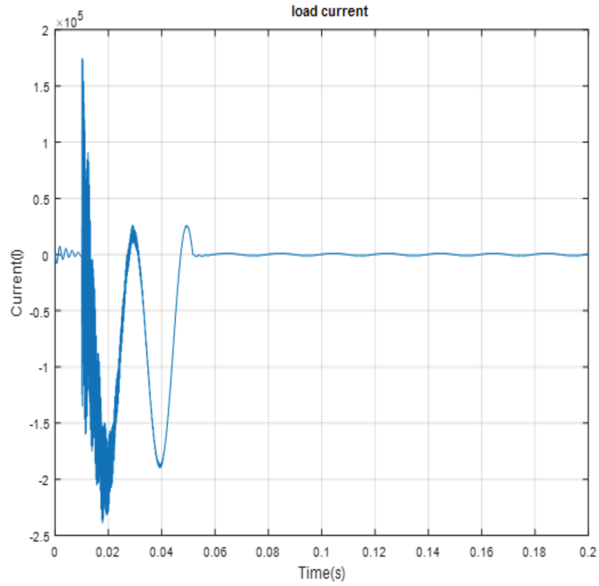

Fig. 10: Current waveform using surge arrestor (before clearing the fault)

IV. Conclusion

This paper outlines the impact of lightning protection using surge arrestors and lightning streamers. A model of an existing a 22kV power system is performed in MATLAB/Simulink library. From the results analyzed, it is seen that lightning streamers clips the surge voltages more efficiently than surge arrestors. The practical reason is that surge arrestors by design are not capable to handle direct lightning surges. This work, aims to provide technical advice to the management team on the lightning technology to be applied on their systems. Future work aims to determine optimal sizing of streamers.

V. References

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