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Techno-economic feasibility of lighting protection of overhead transmission line with multi-chamber insulator arrestors

K.T.M.U. Hemapala [a], O.V. Gnana Swathika [b,*], K.P.R.D.S.K. Dharmadasa [a]

[a] University of Moratuwa, Moratuwa, Sri Lanka
[b] School of Electrical Engineering, VIT University, Chennai, India

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ABSTRACT

The performance of transmission lines has a significant impact on reliability aspects of the power supply system of a country. The lightning back flashover effects are recognized as one of the major causes of transmission line outages. This paper focuses on studying the effect of Multi Chamber Insulator Arresters (MCIA) on lightning back flashover by transient modeling and subsequent simulation of a selected transmission line. Power System CAD (PSCAD) software program is utilized as the software tool for modeling and simulation of the 132 kV, Matugama-Kukule transmission line for this study. Simulation of the created transmission line model is carried out with and without MCIA to evaluate the improvements in lightning back flashover performance after installation of MCIAs in this transmission line. This analysis will contribute to improve the reliability of the Sri Lankan electrical power system.

1. Introduction

A lightning stroke terminating in the shield wires produces waves of currents and voltages travelling on the shield wires known as travelling waves, and reflections occurs at every points where the impedance is discontinuous (Statistical Digest, 2014, 2014; Datsios et al., 2014). The occurrence of component failures due to lightning are predominant in areas where there is significantly high keraunic level. Grounding devices with low impedance and huge quantum of current carrying capability are suggested in (Ekonomou et al., 2007; Minnaar et al., 2012; Visacro et al., 2012) as a solution.

Direct lightning triggers insulation failure, but indirect lightning are more frequent in the presence of tall structures. Most literature focuses on indirect lightning performance which is challenging in terms of computation and it requires solving the field-to-line coupling iteratively before assuming the stochastic variables. It is hence necessary to identify the optimal spacing to be maintained between arrestors (Banjanin et al., 2015; Protection against lightn, 2006a; Visacro and Alipio, 2012; Protection against lightn, 2006b; Napolitano et al., 2016).

The surge voltages that maybe developed across the line insulators due to lightning could exceed the Critical Flashover Voltage (CFO) (Mikropoulos et al., 2014; Napolitano et al., 2014; De Conti et al., 2010). Towers which have high tower footing resistance in lightning prone areas have higher probability of back-flashover occurrence and the cases are worst in hilly terrains (Maslowski et al., 2016; Napolitano et al., 2015; Wu et al., 2016; Jinpeng et al., 2015; Visacro et al., 2011; Brignone et al., 2017a). Back-flashovers occur frequently in overhead lines (OHL) with ground wires. (Chen and Zhu, 2014; Brignone et al., 2012, 2014, 2017b; Andreotti et al., 2015; Banjanin, 2018).

A simulation model is created using the electromagnetic transient analysis subcomponent of PSCAD/EMTDC, which depicts the transmission system as a collection of tower, insulator, transmission line and grounding devices, in order to determine the optimal way of protecting the transmission system from direct lightning. Most of the transmission lines in Sri Lanka traverse through hilly terrains prone to heavy lightning as a result of which many lines are prone to back flashover problems which reduce transmission system reliability. Kukule-Matugama, 132 kV transmission line is one such line that experiences back-flashovers very frequently. As a result, the Kukule Power Station (35 MW X 2) is separated from the transmission network most of the time causing low system reliability. This paper analyzes the back-flashover of Kukule-Mathugama, 132 kV transmission line by performing transient modeling and

* Corresponding author.
E-mail addresses: udayanga@elect.mrt.ac.lk (K.T.M.U. Hemapala), gnanaswathika.ov@vit.ac.in (O.V. Gnana Swathika), dhammika.dharmadasa@gmail.com (K.P.R.D.S.K. Dharmadasa).

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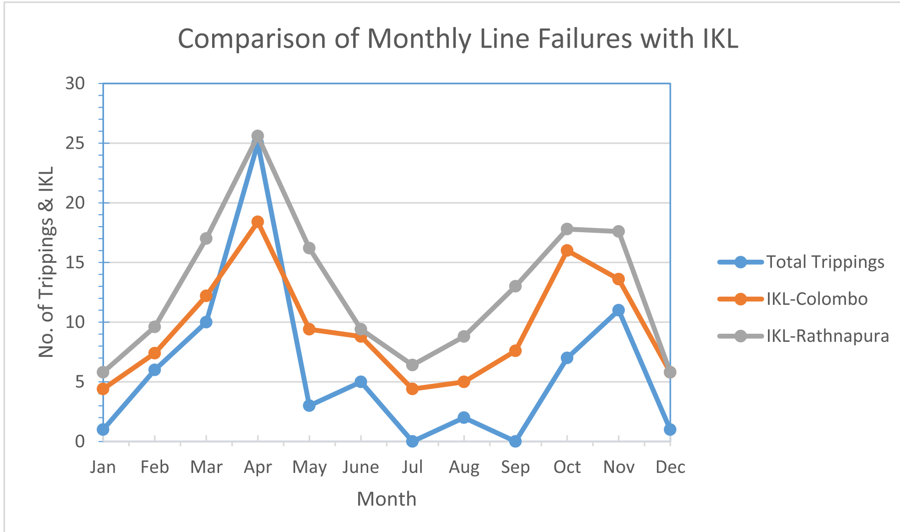

Fig. 1. Comparison of monthly line failures with IKL

simulation. The network is simulated with and without the Multi Chamber Insulator Arresters (MCIA) in the model. The improvement in lightning back-flashover performance is also evaluated after installation of the MCIAs in the selected transmission line.

Section 2 discusses the problem formulation of this paper which highlights the necessity to avoid double circuit failures in transmission line. Section 3 elaborates the complete line model along with MCIA model and back flashover control model using EMTP/PSCAD. It also depicts the method of simulation incorporated in the models. Section 4 showcases the behavior of transmission line with and without MCIA model. It also specifies the optimum location at which the MCIA models may be placed to eradicate the back-flashover event. This section also indicates electrical and mechanical properties of the insulator used in the transmission network.

2. Problem formulation

The selected 132 kV, Matugama-Kukule transmission line is a double circuit line which delivers the power generated by the Kukule Power Station (35 MW * 2) to the national grid. Since a single circuit of Lynx conductor carries approximately 80 MW of power at the rated voltage, the full power output of the power plant may be transmitted even with the tripping of single circuit. Therefore, only the tripping of both circuits is considered for the analysis. Kukule Power Station is used only during the peak load and a sudden outage of this power station creates a drop in the system frequency. In such situations, the loss of generation is recovered from the spinning reserve. The loss of Kukule generation tends to create low voltages in the southern part of the transmission network and in some occasions under frequency load shedding schemes may also have to be activated. Therefore, it is of utmost importance to avoid any double circuit failures by improving the lightning performance of the selected Matugama-Kukule transmission line to avoid partial failures of the power system and the associated heavy financial losses.

According to the past performance records of this transmission line, it is evident that the failure of this transmission line subjects a great influence on the partial failures of the system. It is observed that most of the line outages are due to the effect of frequent lightning strikes that are recorded during April to June and October to November. Fig. 1 illustrates the relationship of Isokaraunic Level (IKL) with the number of transmission line failures in each month.

Reduction in the tower earthing resistance is a key solution to avoid back-flashovers. However, it is not practical and economical when the towers are located at hilly areas where the soil condition is poor. Another solution for preventing back-flashover is by adopting unbalanced or improved line insulation. But this solution proves uneconomical due to the requirement of additional insulator discs which may need modifications in the towers. It is found that the most economical and effective way of preventing back-flashovers is to install Transmission Line Arresters (TLA) at selected tower locations. However, installing TLAs also need special preparations of cross arms or special means of installing on

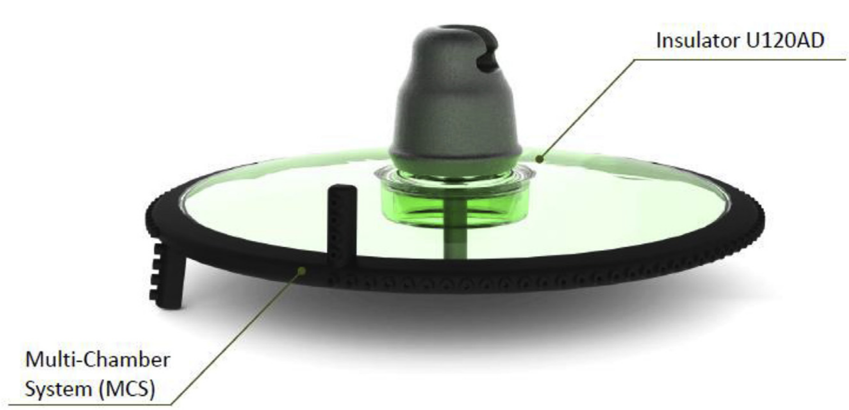

Fig. 2. U120D Glass MCIA.