Chapter - 2

Problem identification

2.1 Introduction

The performance of a power system is mainly depending on the performance of transmission lines. Therefore continues operation of transmission lines without sudden outages is utmost important for the performance in the view point of power delivery as well as system stability. Lightning effects on transmission lines are one of the major reasons which lead to sudden line outages. As described in the section 1.5 of the previous chapter, the back flashover events are the dominant reason of line outages.

The selected 220kV Biyagama-Kotmale transmission line is a double circuit line which delivers the largest amount of power generated by Mahaweli Hydropower Complex to the main load centre at Colombo. Sudden outage of these two circuits creates an excess power generated at Kotmale end and tends to flow through the other two 132kV lines feeding to Badulla and New Anuradhapura Substations connected to Kotmale and Rantembe Substations respectively. Out of these two lines, the new Anuradhapura line has higher impedance due to its higher line length compared to Rantembe-Badulla line. Therefore, Rantembe-Badulla line is more vulnerable to trip off due to overloading. As a result the Kotmale to New Anuradhapura 132kV line will get overload and resulting in loss of all lines connected to the Victoria generation end. Ultimately this creates a sudden loss of around 300MW to the system within few seconds of time which leads the system towards total failure.

Therefore it is utmost important to avoid any double circuit failures by improving the lightning performance of the selected Biyagama- Kotmale transmission line to avoid total failures and associated severe financial losses.

2.2 Preliminary studies

According to the past performance records of this transmission line, it has been noticed that the failure of this transmission line has great influence towards a total failure of the system. Out of those, most of the line outages were due to the effect of lightning, since most of them were recorded in the months, April to June and October to November where the lightning is frequent.

2.2.1 The relationship between monthly Isokeraunic level and line failures

According to the study [4] it has been found that there is a clear relationship between the monthly Isokeraunic level (IKL) variations with the monthly average failures of this line. Tables and graphs showing the "monthly failures" and "IKL variation with monthly failure variation" respectively are reproduced here including few more recently available data. Table 2.1 shows the monthly line failures from 2004 to 2009 whereas the Figure 2.1 illustrates the relationship of IKL level with the monthly transmission line failures.

Year	January	February	March	April	May	June	July	August	September	October	November	December	Total
IKL[5]	2.5	3.3	7.4	13	7.7	2.2	2.9	2.6	3.7	6.2	6.5	3.3	
2004	0	0	0	0	0	0	0	0	0	1	0	0	**01**
2005	0	1	0	3	1	3	1	0	0	0	5	0	**14**
2006	0	0	0	0	0	0	0	0	1	0	0	0	**01**
2007	0	0	0	0	0	0	0	0	0	0	0	0	**00**
2008	1	0	0	1	3	2	0	0	0	0	0	0	**07**
2009	0	0	0	0	3	0	0	0	0	2	2	4	**11**
Total	**1**	**1**	**0**	**4**	**7**	**5**	**1**	**0**	**1**	**3**	**7**	**4**	**34**

Table 2.1 – Monthly line failures and IKL

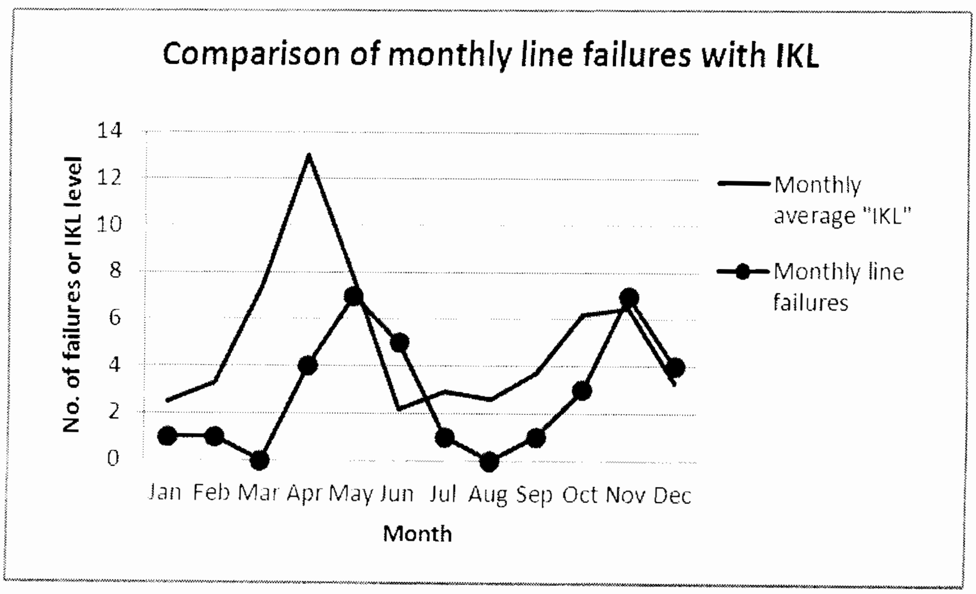

Figure 2.1 – Comparison of monthly line failures with IKL

2.2.2 Line sections having higher probability of insulator failures

It has been found in the previous study [4], that there are two line sections of the selected transmission line have higher probability of insulator damages or flashovers marks according to the breakdown and maintenance records. Those are:

1. The line section having towers, no.33 to 50 and
2. The line section having towers, no.85 to 95 from Kotmale side

Further it has been found that the selected transmission line is crossing over the 132kV Athurugiriya - Polpitiya transmission line at the above two line sections [4]. Therefore the above two line sections have been selected for the study described in this report.

2.3 Back flashover effects on transmission lines

As described in section 1.5, back flashover events occur when the lightning strikes on either tower or shield wires. These strikes produce waves of currents and voltages travelling on the shield wires called travelling waves and reflections occurs at every points where impedance discontinuities. Accordingly surge voltages can be developed across line insulators exceeding the Critical Flashover Voltage (CFO) where flashovers occur from tower to line called back flashovers. The following list shows the parameters those affect the line Back Flashover Rate (BFR).

a) Ground flash density (See equation 1-1)
b) Surge impedances of the shield wires and towers
c) Coupling factors between conductors
d) Power frequency voltage
e) Tower and line height
f) Span length
g) Insulation strength
h) Footing resistance and soil composition

According to a previous study [4] the BFR for the selected Biyagama-Kotmale transmission line is calculated as 4.37per year, whereas there is no direct flashover failures can be expected. Therefore it is concluded that the total expected failures are only due to the back flashover failures of this line which is 4.37per year. Further the calculated expected failure rate 4.37per year is justified by the observed value which is only 4.6per year [4].

2.3.1 Earth faults at power frequency voltage due to back flashover events

An ionization path forms between the Arc horn gaps, when the air insulation between the gaps is breakdown due to a back flashover event. This ionization path acts as a conductive path to form an earth fault condition even at the power frequency voltages. When a transmission line protection system is provided with auto-reclosing facility, the circuit breaker will be reclosed automatically with a set time delay (500ms) after a back flashover trip event to avoid permanent line outage. An earth fault can be developed at power frequency voltage if the ionization path is persists at the moment of first reclosing operation. Therefore the reclosing operation will be blocked and the circuit breaker will be at opened position (breaker lockout) leaving the transmission line at dead condition. This type of line outages can develop severe system instabilities and even total failures. Such events have been reported in the selected Biyagama-Kotmale transmission line in the past history of operation.

Therefore this issue has been addressed in this report by proving a software based analysis approach to provide solutions through a new concept of providing protection called transmission line mounted arresters (TLA).

2.4 Prevention of Back flashover events

Improving tower earthing resistance is the key way of avoiding back flashovers. However it is not practicable as well as not economical when the towers are located at hilly areas where the soil conditions are very bad. Unbalanced or improved line insulation is another way of preventing back flashovers. However this is also not an economical way due to the requirement of additional insulator discs as well as this may need modifications in the towers. Therefore it is found that the most economical and effective way of preventing back flashovers is to install Transmission Line Arresters at selected tower locations.

2.5 Project objectives

The objectives of this study are:

1. Modeling and simulation of 220kV Biyagama-Kotmale power transmission line in EMTP software (PSCAD) for lightning back flashover analysis
2. Conducting sensitivity analysis of line model for back flashover effects
3. Selection and modeling of Transmission Line Arresters (TLA) for EMTP simulations
4. Simulation and performance analysis of line model combined with selected TLAs