Improving Tower Grounding and Insulation Level vs. Line Surge Arresters for Protection of Subtransmission Lines

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Abstract – *Since renewable wind power plants are usually installed in mountain regions and high-level lands, they are often prone to lightning strikes and their hazardous effects. Although the transmission line is protected using guard wires in order to prevent lightning surges to strike the phase conductors, the back-flashover may also occur due to tower footing resistance. A combination of back-flashover corrective methods, tower-footing resistance reduction, insulation level improvement, and line arrester installation, are analyzed in this paper for back-flashover rate reduction of a double-circuit 63 kV line in the south region of Fars province. The line crosses a mountain region in some sections with a moderate keraunic level, whereas tower-footing resistance is substantially high at some towers. Consequently, an exceptionally high back-flashover rate is recorded. A new method for insulation improvement is studied and employed in the current study. The method consists of using a composite-type creepage extender in the string. The effectiveness of this method for insulation improvement of the string is evaluated through the experimental test. Simulation results besides monitoring the one-year operation of the 63-kV line show that due to technical, practical, and economic restrictions in operated sub-transmission lines, a combination of corrective methods can lead to an effective solution for the protection of transmission lines against lightning.*

Keywords: *BF rate, grounding system, insulation level, lightning protection, line surge arrester*

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I. Introduction

Lightning is one of the major causes of transmission line failures. These failures can be caused either by a direct lightning strike to the phase conductors (shielding failure) and results in a flashover or originate back-flashover (BF) by the lightning strike to the shield wire, tower, or ground [1]. Generally, the transmission lines are protected against direct lightning strikes using shield wires. However, in some cases; esp. the regions with high ground resistance, BF may also result in line insulation failure. Different protective schemes have been proposed in the literatures to mitigate BF. The most common approaches for transmission lines are improving the tower grounding system, increasing the insulation level, and installing line surge arresters (LSA) [2]. In this paper, these common approaches are studied for a sub-transmission network in the south region of Fars province, running partly through hilly and mountainous terrain usually with high ground resistivity. Also, considering the geographical topology of the region, the transmission line had experienced increased exposure to lightning, in conjunction with the relatively high keraunic level of this region. Consequently, this line is liable to cause undesirably high BF and failure rates. A straightforward remedial measure is tower-footing grounding impedance enhancement [3]-[7]. By reducing this impedance the amplitude of lightning overvoltage across the insulator string decreases which lowers the probability of flashover. However, due to the terrain characteristics, it is sometimes very hard or economically nonviable [3]. Therefore, other corrective measures, i.e. insulation level improvement or installation of LSAs should also be studied alongside, to reach a technical and economical scheme for enhancing the line reliability [8].

LSAs are broadly used to protect transmission lines from lightning surges in recent years [8]-[10]. Considering the nonlinear characteristic of LSAs, they can limit the overvoltages between phase conductors and tower structure, preventing the occurrence of flashover across insulators [9]. Easy installation due to low weight and small dimensions and high protection efficiency are the main advantages of LSAs. Installing the LSAs in all phases is highly effective in preventing the occurrence of BF. However, installation and maintenance costs of the arresters in addition to the price of the device, are significant in specific. Thus, installing just on critical towers along the line and on the most effective phases of the tower should be investigated. However, the constraint in the proper application of LSAs to count these matters is not addressed thoroughly in the literatures.

Ref. [8] assesses the effectiveness of applying LSAs in transmission lines employing computational simulation. The performance of partial use of LSAs (in critical towers along the line and/or in certain phases) is evaluated both on the stricken towers and unprotected adjacent towers; considering different values of tower-footing impedance. However, the criteria to select the critical towers/ phases are not reported. In order to improve the insulation level of the line, the number of the disc insulator units is increased in the cap-pin type insulator strings. However, regarding the clearance constraints, tower loading, etc. al., a technical limitation always exists to achieve a desirable BF rate by this method. The limitation is more restricted in the current-operated lines. In [11] the relation between the impedance of the grounding system and the number of the disc insulator units in the string is studied in BF rate. Different tower grounding configurations and soil resistivity is considered in the analysis. However, the LSA and its effects on the BF rate are not analyzed.

A combination of corrective methods; tower-footing impedance reduction, insulation level improvement, and LSA installation, are analyzed in this paper for BF rate reduction of a double-circuit 63 kV line in the south region of Fars province. The line is 28.1 km long and crosses a mountain region in some sections with a moderate keraunic level (3.5 flashes/km2-year) whereas soil resistivity is about 800-1000 ohm-m and the measured tower-footing resistance is substantially high at some towers. Consequently, an exceptionally high BF rate is recorded (34 faults/year). A new method for insulation improvement is studied and employed in the current study. The method consists of using a composite-type creepage extender in the string. The effectiveness of this method for insulation improvement of the string is evaluated through the experimental test. The technical and executive aspects are presented in this paper. However, since cost analysis is also a wide-ranging issue, it is not presented. The lightning performance is analyzed by numerical simulations through EMTP-RV software. Results show that a combination of corrective methods can lead to an effective practical solution for the protection of transmission lines against lightning.

II. Transmission Line Modeling

The effectiveness of the combination methods for the BF rate reduction of the studied sub-transmission line is assessed through numerical calculation in EMTP-RV software. The utilized models and parameters are discussed in the following.

A. Tower

The multistory model [12] is used for the tower model in order to enable the calculation of each insulator voltage. The tower model is represented by four distributed-parameter lines. Each section consists of a loss-free transmission line and lumped constants consisting of a damping resistance shunted by an inductance to represent traveling-wave attenuation and distortion, as illustrated in Fig. 1. The cross arms are also considered for more precise modeling of over-voltage waves. Table I gives the surge impedance values of different sections of the tower for the understudy 63 kV line. The surge propagation velocity is assumed to equal 85% of the speed of light [13].

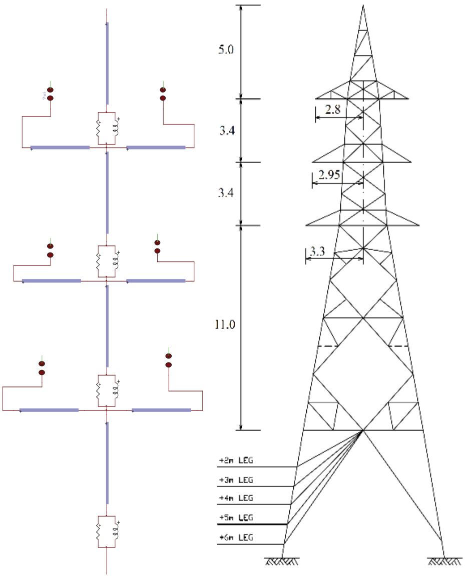

Fig.1. The tower dimensions and circuit model unit model

TABLE I
STUDIED SUB-TRANSMISSION LINE DATA

Parameters	Values
Span length (m)	300
Conductor/ shield wire diameter (mm)	19.53 / 9.8
DC resistance of conductor/ shield wire (20 C) (Ω/km)	0.147 / 1.46
Phase conductor/ Shield wire sag (m)	4 / 2
Number of phase conductor bundle/ shield wire	1 / 1
Number of insulator string disks / total clearance (m)	5 / 0.876

B. Overhead line model

The overhead line is simulated using a frequency-dependent line model. The Frequency Dependent line model takes into account the frequency dependence of *R* and *L* (series resistance and inductance of the line per unit length. This model is also based on modal decomposition techniques. The modal transformation is used to relate modal and phase quantities. The model represents frequency dependence by approximating the rational functions and the characteristic impedance and the propagation function for each mode. The details of the model can be found in [13].

C. Lightning strike model

Modeling of the lightning strike has been analyzed in research reports in which CIGRE and Heidler are the most often used models [7]. In [14] these two models were analyzed and showed that the CIGRE model is stricter in the calculation of lightning overvoltages and is used in the current study. CIGRE offers a lightning strike model by a current source and a parallel resistance, representing the lightning channel impedance. Lightning channel impedance is selected as 1000 Ω.

D. Tower grounding system model

The tower grounding system model is an important issue in the reflection of lightning current waves and the simulation of overvoltages across insulator strings [15]. The primary response of electrodes subjected to impressed currents is grounding potential rise (GPR). For very fast time-varying currents, such as those of lightning return strokes, this response is quite different from that resulting from impressed low-frequency currents [5]. Besides the internal losses in the ground rod and grounding conductor, the longitudinal high-frequency lightning current correspondingly establishes a magnetic field inside the electrode and around it, which leads to the GPR. The equivalent circuit including a series resistance (*Rdx*) inductance (*Ldx*) branch is used to model these effects for a single piece of the tower grounding system. Furthermore, the current establishes an electric field in the soil which determines the flow of conductive and capacitive currents. The branch with the parallel conductance and capacitance (*Gdx*, *Cdx*) in the equivalent circuit of Fig. 2 models this effect.

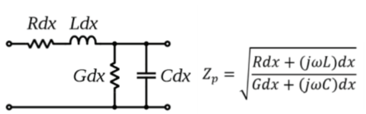

Fig. 2. Partial equivalent circuit model for the grounding system

In order to consider the whole grounding configuration, the electromagnetic coupling between all existent elements has to be computed (capacitive, inductive, and resistive coupling). Thus, the knowledge of the entire grounding behavior requires the solution of a series of circuits similar to the presented one, connected according to the electrode configuration topology and taking into account mutual effects. Amongst several complex models proposed in different literatures [15], [16] indicates that modeling of the tower footing grounding system by the simple surge impedance leads to similar results compared to other complex and accurate models. Based on Fig. 2, the impulse grounding impedance Z_P is given by the ratio of the GPR and stroke current peaks ($Z_P = {V_P}/{I_P}$) that is the impedance seen from the current injection point that corresponds to the ratio between the potential developed at the electrode (concerning a remote point) and the applied current. Although the impulsive grounding impedance is dependent on the current waveform and front-time parameters, however, the instantaneous ratio between the voltage and current values is practically constant [5]. Therefore, the impulsive impedance measured by Sonel MRU-200 [22] is considered in the current study.

Another discussable factor in grounding system simulation is the current dependence of a tower footing impedance to model the soil ionization [17]. It has been illustrated that the current dependence decreases a lightning surge voltage at the tower and thus decreases the probability of BF. Therefore, neglecting this fact would result in a more severe overvoltage.

E. Insulator string flashover model

The insulator string flashover development is modeled based on the CIGRE leader propagation method [18]. The formula is

$$\frac{dl}{dt} = ku(t)\left(\frac{u(t)}{d-l} - E_0\right) \quad (1)$$

Where d is the gap length, l is the leader length, $u(t)$ is the actual voltage across the gap, E_0 is the critical leader starting gradient and k primarily depends on the upward curvature of the time-lag curve for the standard lightning wave. By this model, the flashover on the insulator appears when the leader length (l) is equal to or larger than the air gap distance.

F. LSA model

The surge arrester model proposed by the IEEE W.G. 3.4.11 [19] is used in the current study for modeling LSAs. The model parameters are calculated using the test report data in the arrester data sheets provided by the manufacturer. The LSA data sheet is added in the Appendix.

G. *Overall sub-transmission line model*

Based on the models of the components presented before, the double-circuit 63 kV sub-transmission line model is modeled in EMTP-RV as shown in Fig. 3. Two spans on each side of the lightning strike location are modeled to consider the reflected waves from the adjacent towers, and also to study the effect of LSA on over voltages impinging on these towers. Also, in order to eliminate the reflection of the other part of the line, the length of the last spans on both sides is set to 10 km.

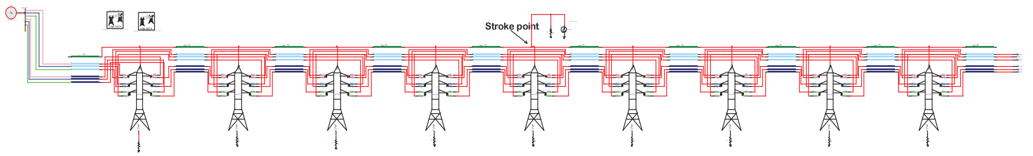

Fig. 3. The system model in EMTP-RV

III. BF Rate Estimation

The BF rate can be estimated as in Eq. (2) by multiplying the probability of the minimum lightning current amplitude causing BF (P_I), the number of the lightning strike to 100 km of line per year (N_L), and the empirical coefficient (0.6) presenting the percentage of the lightning towards to the line that strikes the towers.

$$BFR = 0.6 \times N_L \times P_I \qquad (2)$$

$$P_I = \frac{1}{1+(\frac{I}{31})^{2.6}} \qquad (3)$$

Where N_L is the number of lightning strikes to 100 km of line per year, P_I is the probability of the minimum lightning current amplitude causing BF, I is the minimum lightning current amplitude causing BF in the case when lightning strikes the top of the overhead line tower [kA]. N_L in Eq. (2) is assumed to be 60 strikes/per year/100 km according to the tower geometry. It is noticeable that since the three corrective methods are compared based on Eq. (2), this value is not an effective parameter in the assessments. The value I is estimated through EMTP-RV simulations in each BF remedial countermeasure to evaluate the effectiveness of the methods.

IV. Assessing The Creepage Extenders for Line Insulation Improvement

The creepage extenders are widely used recently for improving the flashover performance of substation insulators in ice, snow, and pollution conditions [20]-[21]. Creepage Extenders increase the flashover performance of insulators by reducing the surface electric stress, reducing the leakage current, and increasing the electric strength of the insulators. The extenders are commonly used in post-insulators however, exploiting in transmission line insulator string can also gain interesting results for the improvement of line insulation level where there is the restriction to add disks to the insulator string. The performance of the silicon-rubber creepage extender in line insulator string is evaluated by laboratory tests. The effect of installing the extender is assessed in three positions along the insulator string i.e. on the upper part of the string; near the tower structure, on the middle of the string, and the lower part; near the live conductor. The lightning impulse withstand voltage level of a 3-disc insulator string is tested based on IEC60383-13. The tests were done in the HV laboratory of “PARS ARRESTER” company with the specifications and conditions mentioned in Table II.

TABLE II
LABORATORY TESTS SPECIFICATIONS AND CONDITIONS

No.	Test performed	Normative document
1	Power frequency withstand voltage	IEC60383-14
2	Lightning impulse withstand voltage	IEC60383-13

Laboratory test results for power frequency and lightning impulse withstand voltage level of a 3-disc insulator string are as follows. The insulator is a ceramic cap-pin insulator type 120 KN.

IV-1. Dry power frequency withstand voltage test (*1 insulator*)

IV-1-a. Without creepage extender (CE): 74 kV

IV-1-b. With CE: 84 kV

IV-2. Wet power frequency withstand voltage (*1 insulator*)

IV-2-a. Without creepage extender (CE): 43 kV

IV-2-b. With CE: 56 kV

IV-3. Dry power frequency withstand voltage test (*3-insulator string*)

IV-3-a. Without CE : 176 kV

IV-3-b. With CE (*installed on the upper part of insulator string*): 188 kV
IV-3-c. With CE (*installed on the middle part of insulator string*): 188 kV
IV-3-d. With CE (*installed on the bottom part of insulator string*): 183 kV
IV-4. Lightning impulse withstand voltage test (*3-insulator string*)
IV-4-a. Without CE : 279 kV
IV-4-b. With CE (*installed on the upper part of the insulator string*): 329 kV
IV-4-c. With CE (*installed on the middle part of insulator string*): 328 kV
IV-4-d. With CE (*installed on the lower part of the insulator string*): 320 kV

Results show that adding the extender on the upper part of the string; near the conductor can obtain the most improvement and increase the lightning withstand level by about 18%.

V. Corrective Measures Analysis

The lightning performance of the transmission lines is highly dependent on the impedance of tower footing. In the transmission lines, the towers are connected to the ground using ground electrodes, which can be a simple electrical conductor or have a complex metal structure in order to obtain a lower equivalent impedance. When the lightning strikes the guard wire, the lightning current is divided into three components: (1) part of the current that passes through the tower (I_{tower}), (2) part of the current from the guard wire forward ($I_{forward}$) and (3) a portion of the current from the guard wire facing backward ($I_{backward}$). Reference [23] shows that I_{tower} is the largest part of these three currents. In this case

$$I_{forward} = -I_{backward} \tag{4}$$

$$I_{stroke} = \frac{V_{tower}}{Z_{tower\ foot}} + \frac{2\ V_{tower}}{Z_{guard\ wire}} \tag{5}$$

When the lightning wave reaches the ground (at the tower foot), the reflected wave returns to the tip of the tower with reverse polarity, which is the primary effect of the lightning wave. The next effects are the reflections coming from the ground electrodes of the nearby tower, etc. Ignoring the wave impedance of the tower against the tower-footing impedance ($Z_{tower\ foot}$), the voltage at the top of the tower, or in other words the voltage of the guard wire is calculated as follows:

$$V_{tower} = I_{stroke}\ \left(\frac{Z_{guard\ wire}}{2+\frac{Z_{guard\ wire}}{Z_{guard\ wire}}}\right) \tag{6}$$

Therefore, considering the coupling between the guard wire and the phase wire (k), the voltage at both ends of the chain of insulators is equal to:

$$V_i = (1-k)V_t \tag{7}$$

If V_i is higher than the lightning withstand voltage of the insulator, it will cause a flash on the insulator and return arc phenomenon. The numerical coupling coefficient is considered between 0.15 and 0.3 for overhead transmission lines. Since the coupling coefficient has an inverse relationship with the distance between the conductors, therefore, for the lower phase conductors whose distance is greater than the guard conductor, the coefficient k is smaller and the voltage between the two ends of the insulator is higher, and the probability of arc return is higher.

A. Tower-footing impedance effect

Considering the traveling wave theory, the lower the tower-footing resistance, the higher the amplitude of the lightning reflection wave, so the overvoltage at the tip of the tower will be reduced and lowers the possibility of back flashover. According to Eq. (7), if we assume the lightning current is 20 kiloamperes and the wave impedance of the wire guard is 300 ohms, for the different tower-footing impedance, the voltage value at the top of the tower is obtained as shown in Fig. 4. It can be concluded that the impedance value of the tower foot will contribute a lot to the back flashover phenomenon.

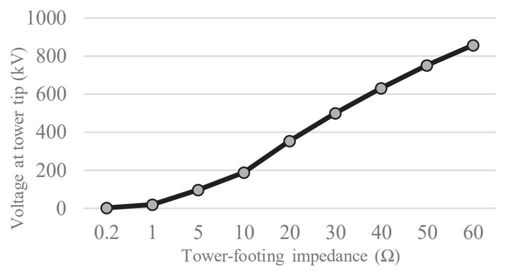

Fig. 4. The effect of the tower-footing impedance on the high voltage of the tower due to the lightning wave

B. The effect of LSA

LSA with its nonlinear $V \times I$ characteristics is applied between phase conductors and tower structure (parallel with insulator string) to limit overvoltages. It can limit the insulator overvoltage from exceeding the insulator BIL, which would lead to the occurrence of flashover across insulators. According to the above discussion, during the lightning stroke when the voltage V_i is applied on the insulator string, the LSA can pass the lightning current and prevent the back flashover.

VI. Procedure for the Assessment of Improving Methods

In the current study, three corrective methods: tower footing impedance reduction, insulation level improvement, and LSA installation, are analyzed for BF rate reduction of a double-circuit 63 kV line. The effect of each method on BF and also the combination of these are assessed to reach a practical and executable solution for failure reduction of the line. The measured tower-footing resistance along the under study line varies between 5 to about 40 Ω. Since the line crosses a mountain region in some sections whereas soil resistivity is about 800-1000 ohm-m, the tower-footing resistance cannot be reduced to the desired level. Therefore, insulation level improvement is also considered a secondary solution. However, due to restrictions in the conductor sag and also the tower loading, the general approach to increase the insulator unit number [11] cannot be achieved in many spans and towers a new approach is followed in this work by using silicon creepage extenders along the insulator string. Finally, in the cases where the former remedies are not approved, LSAs are located and used. The initially executed insulation of the under-study sub-transmission line consists of a five-disk cap-and-pin standard insulator string, the height of each is 0.146 m. The BIL of the insulator string is about 415 kV. Electro-Magnetic Transient Program Restructured Version (EMTP-RV) is used in the current study for the simulation of lightnings and its effects. EMTP-RV is a technically advanced software for simulation and analysis of power systems transient behavior. EMTP-RV has been widely used in power system studies to analyze switching and lightning over voltages to design power stations and substations from the viewpoint of insulation coordination. A schematic of the simulated system in EMTP-RV is shown in Fig. 2. An iterative simulation is done for the calculation of the BF rate using EMTP-RV linked by MATLAB. This procedure is applied considering different conditions of the tower-footing grounding resistance, LSA installation, and insulation level development by changing the flashover voltage of the insulator. The flow chart of the procedure described above is represented in Fig. 5.

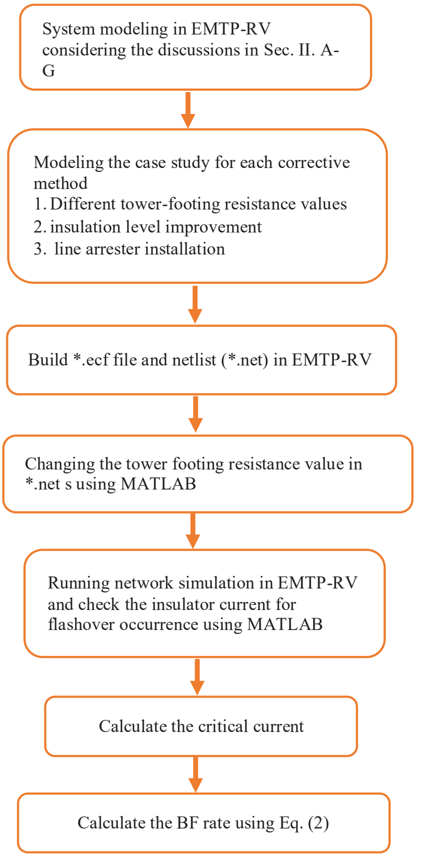

Fig. 5. Flowchart of the procedure used for calculating the BF rate

VII. Results and Discussions

According to simulations for the calculation of BF rate, estimated results for the studied overhead line are presented in Fig. 6. It is important to notice that just the lightning BF failures are considered in this study and the discussed remedies are compared based on their effectiveness in reducing the BF rate. A typical voltage across the insulator for a 20 kA lightning current and tower footing resistance of 20 Ω is shown in Fig. 7 for the six insulator string of the double-circuit line. It can be seen that flashover occurs on left-side phase B due to BF.

In order to improve the performance of the understudy 63 kV sub-transmission line, the tower footing resistance of all the towers is measured and the critical towers were selected. In order to ensure a given lightning performance of the line, a threshold value of the tower-footing grounding resistance is calculated by simulations. This value is determined by applying a methodology discussed in Fig. 4. Therefore, by applying this methodology, for the towers in which the grounding system improvement was feasible, this remedy is selected as the best economical and feasible solution. For the others where the grounding system modification was not feasible, one disc of the insulator along with one creepage extender is added over the insulator string. Moreover, the use of LSAs partially protecting the phases of the line can be an efficient measure to improve lightning performance whereas the other two methods are not efficient. Due to economic aspects, the LSA is installed on only one phase of the tower (the bottom phase). A typical executed corrective method is shown in Fig. 8. It is noticeable that for the effective performance of the LSA, it still requires observing threshold values of the tower-footing resistance of adjacent towers. For each tower necessary to install the LSA, the other two adjacent towers (upstream and downstream towers) must have a good grounding system. Otherwise over voltage wave may be transferred to the adjacent towers and cause a flashover.

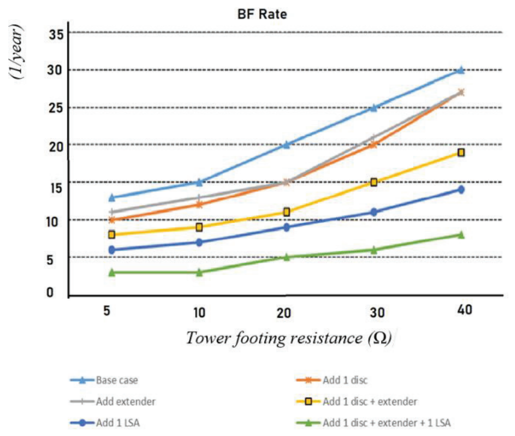

Fig. 6. BF rate calculation for different lighting protection methods

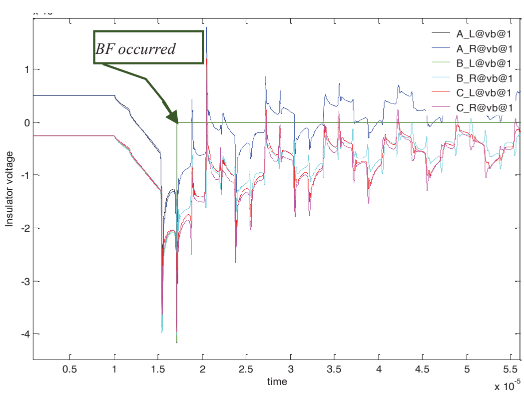

Fig. 7. Voltage across the insulator

Fig. 8. A typical modified tower of the 63 kV line

According to the above discussions, 41 towers out of 210 towers are modified by insulation improvement and installing one LSA at the bottom phase of one circuit. Results of monitoring one-year performance showed a grateful reduction of line outages from 17 to 3 (outage/year).

VIII. Conclusion

A combined BF corrective method is used in the current study to improve the performance of the sub-transmission lines BF. Tower footing resistance reduction, insulation level improvement, and LSA installation, are analyzed for BF rate reduction of a double-circuit 63 kV line in the south region of Fars province. A creepage extender is used in addition to increasing the number of insulator disks for insulation improvement. The performance of the proposed combined method is evaluated by simulations and calculation of BF rate by linking MATLB and EMTP-RV software. Simulation results besides monitoring the one-year operation of the 63-kV line show that due to technical, practical, and economic restrictions in operated sub-transmission lines, a combination of corrective methods can lead to an effective solution for the protection of transmission lines against lightning. the one-year performance showed a grateful reduction of line outages from 17 to 3 (outage/year).

Appendix

GUARANTEED TECHNICAL INFORMATION OF LIGHTNING ARRESTER

ITEM	DESCRIPTION	TECHNICAL PARTICULARS 63 KV
1	**General**	
1-1	Manufacturer's name and country	PARS ARRESTER, I.R.IRAN
1-2	Manufacturer's type designation	**PAPL 060 -2K31**
1-3	Class (outdoor/indoor)	Outdoor
1-4	Applicable standard	IEC60099-4
1-5	Applicable site and ambient conditions :	
1-5-1	Max.design ambient temperature °C	+50
1-5-2	Min.design ambient temperature °C	-40
1-5-3	Design altitude above sea level m	2500
1-5-4	Pollution level	Very Heavy
1-5-5	Max. Permissible ice thickness mm	50
1-5-6	Design seismic accelraration	0.45g
1-5-7	Max. permissible wind velocity m/s	50
1-6	Document (test reports /outline/drawings/catalogues /maintenance & Installation manuals /instruction manuals/refrences/list of spare parts)	Available In case of order
2	**Rated values & characteristics:**	
2-1	Continous operating voltage KV	48
2-2	Rated voltage KV	60
2-3	Rated frequency HZ	$16^2/_3$ to 60
2-4	Reference voltage (under defined ambient temperature) KV	≥ 62
2-5	Reference current (under defined ambient temperature) mA	3
2-6	Continuous current (under defined ambient temperature) mA	1.5
2-7	Resistive & capacitive component of the continuous current (under Defined ambient temperature):	
2-7-1	Capacitive component mA	1.3
2-7-2	Resistive component mA	0.1
2-7-3	Total mA	1.5
2-8	Mas.residual voltage for lightning impulse current with 8/20 Microsecond wave shape with following peak values of impulses:	
2-8-1	5 KA KV peak	138
2-8-2	10 KA KV peak	147
2-8-3	20 KA KV peak	165
2-9	Max.residual voltage for switching impulse current with 30/80 microsecond Wave shape with following peak values of impulses:	
2-9-1	0.5KA KV peak	118
2-9-2	1 KA KV peak	122
2-9-3	2 KA KV peak	128
2-10	Max residual voltage for steep current impulse with 1/20 microsecond wave shape wth following peak values of impulses:	
2-10-1	10 KA KV peak	156
2-11	Nominal discharge current KA	10
2-12	Line discharge class as per IEC 60099-4	3
2-13	Specific absorbed energy capability KJ/KV(UR)	8
2-14	Power frequency voltage versus time characteristics ncluded? Yes/No	Yes
2-15	Max internal partial discharge at 1.05.UC pC	< 10
2-16	High current /short duration impulse withstand KA peak	100
2-17	Low current /long duration impulse withstand (Rectangular wave):	
2-17-1	Current KA peak	1 (1000 A)
2-17-2	Virtual duration of peak µsec	2000
2-18	Pressure relief capability KA/sec	63 @ 0.2Sec
2-19	Thermal capability to discharge a line with following characteristics:	
2-19-1	Thermal capability KJ	480
2-19-2	Length of line Km	360
2-19-3	Surge impedance of line Ω	78
2-19-4	Subjected to a switching surge KV	165
2-20	Max RIV level measured at 1.1 Um/ √3 and 1 MHZ µVolt	150
2-21	Will the voltage and currents (protected level) be affected by pollution on external insulation Yes/No	No
2-22	TOV capability for surge arrester in multiples of rated voltage (1Sec/10Sec) KV	71 / 67
3	**Constructional features**	
3-1	No.of arrester units	1
3-2	Rated voltage of each arrester unit KV	60
3-3	Dimension of each series non-linear resistance block:	
3-3-1	Diameter mm	58
3-3-2	Height mm	35
3-4	Total width of arrester mm	187 (Insulator)
3-5	Total height of arrester mm	869
3-6	Total weight of single unit kg	20
3-7	Total weight of arrester kg	20
3-8	Material employed in series non-linear resistance block	ZnO Block (Metal Oxide)
3-9	Sealing method of complete arrester	---
3-10	Method used to scaling test	---
4	**External insulation**	
4-1	Manufacturer's name and type of designation	PARS ARRESTER, Wacker (Powersil 310)
4-2	Material	High Quality Silicone

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