Performance Enhancement of Surge Lightning Arrester for Substations

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Abstract: The research communities have been much interesting on the protection as well as performance enhancement for substation. In this aspect surge arrestor plays an important role in order to restricting switching as well as lightning surges and sending those sugers to the earth. In another way the number of surge arrestor and position of those depends on the design of HV substation. Surge arrestors can be fixed on both sides of transformers, substations, reactors, capacitors, circuit breakers and for the lengthy bus bar, etc. Hence, if in the case over voltage the arrestors will failure, due to this substation will be at risk. Because of ageing phenomena or unprofessional quality in common situation surge arrestors get short circuited when it inclined. This paper aims three designs such as: (A) One & half breaker, (B) Double bus with double breaker, (C) Ring bus bar for separate location for surge arrestors. The highest voltage on the device can be measured by simulation in EMTP-RV at distinct lighting stroke positions. Much research report have been produced introduction with and without surge arrestors and concluded that with surge arrestor can enhance the performance.

Keywords: Lightning effect, High Voltage Substation, Surge Arrestor, EMTP-RV

Introduction: Substations are the important fragment of electrical network which supply the electrical power to the customer via distribution and transmission lines. Nowadays, substations are more crucial due to expansion in requirement of power as well as development of energy network. The main function of substation is to find as well eliminate the failures in the transmission network. The failures occurs by the reason of high voltages by lightning along with a lot of person will not get electricity due to switching. The occurrence of lightning strokes has been a major problem like it can produce a very high voltage that causes power supply breakages; this causes more damages to the substation's equipment [1]. Shield wires as well as surge arrestors are utilized to secure the network against the lightning surge. At the time of over voltages, shielding failure has been occurred this causes insulation failure to the equipment. To improve the efficiency of the network need to introduce surge arrestors to the existence networks so that the failure will be reduced [2]. The Surge arrestors are such devices that they installed in the middle of the phase as well as ground. The distribution and transmission lines have been secured by the surge arrestors. They provide a small impedance way to earth in order to extra voltage current. The relationship between potential and current (V-I) is non-liner of the surge arrestor [3]. The strategy of lightning overvoltage safety has been identified as per type, number as well as place of surge arresters inside substation. In years of 1980, ZNO polymeric surge arresters were introduced as well as brought in to operation upon the transmission lines [4]. Lack of operation skills of safety systems are the reasons like it is not operating when it should in operation failure and operating, when it should not in the false tripping [5]. Reasons for the failures of an arrester are may be over voltages are current, moisture ingress are the many units with the multi-unit arrester has been reasons due to the extrinsic pollution are more voltages, instability in thermal by the effect of excessive extrinsic pollution, extreme temporary over voltages, damages of several blocks within the some units because of energy as well as current release and it tends to extreme power density of the persist section of the arrester.

The mechanical burden tends to failure of electrical. Irregularities in ZnO slabs, low electrode bond with material, lack of outer insulation, etc. [6]. More heat and unpredicted aging produces because of the increment of leakage current [7]. The failure of arrester has a major effect on substation efficiency. Substation has been simulated due to electromagnetic transient program (EMTP) as well as the method of by cut set and the results in simulation.

Substation Simulation: This article has three main lay of design with high voltage substation (230/63 KVA), with one & half breaker as well as double breaker with ring bus bar as shown in Figure 1 has been used in order to study surge arrester effect on the above mentioned substation. These type substations are simulated throughout the EMTP-RV type software program.

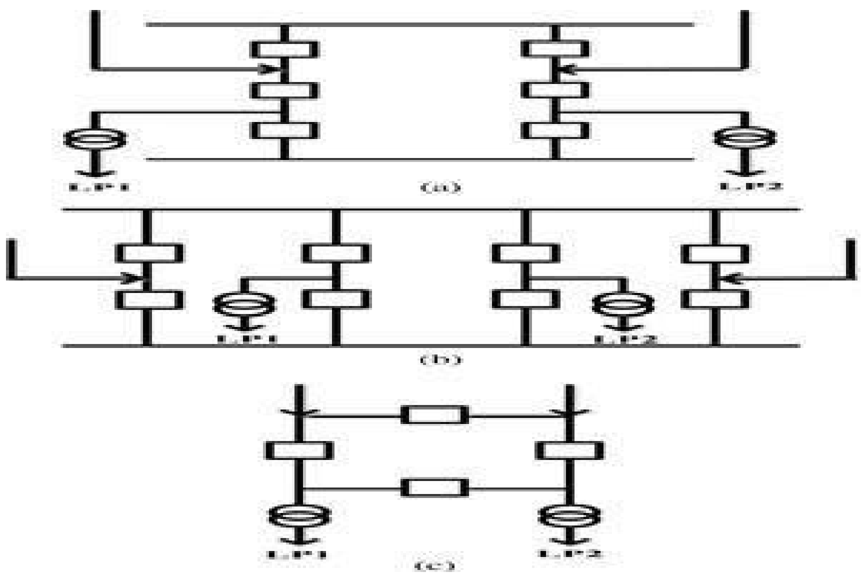


Figure 1 Substation layout with circuit breakers (a) one & half breaker, (b) Double bus with Double breaker, (c) ring bus bar

To achieve the efficiency results via simulation of power system as towers, transmission lines, substation tools should be design correctly. ZnO arrester presents the dynamic effects when there exists fast wave front surges, this has been shown in fig. (2).

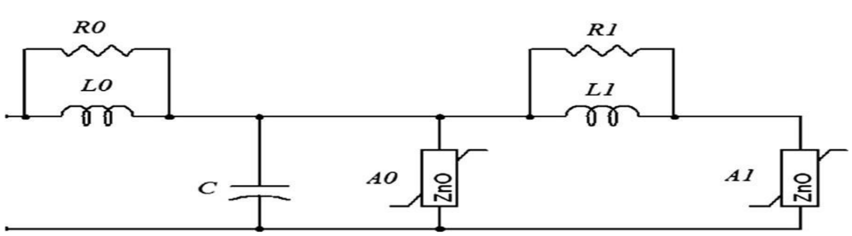


Fig.2. IEEE Model for surge arrester

IEEE model parameters as well as their characteristics of the arrester have been shown in table 1.

The arrester parameters:

Parameter	Value
R_1 (X)	143.325
L_1 (**1**H)	33.075
C (nF)	0.04535
R_0 (X)	220.5
L_0 (**1**H)	0.441
V_r (kV)	198
I_d (kA)	10

Where V_r is related voltage of arrester and I_d is discharge current of arrester. Towers of steel are indicated as one conductor divided in parameter line, which is ending through a resistance indicating the steel tower base footing impedance [9]. In general footing impedance leads to capacity in high earth resistivity, also inductive within lower earth resistivity. However, there exist a problem about the identification of footing impedance and it would be inductive, resistive as well as capacitive, that based upon the seasons and the climates measurement has been made. Hence, the selecting of a pattern about the impedance of footing is difficult. By that reason a resistance pattern is adapted [10].Constant parameter (CP) line is utilized for simulation of single conductor of the tower pattern. Surge impedance of the tower as well as wave speed like important parameter's CP line and determine 160Ω as well as light speed. 5Ω is the resistance which used for tower footing. The time slot for lightning wave is very short period. Hence, under lightning high voltages substation equipment has been substituted by capacitors. Table 2 & 3 represent electrical parameters of lines as well as equal to capacitance of substation equipment have been utilized in order to simulate the substation. R_0, L_0, C_0 are zero series parameters and R_1, L_1, C_1 are positive sequence parameters.

Table 2

Lines of electrical parameters:

Parameter	Value
R_0 (X/km)	0.0892
L_0 (mH/km)	2.3679
C_0 (**1**F/km)	0.00827
R_1 (X/km)	0.032
L_1 (mH/km)	0.9261
C_1 (**1**F/km)	0.0127

Table 3

Substation equipment Equivalent capacitance (pF):

Equipment	Equivalent capacitance (pF)
Power transformer	2000
Current transformer(CT)	200
Capacitive voltage transformer (CVT)	5000
Disconnector	150
Circuit breaker	500

Simulation result tells that the lightning stroke for capturing for 1200 meters and later one & half breaker with double breaker substation with 1300 meters further away than ring bus-bar substation has not been a dangerous for substation.

Reliability Assessment: In last sections, in various scenarios the effects of surge arrester on the potential of instruments were estimated through EMTP-simulation. At the moment, the methods of reliability could be working to explain surge arresters contribution inside substation. The equation which is required for reliability can be calculated by the equation [11] in connection with repair time (r) and failure rate (λ) and as well as unavailability (U) in order to series together with parallel arrangement, those system arrangement may be either one or two or plenty of elements.

As two elements are together parallel alternatively in next failure incident order:

$\lambda_p = \lambda_1\lambda_2(r_1+r_2)$………………(1)

$U_p = \lambda_1\lambda_2(r_1r_2)$……………….(2)

$r_p= U_p/ \lambda_p$………………..(3)

If n numbers of elements are within series than failure series event:

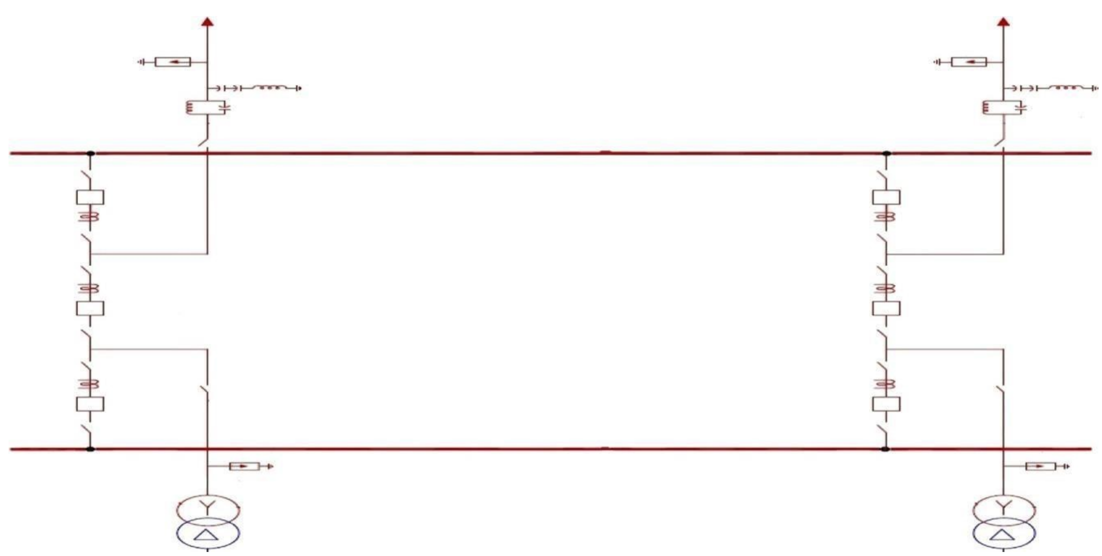
4

$\lambda_s = \sum_{i=1}^{n} \lambda i$………………(4)

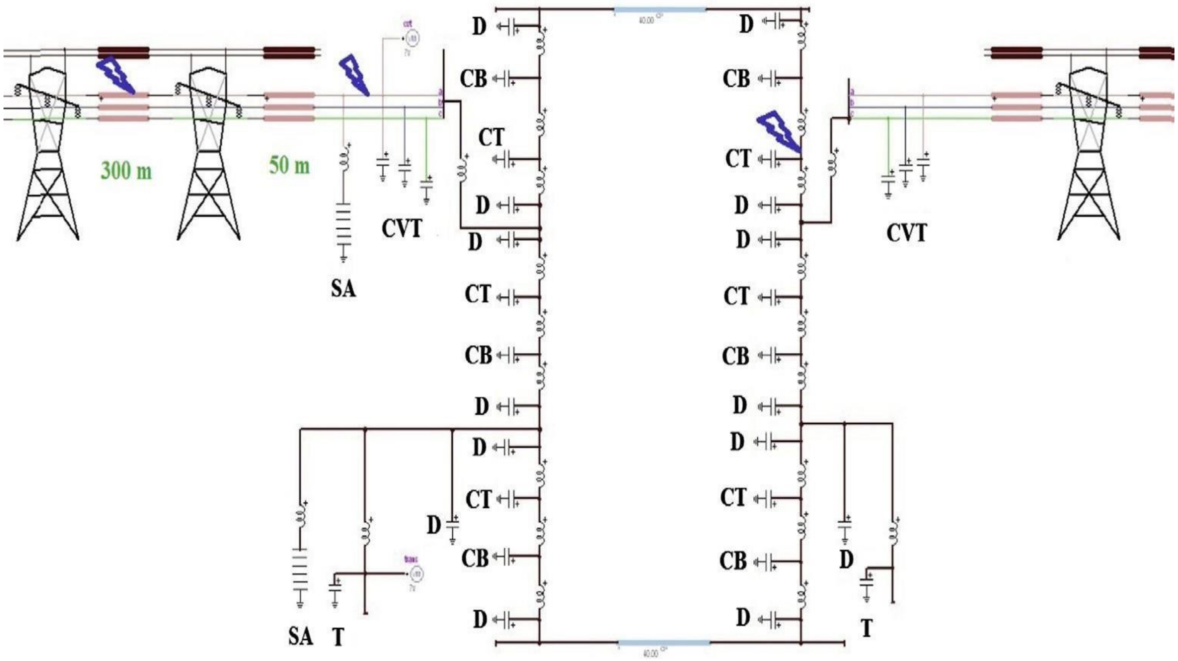
$U_s = \sum_{i=1}^{n} \lambda i r_i$……………(5)

$r_s = U_s / \lambda_s$………………..(6)

Many researchers along with papers have been introduced in order to analyze as well as to find the substations reliability like Markov modeling [12], minimal cut set [13] including Mont Carlo simulation [14] to get the best result the modeling of the substation must be as much as realistic as possible. There is a requirement in order to design the substation along with to observe the performance under contingencies [15]. Among the all models the technique of minimal cut set is the most advantaged one due to its finding reliability of the system is easy [16]. Because the technique of minimal cut set is the little set of elements, this causes a module to fail [17]. The important portion of minimal set technique is to investigate under survey failure modes of the module. The minimal cut set technique is utilized in order to identify of failure modes. Failures modes can be found by either visually are by using the technique of minimal cut set [18]. The failure can be identified by detecting the paths through source points up to load points. Every node has been identified as circuit breaker and bus bar as well as the surge arrester.
The arrester should work closely in order to display the substations configurations. The arrester should work quite different in the normal operating condition (open circuit) along within the over voltage for short circuit but they lean towards short circuit with in exhaust phase of their lengthy run which is the outcome will increase with the failure rate of arrester. However, there exist some problems for the quality as ordinary electrode adhesion on the components. Hence, the insufficient insulation on surface increases the failure rate of arrester. Thus, analyzing of reliability for substation considers arrester in the study, have been analyzed and to find operating and over voltage condition.



(a)



(b)

T, CVT, SA, D, CB and CT represent power transformer, capacitive voltage transformer, surge arrester, Disconnector, circuit breaker and current transformer respectively.
Figure 3. (a) Schematic design of one breaker with half substation as well as (b) equivalent circuit of one breaker with half substation (EMTP-RV simulated).

Table 4

Highest voltage on CVT and transformer of one breaker & half substation because of 1st lightning stroke

Lightning stroke location	**Maximum Voltage in kV**							
	CVT				Transformer			
	A	E	T	E+T	A	E	T	E+T
In the substation	1849.38	711.343	930.62	590.01	1903.76	1029.25	709.69	617.64
Substation entrance	2108.63	777.87	1257.07	698.99	2013.63	820.97	750.10	557.52
50m from substation	1696.33	637.59	908.54	580.41	1813.50	658.19	603.32	515.15
100m from substation	1559.06	675.12	829.10	634.93	1665.12	675.77	584.32	530.91
350m from substation	1451.77	655.53	936.63	597.52	1564.13	710.42	636.34	503.53
1200m from substation	920.55	487.48	616.76	442.11	878.64	523.79	448.76	412.23
1250m from substation	851.88	445.14	611.68	431.10	827.58	521.41	444.15	402.73

Table 5

Highest voltage on CVT and transformer of double breaker substation because of 1st lightning stroke.

Lightning stroke location	**Maximum Voltage in kV**							
	CVT				Transformer			
	A	E	T	E+T	A	E	T	E+T
In the substation	2223.23	692.27	941.54	570.20	2748.30	1369.71	731.91	708.73
Substation entrance	2286.50	783.22	1332.83	721.67	2427.27	889.31	716.38	538.98
50m from substation	1971.34	643.91	946.52	592.67	2114,24	766.74	597.27	510.80
100m from substation	1446.42	707.50	936.44	646.15	1477.89	780.42	574.01	527.53
350m from substation	1412.23	511.23	651.16	470.20	1394.14	580.47	492.77	448.62
1200m from substation	970.64	457.43	621.75	423.63	880.67	521.31	432.57	419.08
1250m from substation	912.54	439.09	621.58	420.72	844.35	516.50	430.85	416.82

Table 6

Highest voltage on CVT and transformer of ring bus-bar substation because of 1st lightning stroke.

Lightning stroke location	**Maximum Voltage in kV**							
	CVT				Transformer			
	A	E	T	E+T	A	E	T	E+T
In the substation	1972.91	868.99	1227.16	708.21	2277.85	1220.00	896.55	712.06
Substation entrance	2060.00	774.48	1249.02	695.01	2013.06	777.74	770.01	564.30
50m from substation	1982.43	643.94	879.34	583.46	2195.24	651.54	612.70	518.10
100m from substation	1914.36	655.75	843.48	596.10	2020.00	651.36	614.23	526.68
350m from substation	1311.23	502.20	607.15	483.79	1271.18	540.00	492.57	447.10
1300m from substation	935.39	432.53	544.68	426.86	887.87	503.10	434.69	405.82
1350m from substation	852.13	431.18	526.39	416.30	845.30	482.91	432.37	398.58

Table 7
Highest voltage on CVT and transformer of one breaker & half substation because of subsequent lightning stroke.

Lightning stroke location	**Maximum Voltage in kV**							
	CVT				Transformer			
	A	E	T	E+T	A	E	T	E+T
In the substation	2126.3	703.29	1336.30	572.53	2470.8	1790	771.3	715.53
Substation entrance	2058.97	1037.52	1999.95	1034.35	2063.71	926.95	880.47	703.35
50m from substation	1019.21	492.32	831.72	458.71	950.34	614.75	522.37	469.90
100m from substation	933.14	492.62	805.80	471.32	875.30	567.73	502.77	456.68
150m from substation	822.20	470.47	744.40	460.83	733.62	555.11	476.91	443.86
200m from substation	739.94	453.30	696.39	447.95	682.37	550.72	447.69	434.96
250m from substation	740.03	448.03	484.54	478.79	552.17	610.87	487.98	384.58
300m from substation	681.87	483.16	669.83	478.40	531.04	478.52	428.13	397.82

Table 8

Highest voltage on CVT and transformer of double breaker substation because of subsequent lightning stroke.

Lightning stroke location	**Maximum Voltage in kV**							
	CVT				Transformer			
	A	E	T	E+T	A	E	T	E+T
In the substation	2180	630.08	1530.11	609.26	2002.08	1768.09	803.44	758.92
Substation entrance	2456.44	1040.50	2456.44	1038.33	2104.25	1075.75	954.57	688.33
50m from substation	833.94	506.66	786.11	506.66	942.25	736.29	537.61	477.39
100m from substation	765.06	489.22	685.86	685.81	862.70	708.71	491.08	474.73
150m from substation	690.23	465.39	622.74	465.39	687.01	660.57	485.22	468.49
200m from substation	658.84	465.95	625.25	465.95	633.96	611.78	469.50	466.84
250m from substation	632.38	467.47	618.38	467.47	607.92	518.97	449.13	431.28
300m from substation	596.01	456.98	596.04	456.98	566.69	490.04	429.02	403.41

Table 9:

Highest voltage on CVT and transformer of ring bus-bar substation because of subsequent lightning stroke

Lightning stroke location	**Maximum Voltage in kV**							
	CVT				Transformer			
	A	E	T	E+T	A	E	T	E+T
In the substation	2676.71	826.09	2055.1	659.13	3209.21	2132.14	977.5	978.62
Substation entrance	2547.13	1041.18	2051.08	1038.68	2310	961.94	991.19	732.48
50m from substation	1063.17	514.55	735.27	465.70	1048.93	663.02	532.54	503.46
100m from substation	941.33	484.29	687.68	449.20	977.07	640.36	508.32	487.24
150m from substation	829.29	487.37	640.28	456.29	868.64	621.07	502.29	480.16
200m from substation	764	477.99	609.82	454.54	769.95	580.29	484.28	469.58
250m from substation	744.83	467.68	643.36	437.35	691.44	498.13	495.85	445.83
300m from substation	652.67	445.56	595.23	435.35	620.92	498.20	486.39	449.79

Table 10

Constants used within the reliability test.

Constant	Details
k_{sc} (fail/year)	Short circuit break down rate of arresters through common operating situation of the system
r_{sc}	restore time of arresters because of short circuit break down (hour)
k_{oc}	Open circuit break down rate of arresters through overvoltage (fail/year)
k_1, k_2	Failure rate of Bus Bar (fail/year)
r_1, r_2	Replacement time of Bus-bars (hour)
$k_3, \ldots, k_8$	Circuit breakers breakdown rate (fail/year)
$r_3 \ldots r_8$	Circuit breakers replacement time (hour)
k_9, k_{10}	Failure rate of power transformers (fail/year)
r_9, r_{10}	Power transformers replacement time (hour)
r_{CVT}	Capacitive voltage transformer replacement time (hour)
t_{OV}	Overvoltage timing (hour)
k_{L1}	Yearly number of lightning stroke within the substation because of shield wire failure (stroke/year)
k_{L2}	Yearly number of lightning stroke at the entrance of substation because of shield wire failure (stroke/year)
P_{L1}	Yearly lightning stroke probability within the substation because of shield wire failure
P_{L2}	Yearly lightning stroke probability at the entrance of substation because of shield wire failure
k_{L3}	Yearly number of lightning strokes to points b/w 50m and 1200m out from substation because of shield wire failure (stroke/year)
P_{L3}	Yearly lightning stroke probability to points b/w 50m & 1200m out from substation by shield wire failure

This is excellence noted that lightning stroke yearly and lightning stroke probability yearly with same value. The parameters that are utilized in order to understand the substation reliability has been demonstrated in table 10. In the case of substation be simulated as four events (A, E, T & E + T), the analysis of reliability would be carry forward of these events also. Every event has been splitted in to two parts, such as normal operating as well as high voltage cases. The reliability analysis of every part must be carry forward individually. The main cause of reliability analysis in this article is in order to find the indices load point. The generated load point-reliability has been relay in the substation device alignment including its device reliability data. The load point sureness indices would be finding for only load point 1. In this partition, the proposal of sureness inspection has been encapsulated in the order of one-breaker including half-substation, and for more designs the identical method could be implemented. The result of first as well as next lightning stroke can be analyzed in table 4-6 is the sureness analysis especially for high voltage condition, the next lightning has been analyzed in table 7-9.

Absence of Arrester:

Figure 4 is the schematic representation of normal operating condition. Square and circle stand for circuit breaker as well as transformer individually.

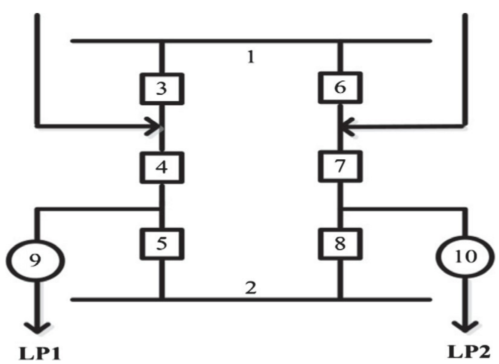


Figure 4. Normal operating condition graph in the situation of lack of arrester

In the condition of first order: 9

In the condition of Second order: 2 to 4, 4 to 5, 4 to 7, 4 to 8

Reliability indices could be determined using "(7)", "(8)" & "(9)":

$$\lambda_{A1} = \lambda_9 + \lambda_2\lambda_4(r_2+r_4) + \lambda_4\lambda_5(r_4+r_5) + \lambda_4\lambda_7(r_4+r_7) + \lambda_4\lambda_8(r_4+r_8) \quad (7)$$

$$U_{A1} = \lambda_9 r_9 + \lambda_2\lambda_4 r_2 r_4 + \lambda_4\lambda_5 r_4 r_5 + \lambda_4\lambda_7 r_4 r_7 + \lambda_4\lambda_8 r_4 r_8 \quad (8)$$

$$r_{A1} = U_{A1} / \lambda_{A1} \quad (9)$$

High Voltage Condition:
Figure 5 is the schematic representation of high voltage condition

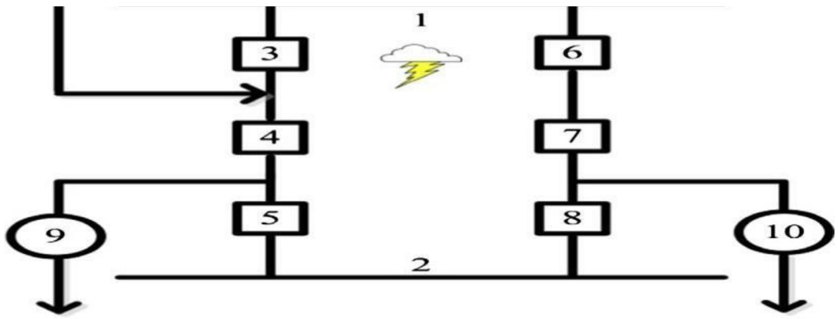


Fig. 5. Graph of high voltage in the case of absence of arrester

As per the report of simulation, represented in the table number 4, reflects striking such lightning surge with in the points of substation. The substation opening including in b/w 50m as well as 1200m far from the substation. Where in case of the absence of the arrester, can destroy CVT as well as the transformer, it can be the reason for load interruption along with its lightning strokes yearly numbers should be noticed within the sureness indices.

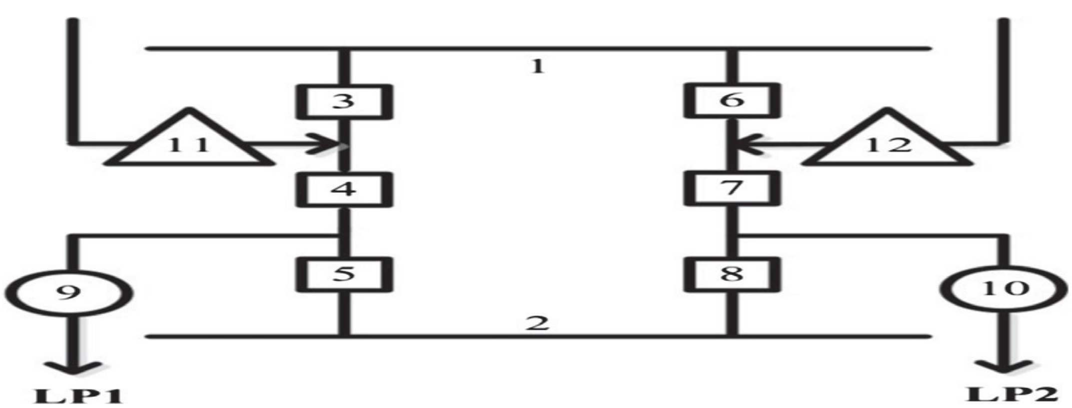
The load-point sureness indices in this condition can be find by utilizing the following equations:

$\lambda_{A2} = \lambda_{L1}+\lambda_{L2}+ \lambda_{L3}$ ....(10)

$U_{A2} = \lambda_{A2}r_9$ ....(11)

$r_{A2}= U_{A2}/ \lambda_{A2}$ ....(12)

Arrester presence in the entrance (E) of the substation:



Triangle stands for surge-arrester

Figure 6. Graph of arrester presence in the entrance of the substation in normal operating condition

Figure 6 shows the graph of *Normal operating condition*. In this condition the minimal cut-sets are as below mentioned:

In first order: 9
In second order: 2-4, 4-5, 4-7, 4-8, 11-12
The reliability indices at load point could be determined using "(13)", "(14)" & "(15)":

$\lambda_{E1} = \lambda_9 + \lambda_2\lambda_4(r_2+r_4) + \lambda_4\lambda_5(r_4+r_5) + \lambda_4\lambda_7(r_4+r_7) + \lambda_4\lambda_8(r_4+r_8) + 2\lambda^2_{SC}r_{SC}$.......(13)

$U_{E1} = \lambda_9 r_9 + \lambda_2\lambda_4 r_2 r_4 + \lambda_4\lambda_5 r_4 r_5 + \lambda_4\lambda_7 r_4 r_7 + \lambda_4\lambda_8 r_4 r_8 + \lambda^2_{SC} r^2_{SC}$....................(14)

$r_{E1} = U_{E1} / \lambda_{E1}$...(15)

High Voltage Condition:

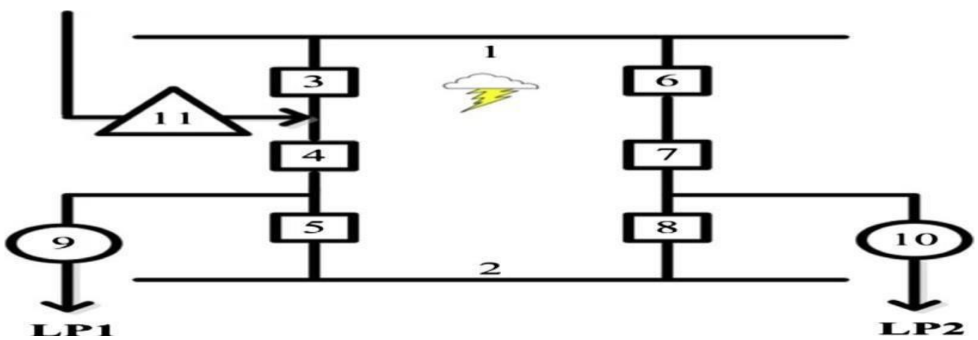


Figure 7. Graph of high voltage arrester presence in the entrance of the substation

The figure 7 is the schematic representation of high voltage condition. It calculating of sureness indices of the configuration needs all possible failure conditions of substation, as mentioned in table 4. The values where greater than of BIL has been noticed that can destroy CVT, all possibilities of substation failure and failure rate of substation has been represented in table 11. The load point sureness indices can be calculated from the following "(16)", "(17)" and "(18)" equations:

$\lambda_{E2} = \lambda_{L1} + P_{L2}\,\lambda_{oc} + P_{L3}\,\lambda_{oc}$...........................(16)

$U_{E2} = \lambda_{E2} r_9$...................................... (17)

$r_{E2} = U_{E2} / \lambda_{E2}$.....................................(18)

Where λ_{L1} = The case of failure rate.

$P_{L2}\,\lambda_{oc}$= The case of damaged and failure rate.

Table: 11

All conditions which can happen at the time of overvoltage cause of first lightning stroke in the case of arrester presence in the entrance substation

Location of lightning stroke			Status of entrance-arrester	Rate of failure
In the substation	at Substation-entrance	B/w 50mt and 1200mt far from substation		
/			SC./OC.	k_{L1}
	/		SC.	0
	/		OC.	$P_{L2}k_{oc}$
		/	SC.	0
		/	OC.	$P_{L3}k_{oc}$

SC & OC denote short circuit as well as open circuit status of arrester individually.

Arrester presence in the transformer-feeder (T):

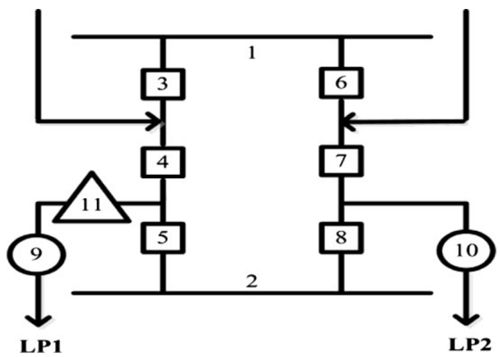


Figure 8. Graph of arrester presence in the feeder of the transformer in normal operating condition

In normal operating condition: Minimal cut set is as mentioned below:

In first order: 9 & 11

In second order: 2-4, 4-5, 4-7, 4-8

The reliability indices of load point can be determined using "(19)", "(20)" & "(21)".

$$\lambda_{T1} = \lambda_9 + \lambda_{sc} + \lambda_2\lambda_4(r_2+r_4) + \lambda_4\lambda_5(r_4+r_5) + \lambda_4\lambda_7(r_4+r_7) + \lambda_4\lambda_8(r_4+r_8) \quad (19)$$

$$U_{T1} = \lambda_9 r_9 + \lambda_{sc} r_{sc} + \lambda_2\lambda_4 r_2 r_4 + \lambda_4\lambda_5 r_4 r_5 + \lambda_4\lambda_7 r_4 r_7 + \lambda_4\lambda_8 r_4 r_8 \quad (20)$$

$$r_{T1} = U_{T1} / \lambda_{T1} \quad (21)$$

$$\lambda_{T2} = P_{L1}\lambda_{oc} + \lambda_{L2} + P_{L3}\lambda_{oc} \quad (22)$$

$$U_{T2} = P_{L1}\lambda_{oc} r_9 + \lambda_{L2} r_{RCT} + P_{L3}\lambda_{oc} r_9 \quad (23)$$

$$r_{T2} = U_{T2} / \lambda_{T2} \quad (24)$$

High Voltage Condition:

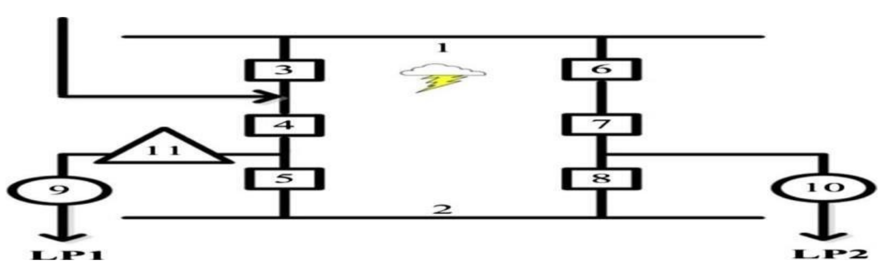


Figure 9. Graph of High Voltage in the case of presence of arrester in transformer feeder

The figure 9 is the schematic representations of the condition of all possibilities have to be investigated by table 12 as well as the load point sureness indices could be calculated.

Table 12
All conditions which can happen at the time of overvoltage cause of first lightning stroke in the case of arrester presence in transformer feeder

Location of lightning stroke			Status of transformer arrester	Rate of failure
In the substation	at Substation-entrance	B/w 50mt and 1200mt far from substation		
/			SC.	0
/			OC.	$P_{L1}k_{oc}$
	/		SC. / OC.	k_{L2}
		/	SC.	0
		/	OC.	$P_{L3}k_{oc}$

SC. & OC. denote short circuit as well as open circuit status of arrester individually.

Presence of arrester in normal operating condition as shown in figure: 10

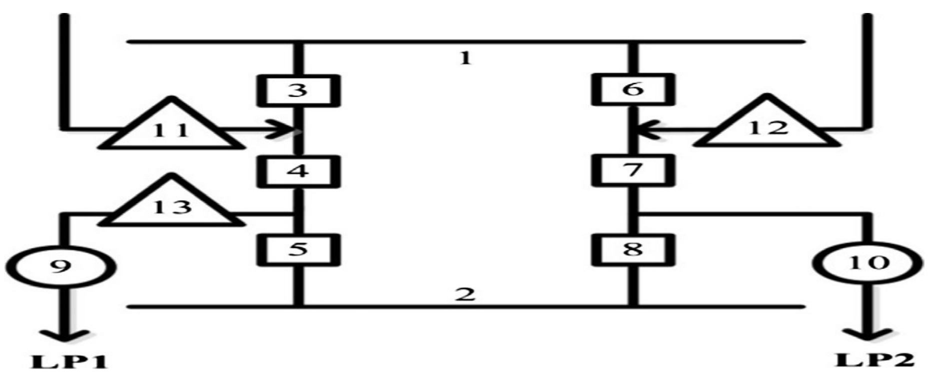


Figure 10. Graph of arrester presence in the entrance of substation as well as feeder of the transformer in normal operating condition

As shown in figure 10, the cut set case can be achieved by following:

In first order: 9 & 13
In second order: 2-4, 4-5, 4-7, 4-8, 11-12
The reliability as mentioned below according to the cut sets:

$$\lambda_{(E+T).1} = \lambda_9 + \lambda_{sc} + \lambda_2\lambda_4(r_2+r_4) + \lambda_4\lambda_5(r_4+r_5) + \lambda_4\lambda_7(r_4+r_7) + \lambda_4\lambda_8(r_4+r_8) + 2\lambda^2_{SC}r_{SC} \ldots(25)$$

$$U_{(E+T).1} = \lambda_9 r_9 + \lambda_{sc}r_{sc} + \lambda_2\lambda_4 r_2 r_4 + \lambda_4\lambda_5 r_4 r_5 + \lambda_4\lambda_7 r_4 r_7 + \lambda_4\lambda_8 r_4 r_8 + \lambda^2_{SC}r^2_{SC} \ldots\ldots(26)$$

$$r_{(E+T).1} = U_{(E+T).1} / \lambda_{(E+T).1} \ldots\ldots(27)$$

High Voltage:

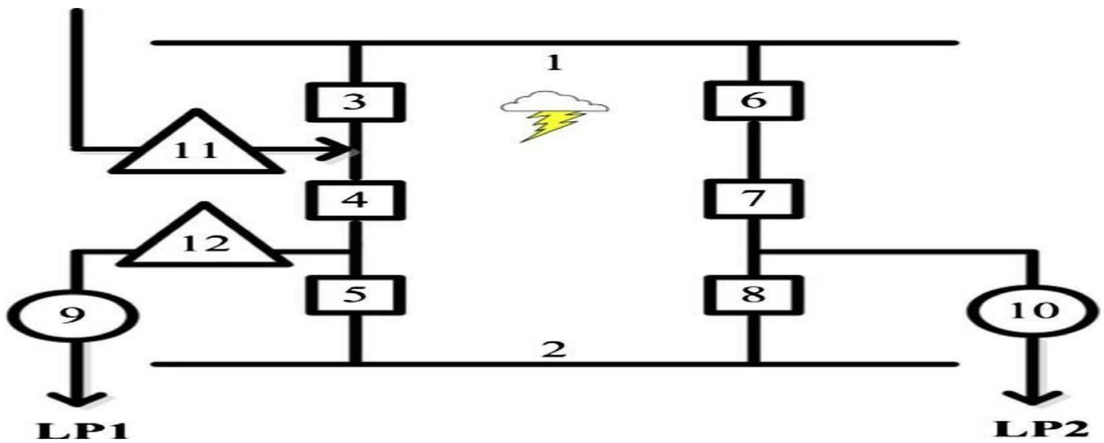


Figure 11. Graph of High voltage in the condition of the availability of arrester in the entrance of substation as well as transformer feeder

High Voltage condition: Here by the reason of present of excessive arrester, thus many possibilities than earlier condition must be noticed in the table No. 4. As Table No. 13 represents the probabilities depending upon lightning strokes location along with arresters status. It finalizes the failure rate. The case of load point sureness indices are followed by the equations 28, 29, 30 and Table 13.

$\lambda_{(E+T).2} = P_{L1}\,\lambda_{oc} + P_{L2}\,\lambda_{oc}$ .... (28)

$U_{(E+T).2} = (P_{L1}\,\lambda_{oc})\, r_{CVT} + (P_{L2}\,\lambda_{oc})\, r_9$ ....(29)

$r_{(E+T).2} = U_{(E+T).2} / \lambda_{(E+T).2}$.......................................(30)

Table 13

All conditions which can happen at the time of overvoltage cause of first lightning stroke in the case of arrester presence in substation entrance as well as in transformer feeder

Location of Lightning stroke			Status of Arrester		Rate of Failure
In the substation substation	At Substation entrance	B/w 50mt & 1200mt far from	Entrance-Arrester	Transformer-feeder-Arrester	
/			SC.	SC.	0
/			OC.	SC.	0
/			SC.	OC.	$P_{L1}k_{OC}$
/			OC.	OC.	$2P_{L1}k_{oc}$
	/		SC.	SC.	0
	/		OC.	SC.	$P_{L2}k_{OC}$
	/		SC.	OC.	0
	/		OC.	OC.	$2P_{L2}k_{oc}$
		/	SC.	SC.	0
		/	OC.	SC.	0
		/	SC.	OC.	0
		/	OC.	OC.	$2P_{L3}k_{oc}$

SC. & OC. denote short circuit as well as open circuit status of arrester individually.

Numerical Analysis:

The sureness data has been mentioned in table 14.

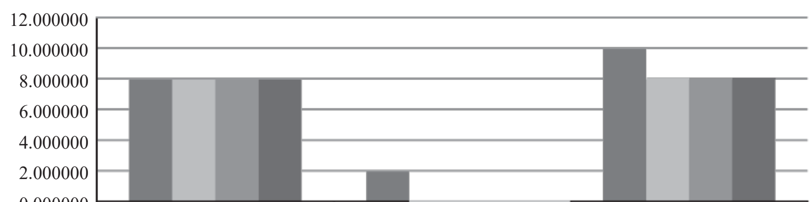
The sureness indices for different conditions in normal operating condition, high voltage condition along with the sum of these two scenarios can be achieved. The corresponding results are repented in fig. 12-14.

Table 14
Reliability-Data:

Details	k (yearly-fail)	*r* (Hours)	*P*
Bus-bar	0.0019	10	–
Circuit-Breaker	0.0050	48	–
Transformers	0.015	528	–
Arrester SC. failure	0.0048	50	–
Arrester OC. failure	0.0025	–	–
Voltage Capacitive Transformer replacement time	–	35	–
Yearly No. of lightning strokes inside the substation cause of shield-wire failure	0.0010	–	–
Yearly No. of lightning strokes at substation entrance cause of shield-wire failure	0.0010	–	–
Yearly No. of lightning strokes to points b/w 50m & 1200m far from substation(shield-wire failure)	0.0020	–	–
Possibilities of yearly lightning strokes inside the substation cause of shield-wire failure	–	–	0.0010
Probability of yearly lightning stroke at substation entrance cause of shield-wire failure	–	–	0.0010
Probability/year lightning strokes to points b/w 50m & 1200m from substation(shield-wire failure)	–	–	0.0020

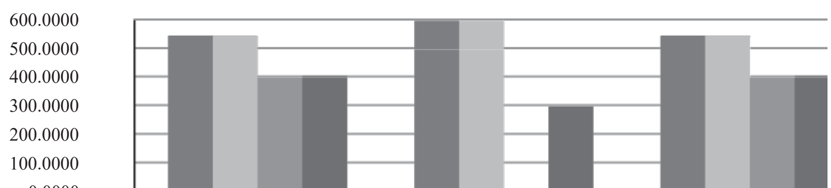
	Normal operating condition	Overvoltage condition	Total
A	0.015001	0.004000	0.019001
E	0.015001	0.001007	0.016008
T	0.019800	0.001007	0.020807
E+T	0.019801	0.000005	0.019806

Figure 12. Rate of Failure of load point one of one breaker & half substation cause of first lightning-stroke (fail/year)



	Normal operating condition	Overvoltage condition	Total
A	8.097600	2.112000	10.209600
E	8.155200	0.531960	8.687160
T	8.337600	0.038960	8.376560
E+T	8.395200	0.001407	8.396607

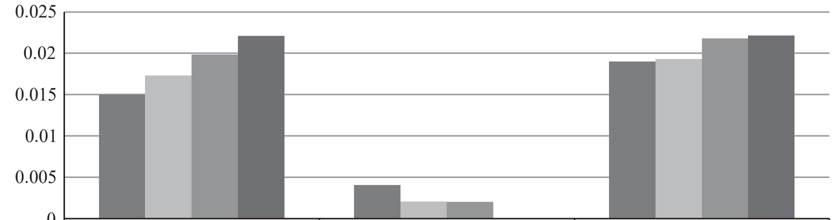
Figure 13. Impossibilities of load point one of one breaker & half substation cause of first lightning-stroke (hour/year)



	Normal operating condition	Overvoltage condition	Total
A	539.8080	528.0000	537.3223
E	543.6383	528.0000	542.6541
T	421.0720	38.6700	402.5569
E+T	423.9754	281.5000	423.9394

Figure 14. Breakdown time of load point one of one breaker & half substation cause of 1st lightning stroke (hour)

The sureness indices on double-breaker along with ring-bus-bar substations as explained in Figure 15-20



	Normal operating process	Overvoltage process	SumTotal
A	0.015001	0.004000	0.019001
E	0.017304	0.002005	0.019309
T	0.019801	0.002005	0.021806
E+T	0.022104	0.000010	0.022114

Figure 15. Rate of failure of load point one of double-breaker substation cause of first lightning-stroke (fail/year)

The method which follows to demonstrate the sureness indices of high voltage condition by the reason of next lightning stroke cab be calculated from table 15-17.

Table 15
Reliability indices of one breaker and half substation due to subsequent lightning stroke.

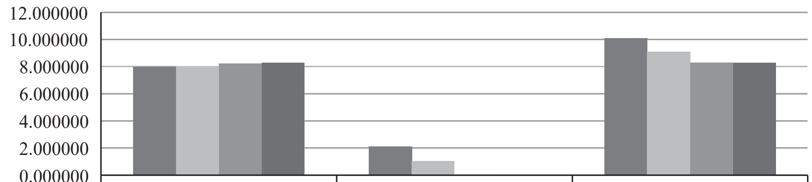
	High voltage			Total		
	k	*U*	*r*	k	*U*	*r*
A	0.004001	2.112000	528.0000	0.019001	10.209600	537.3223
E	0.002005	1.058640	528.0000	0.017006	9.213840	541.7945
T	0.002005	0.565640	282.1147	0.021806	8.903240	408.2952
E + T	0.000010	0.004047	404.7500	0.019811	8.399247	423.9656

Table 16
Reliability indices on double-breaker substation cause of subsequent lightning stroke.

	High voltage			Total		
	k	*U*	*r*	k	*U*	*r*
A	0.004000	2.112000	528.0000	0.019001	10.209600	537.3223
E	0.002005	1.058640	528.0000	0.017006	9.213840	541.7945
T	0.002005	0.565640	282.1147	0.021806	8.903240	408.2952
E + T	0.000010	0.004047	404.7500	0.019811	8.399247	423.9656

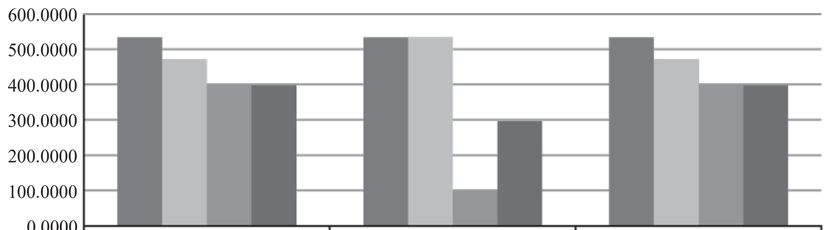
Table 17
Reliability indices on the ring-bus-bar substation cause of subsequent lightning stroke.

	High voltage			Total		
	k	*U*	*r*	k	*U*	*r*
A	0.004000	2.112000	528.0000	0.019001	10.147200	534.0478
E	0.002005	1.058640	528.0000	0.019309	9.151440	473.9334
T	0.002005	1.058640	528.0000	0.021806	9.333840	428.0489
E + T	0.001005	0.530640	404.7500	0.023109	8.863440	383.5714



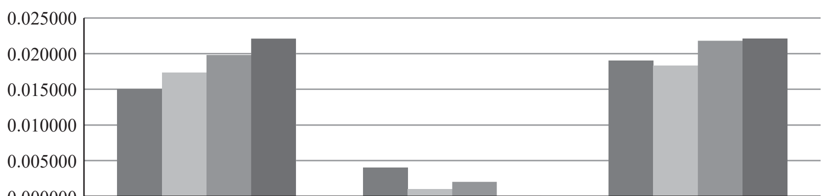
	Normal operating Condition	Overvoltage condition	Total
A	7.987600	2.112000	10.099600
	8.045200	1.058640	9.103840
E	8.227600	0.072640	8.300240
	8.285200	0.002815	8.288015

Figure 16. Lack on load point one of double-breaker substation cause of 1st lightning stroke (hour/year)



	Normal operating Process	High voltage condition	Total
A	532.4919	526.0000	531.5463
E	464.9218	528.0000	471.4715
T	415.5266	36.2294	380.6504
E+T	374.8210	281.5000	374.7788

Figure 17. Blackout time on load point one of double-breaker substation cause of 1st lightning stroke (hours)

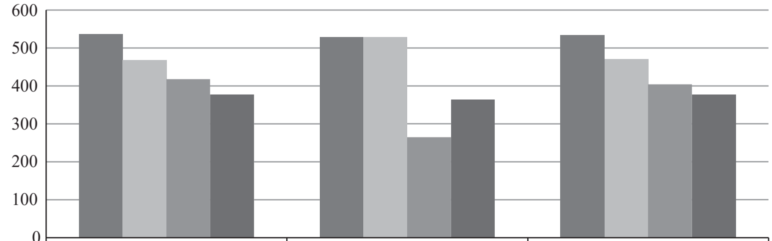


	Normal operating Process	High voltage condition	Total
A	0.015001	0.004000	0.019001
E	0.017304	0.001007	0.018312
T	0.019801	0.002005	0.021806
E+T	0.022104	0.000007	0.022112

Figure 18. Rate of failure on load point one of ring bus-bar-substation cause of 1st lightning stroke (fail/year)

	Normal operating condition	Overvoltage condition	Total
A	8.035200	2.112000	10.147200
E	8.092800	0.531960	8.624760
T	8.275200	0.530727	8.805927
E+T	8.332800	0.002727	8.335527

Figure 19. Lack on load point one of ring bus-bar-substation cause of 1st lightning stroke (hour/year)



	Normal operating condition	Overvoltage condition	Total
A	535.6604	528.0000	534.0478
E	467.6690	528.0000	470.9883
T	417.9278	264.7020	403.8389
E+T	376.9722	363.6667	376.9677

Figure 20. Blackout time of load point 1 of ring bus bar substation cause of 1st lightning stroke (hours)

Conclusion: High Voltage like lightning surge high voltage within power-system obligates inventors in order to survey of surge arresters for the substations as save the devices from transient waves. When the arrester fails with in the normal operating condition in short circuit along with open circuit failure from over voltage will tends to load interruption as well as substation sureness decreases. In this article first there were three substations of different conditions have been simulated for separate cases on lightning strokes with locations of surge arrester. After the results obtained from the simulation the sureness test has been conducted. From this during a normal operating condition if we add surge arrester, the reliability of the substation has been reduced in the absence of arrester. Within the over voltage in the absence of arrester the substations reliabilities drops along with the case where the arrester in the entrance of substation within the transformer- feeder

In general the surge arrester are more reliable devices, however the failure of surge arrester produces a major risk. Thus it should require more attention towards arrester in fatigue-phase for their life is essential.

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