Reliability Analysis of two parallel connected combined transmission line (over head/ cable)

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Abstract: Reliability is a major factor while designing and planning the power system. Poor reliability causes high maintenance costs. Reliability analysis of power system that contained combined transmission line and cable is very important because most faults on the line are transient and causes line permanently out of the service. These transients are automatically cleared by auto re-closer operation of the line circuit breaker. Over voltage caused by lightning must be considered when designing the cable insulation system because it can be major cause for the underground cable failure. Surge arrester is used to decrease cable line faults.

In this paper the reliability analysis of transmission system (line/ cable) with and without surge arrester is discussed by using even tree method.

Keywords: reliability, surge arrester, combined line, reliability indices.

I. INTRODUCTION

Now a days power system can be expanded by using combined line (line/cable) because cable lines are designed with high voltage insulations, which are weak points in power system in view of reliability[1,2]. When the load demand increases one or more lines are connected in parallel to each other. Parallel connected lines are more reliable than single transmission line[3]. Combined transmission lines are widely used to transmit the power in more density areas. The system reliability can be increased by using the surge arrester in the cable line.

II. RELIABILITY ANALYSIS

In this analysis availability and unavailability have been used as reliability indices[4,5]. These indices are performed by using even tree method. For computing reliability indices, it is assumed that the failure of each component has exponential distribution function. Indices are evaluated by using the following equations[6].

\[
\text{Availability/ Reliability} = A = e^{-\lambda t} \\
\text{Unavailability} = U = 1 - e^{-\lambda t}
\]

Where \( \lambda \) = failure rate of the each component
\( t \) = time period between consecutive tests

III. RELIABILITY ANALYSIS OF COMBINED LINE (LINE/CABLE)

Fig 1 shows the two parallel connected combined lines without surge arrester.

![Diagram of combined transmission line (line/cable) without surge arrester](image)

Fig 1: combined transmission line (line/cable) without surge arrester
In Fig 1 L₁, L₁', L₂, L₂' are overhead lines, C₁, C₂ are cables. For reliability analysis two cases are considered one is combined line without surge arrester and second is with surge arrester.

3.1 Without surge arrester: In Fig 1 two combined lines are connected in parallel. Each line is combined with lines and cable. In Fig 1 all L₁, C₁ and L₁' are connected in series and combination is connected in parallel to the line L₂. For the system reliability any of the line must be work for the system success[7]. Even tree diagram for Fig 1 is as shown in Fig 2.

![Fig 2: Even tree diagram of combined transmission line (line/cable) without surge arrester](image)

For Fig 2 the probability values of each route is evaluated and tabulated in Table 1. Table 1 consists three states, state 1 represents two lines are in service or available, state 2 only one line is available, and state 3 represents two lines are unavailable.

<table>
<thead>
<tr>
<th>State</th>
<th>Probability</th>
<th>Individual probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A₁A₂</td>
<td>(0.97912)^2 = 0.9586759</td>
</tr>
<tr>
<td>2</td>
<td>A₁U₂ + U₁A₂</td>
<td>2X0.02088X0.97912 = 0.040888</td>
</tr>
<tr>
<td>3</td>
<td>U₁U₂</td>
<td>(0.02088)^2 = 0.0004359</td>
</tr>
</tbody>
</table>

From Table 1
Availability/reliability = A = 0.9586759
In series redundancy availability of the system is known as reliability of the system.

3.2 With surge arrester: In this case surge arresters are provided at both ends of the cable as shown in the Fig 3. In Fig 3 S₁,S₁',S₂ and S₂' are surge arresters.
Even tree diagram for Fig 3 is as shown in Fig 4.

In Fig 4 if the line $L_1$ does not become failure in contrast overvoltage and surge arrester $S_1$ operates appropriate, route 1 will be constructed. In following, if line $L_1$ does not become failure against of over voltage but surge arrester $S_1$ does not have suitable operation and also cable can tolerate over voltage and surge arrester $S_2$ has suitable operation, route 2 will be constructed. Route 3 will be constructed if surge arrester $S_2$ does not have suitable operation and line $L_1$ tolerates overvoltage, route 4 will be constructed. Route 5 will be constructed if overhead line $L_1$ tolerates over voltage but surge arrester $S_1$ and cable line do not limit over voltage. Failure of line $L_1$ causes route 6. Similar procedure for line $L_2$.

For Fig 4 probability values are evaluated and tabulated in table 2. In table 2 there are three states, state 1 represents two lines are available state, state 2 any one line is available and state 3 represents two lines are unavailable.
Table 2: Capacity outage probability table of combined transmission system with surge arrester

<table>
<thead>
<tr>
<th>State</th>
<th>Probability</th>
<th>Individual probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$A_1A_2$</td>
<td>$(0.9950164)^2 = 0.99005764$</td>
</tr>
<tr>
<td>2</td>
<td>$A_1U_2+U_1A_2$</td>
<td>$2 \times 0.00498 \times 0.9950164 = 0.00099175$</td>
</tr>
<tr>
<td>3</td>
<td>$U_1U_2$</td>
<td>$(0.0049836)^2 = 0.000024836$</td>
</tr>
</tbody>
</table>

From Table 2
Availability/ reliability = $A = 0.99005764$
Reliability values of two cases are tabulated as shown in Table 3.

Table 3: Reliability values of combined line with and without surge arrester

<table>
<thead>
<tr>
<th></th>
<th>Reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without surge arrester</td>
<td>0.95867597</td>
</tr>
<tr>
<td>With surge arrester</td>
<td>0.99005764</td>
</tr>
</tbody>
</table>

Fig 5: Comparison between the reliability of combined line (line/cable) with and without surge arrester

Table 3 and Fig 5 show the comparison between the reliability values of two cases. From this it is observed that the reliability of the system is increases by providing the surge arrester at two ends of the cable compared with the cable without surge arrester.

IV. CONCLUSIONS

In this paper the effect of surge arrester combined line (line/cable) is discussed and compared. The results shown that the reliability of the system without surge arrester is less compared to the system with surge arrester.

REFERENCES