CARRIER-AIDED PROTECTION OF TRANSMISSION LINES
Need for Carrier-aided Protection

<table>
<thead>
<tr>
<th>Type of fault</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transient</td>
<td>80%</td>
</tr>
<tr>
<td>Semi-permanent</td>
<td>10%</td>
</tr>
<tr>
<td>Permanent</td>
<td>10%</td>
</tr>
</tbody>
</table>

Fault statistics

<table>
<thead>
<tr>
<th>System voltage</th>
<th>Typical de-ionization time</th>
</tr>
</thead>
<tbody>
<tr>
<td>66 kV</td>
<td>0.10 s</td>
</tr>
<tr>
<td>132 kV</td>
<td>0.17 s</td>
</tr>
<tr>
<td>220 kV</td>
<td>0.28 s</td>
</tr>
<tr>
<td>400 kV</td>
<td>0.50 s</td>
</tr>
</tbody>
</table>

Typical de-ionization times
Only 60% of line length in the middle gets high speed protection from both ends.
Coupling and Trapping the Carrier into the Desired Line Section

Coupling a carrier and trapping it into the desired line section (single line-to-ground coupling)
Single Line-to-ground Coupling

In the above figure, we have shown carrier coupling on a single line-to-ground basis.

This is bound to cause severe attenuation of the carrier signal, rendering it unusable at the remote end. Thus, line-to-ground coupling is not a very sound choice as far as carrier coupling is concerned.
Figure shows carrier coupling on the line-to-line basis. The carrier signals propagate through air between the line conductors, therefore, the attenuation is much less. This mode of transmission, known as the aerial mode, results in a much better performance during single line-to-ground faults.
Unit Type Carrier-aided Directional Comparison Relaying

Unit type carrier-aided directional comparison relaying: internal fault.
Unit type carrier-aided directional comparison relaying: external fault
Carrier-aided Distance Schemes for Acceleration of Zone II
Carrier-aided Distance Schemes for Acceleration of Zone II

- **Permissive Inter-trip**

  At times, noise may cause false tripping in the scheme described in Section 7.5.1. Therefore, we can take advantage of the fault detector output. Hence if point P, in Figure 7.5 is connected to point \( P_2 \) then the scheme is known as permissive inter-trip.

- **Acceleration of Zone II**

  Alternatively we can simply bypass the zone II timer contact \( T_2 \), in Figure 7.5, with \( \text{CRR}_A \), in which case the scheme is known as acceleration of zone II.
Continued...

Pre-acceleration of Zone II

Pre-acceleration of zone II.
Phase Comparison Relaying (Unit Scheme)

Phase comparison relaying (currents shown on the CT secondary side)

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Phase comparison relaying (currents shown on the CT secondary side)
Phase comparison relaying.
Continued...

\[
\frac{(180 - \delta)(20)}{180} = 2.22 \text{ ms}
\]

Phase comparison relaying.
Continued...

Phase comparison relaying (internal fault).

- **I:** End A current for internal as well as external fault.
- **II:** Modulated carrier sent by end A for internal as well as external faults.
- **III:** Demodulated end A carrier.
- **IV:** End B current for internal fault.
- **V:** Modulated carrier sent from end B and received at end A for internal fault.
- **VI:** Demodulated end B carrier available at end A.
- **VII:** Coincidence period pulse obtained by ANDing III and VI.
Phase comparison relaying (external fault).

I: End A current for internal as well as external faults.

II: Modulated carrier sent by end A for internal as well as external faults.

III: Demodulation of end A carrier.

IV: End B current for external fault.

V: Modulated carrier sent by end B during external fault.

VI: Demodulation of end B carrier received at end A.

VII: Pulse corresponding to coincidence period obtained by ANDing of III and VI.

No coincidence

No output
Hardware to measure coincidence period.
Review Questions

1. What do you mean by reclosure?
2. What is the motivation for using reclosure?
3. Differentiate between reclosure in case of low-voltage systems and high-voltage systems.
4. What is meant by single-shot reclosure and multi-shot reclosure?
5. What is the motivation for using a carrier?
6. What are the various options for implementing the carrier communication channel?
7. What are the advantages of power line carrier?
8. What frequency band is normally used for power line carrier signalling?
9. What is the frequency band used for microwave communication?
10. What is the motivation for coupling the carrier between two of the lines rather than between a line and ground? Which method results in more reliable carrier communication?
11. Explain why only middle 60% of the double-end-fed line gets instantaneous distance protection from both ends in a three-stepped distance scheme.
12. How does the carrier help in overcoming the limitation of the three-stepped distance protection?
Review Questions

13. Explain the difference between transfer trip and permissive inter trip schemes. Which scheme is more robust?

14. How does the carrier-based acceleration of zone II differ from the transfer trip and permissive inter-trip schemes?

15. Why does sending the carrier over a faulty line need to be avoided?

16. What do you mean by tripping carrier and blocking carrier? Which one is more robust?

17. What do you mean by pre-acceleration of zone II?

18. In practice, the zone II cannot be pre-accelerated to an instantaneous operation. Explain.

19. Explain the operation of the unit type of carrier-based directional protection.

20. Explain the principle of carrier-based phase comparison scheme.