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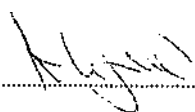
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Business Process Document

Protection standards and methods of calculation for 25 kV ac electrified lines

Endorsement & Authorisation

Endorsed by:



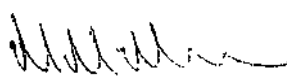
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Section A Distance relays

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I. Primary impedance diagram

The electrical representation of the electrified system is shown on the major feeding diagram. This must be simplified to show only basic information required for calculation and is redrawn as a primary impedance diagram.

Each track section is shown as a number and a primary impedance modulus. Impedances consist of both resistive and reactive components. These are combined together as complex numbers and converted to polar form on a section impedance diagram. The polar form consists of an impedance modulus (Z') and a phase angle (θ).

$$Z = R + jX = Z' \angle \theta^\circ$$

During calculation, all section phase angles are assumed similar (they usually fall between 65 and 75 degrees) and the section impedances are treated as simple numbers.

I.1 Primary to secondary conversion

The protection relays monitor voltage and current using transformers. Since these have a ratio greater than 1:1, the fault impedances seen by the relay will be related by the transformer ratios to the primary values.

$$\text{Secondary impedance} = \text{primary impedance} \times \frac{\text{ct ratio}}{\text{vt ratio}}$$

$$\text{vt ratio is typically } \frac{26400}{110}$$

$$\text{ct ratio } 400/1 \text{ ohms (sec)} = \text{ohms (pri)} \times \frac{5}{3}$$

$$\text{ct ratio } 600/1 \text{ ohms (sec)} = \text{ohms (pri)} \times 2.5$$

2 Section impedance values

A section impedance value is produced for each group of electrical sections between two substations or other key locations. The details are entered on a pro-forma record sheet; an example is shown in Figure 1.

2.1 Section number

This is the designation of the electrical section.

2.2 Length

The length of the section or part-section is in kilometres. This can be obtained from the relevant major feeding diagram and Sectional Appendices.

2.3 Configurations

The nature of the section: e.g. 2 track, 4 track (inner) etc.

2.4 Unit Z values

The unit impedance value is dependent on the track configuration, equipment type (e.g. Mk III), return and booster arrangements - etc.

The unit impedance value per kilometre is given in the Appendices (to be added). For new equipment types, unit impedance values have to be calculated from first principles.

2.5 OLE Z values

The impedance (in complex form) of the section or part-section of track (excluding booster transformer values).

2.6 Booster transformers

Number, type (current rating: e.g. 300A), unit impedance and total impedance as a contribution to section or subsection value.

2.7 Subsection Z

The total subsection (or section) impedance including booster.

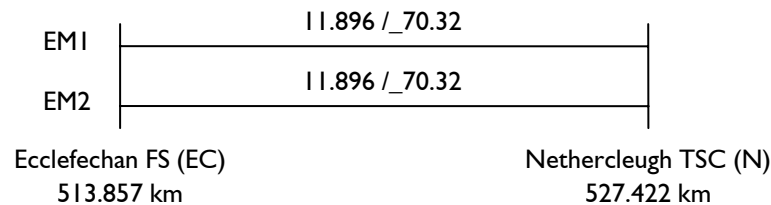
2.8 Total section impedance

Individual subsection Z values are added in complex form and then converted to a polar equivalent.

$$Z' \angle \theta = R + jX \quad \text{where} \quad Z = \sqrt{R^2 + X^2} \quad \tan \theta = \frac{X}{R}$$

25 kV ELECTRIFICATION SECTION IMPEDANCE CALCULATION

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Section Number	Quantity	Equipment Type	Unit Impedance R+jX	Total Impedance R+jX
EMI Up Main	13.565 km	Mark IIIA 2Track, BT with RC	0.267 +j 0.731	3.622 +j 9.916
	5	Booster Transformer 200A Bonar Long	0.077 +j 0.257	0.385 +j 1.285
	Total Section Impedance		Rectangular Polar	4.007 +j 11.201 11.896 / -70.32
EMI Up Main	13.565 km	Mark IIIA 2Track, BT with RC	0.267 +j 0.731	3.622 +j 9.916
	5	Booster Transformer 200A Bonar Long	0.077 +j 0.257	0.385 +j 1.285
	Total Section Impedance		Rectangular Polar	4.007 +j 11.201 11.896 / -70.32

Figure 1 Example of impedance diagram and section impedance calculations

3 Zones and discrimination

To limit disruption to traffic, only the minimum number of circuit breakers necessary to isolate a fault must open. The relay settings must take this into account and discrimination between relays results in a number of setting stages or zones being provided, separated by time delays.

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A tolerance of 15% is generally allowed when calculating settings for Zones 1 and 2. For Zone 3 a tolerance of 20% is generally used. This means that the Zone 1 reach can only normally be set to 85% of its section impedance value to avoid overlapping into another section. A second zone extends the relay reach after a time delay to cover the remainder of the section. The second zone can also be used to provide back-up for relay failure on other sections further away from the feeder station. All distance relays apart from the ASEA relay, which only has two zones, have a third zone to improve discrimination in a back-up situation.

All distance relays are directional and the zone settings are calculated on the basis of power flow away from the substation busbar.

The following notes are based on a three zone relay, allowing tolerances of 15% and 20%. Section 12 deals with the ASEA two zone relay and for this a 10% tolerance is used.

4 Tolerance correction

During normal feeding, relays 'looking' towards the feeder station can only detect faults occurring in their own section. Consequently, discrimination problems cannot occur and zones can have any value greater than the section impedance.

Settings that cater for power flow reversal during alternate feeding arrangements, the normal tolerances must be included.

To maintain discrimination during normal and alternate feeding arrangements, the following should be apply:

4.1 For relays without setting groups such as RYZBC, DZA and YTG14 relays

- a) Relays which can see forward power flow during normal or alternate feeding arrangements must maintain discrimination with all other relays.
- b) Relays which only see power flow into the busbar during all feeding arrangements can have any reasonable setting value.

4.2 For relays setting groups such as the Optimho and Micom P438 relays

The setting groups are typically set as follows also there are variations:

- Group 1 If Zone 1 extension (ZIX) is not applied - normal feeding arrangements.
If ZIX is applied - normal and reverse feeding arrangements.
- Group 2 If ZIX is not applied in Group 1 - alternate feeding arrangements (power flow reversed from normal feeding).
If ZIX is applied in Group 1 – normal arrangements without ZIX.

Group 3 By-passed settings of next location

Group 4 Tee feeding arrangements

Where protection settings to a Group are not applicable then a copy of Group I settings should be plied to the Group.

5 Basic principles

Let us consider a system of simple plain route with forward power flow during normal feeding arrangements, see Figure 2.

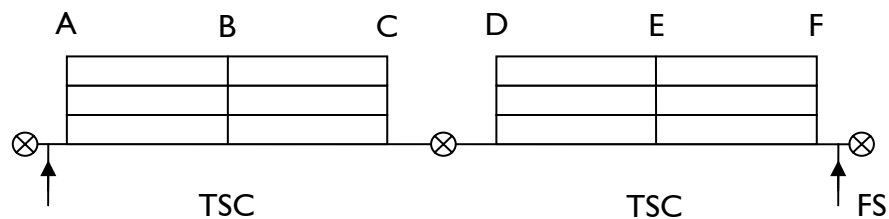


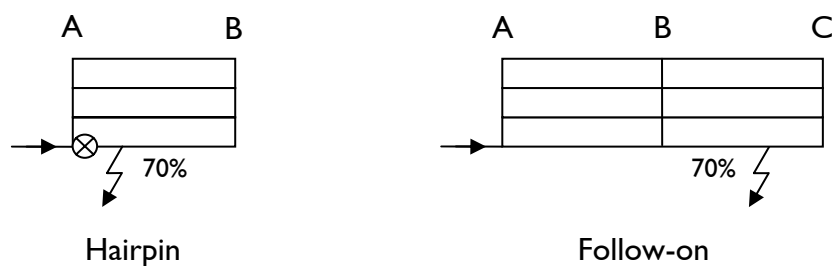
Figure 2 A simple 4 track arrangement

5.1 Zone 1

The Zone 1 setting is independent of track configuration. Assuming a 15% tolerance, the Zone 1 is set to $0.85 \times$ section impedance.

5.2 Zone 2

There are two scenarios to examine for Zone 2, the hairpin and the follow-on.



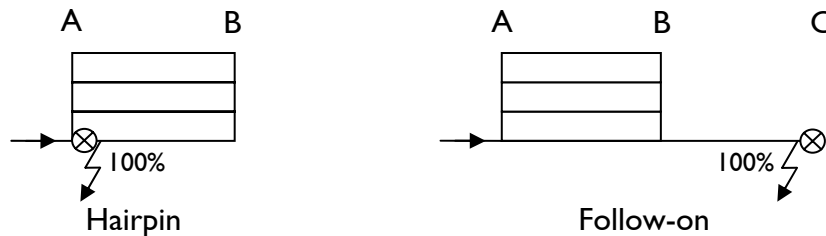
The fault is applied to the section with the lowest impedance.

Figure 3 Zone 2 hairpin and follow-on scenarios

For Zone 2, the relays at A must discriminate with both B feeding towards the feeding location A and feeding towards location C.

The fault positions shown are necessary to maintain discrimination with B relays.

5.3 Zone 3



The fault is applied to the section with the highest impedance.

Figure 4 Zone 3 hairpin and follow-on scenarios

For Zone 3, relays at A must fully back up relays at B in the event of a single failure. These arrangements give the worst case.

5.4 Relay settings

Having determined the fault position, the equivalent impedance reaches must be determined for the relays at A for each zone.

In all cases, the impedance seen by a particular relay can be derived from the total fault impedance between the relaying point and the fault location.

Consider any number of parallel sections feeding a fault as shown in Figure 5.

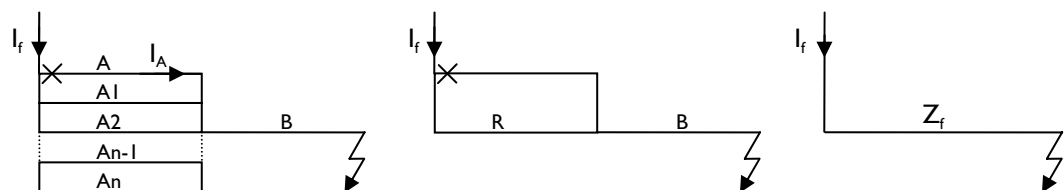


Figure 5

A is the impedance of the section with the relay to be set

R is the equivalent impedance of the remaining branches A1 to An

Z_f is the total fault impedance. It can be shown that the impedance seen by the relay on A is given by

$$\frac{A + R}{R} \cdot Z_f$$

This can be used to determine any Zone 2 or 3 setting by including a suitable tolerance correction factor. Zone 2 must discriminate, Zone 3 must fully back up.

Rule 2

$$\begin{aligned} \text{(a) Zone 2 setting} &= \frac{A + R}{R} \cdot \frac{Z_f}{K} \\ \text{(b) Zone 3 setting} &= \frac{A + R}{R} \cdot Z_f \cdot K \end{aligned}$$

where A = protected section impedance
R = equivalent impedance of remaining parallel branches
Zf = total fault impedance
K = tolerance correction factor (1.15 for Zones 1 & 2 or 1.2 for Zone 3)

It is now a simple matter of determining the fault impedance and applying Rule 2 for each case.

It must be remembered that for Zone 2, the lowest value produced by each case is used, to maintain discrimination in all cases, whilst for Zone 3, the largest value calculated for a given relay is the one which should be used.

For the relays at B looking towards C, the bus section circuit breaker is closed and the two busbars C and D considered as one unit. The settings are then calculated in the same way as for relays at A.

6 Tee feeder stations

Feeder Stations without neutral sections tee feed into the system without breaking the continuity of the section.

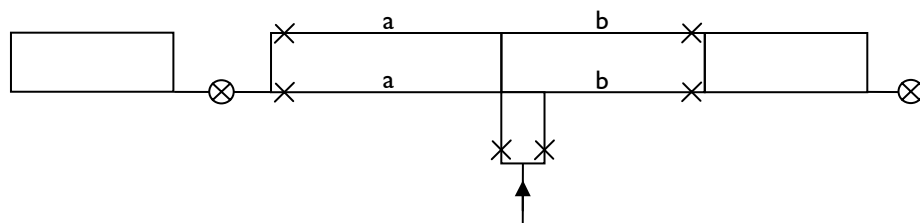


Figure 6 Tee feeding arrangement