

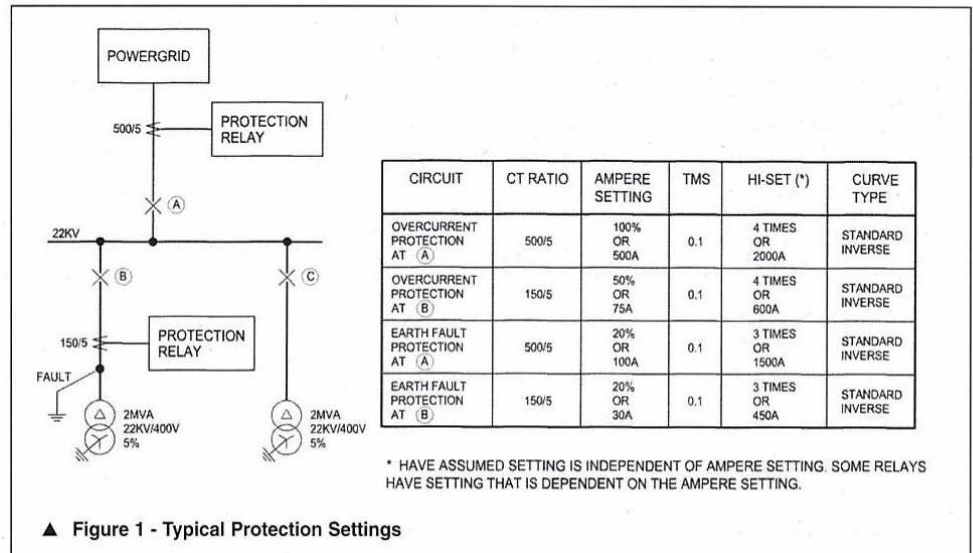
# The Loss of Discrimination Due to Instantaneous Trip Elements of Overcurrent and Earth Fault Protection at the Customer 22kv Electrical Installation

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## Introduction

Discrimination is the ability of a protection scheme to select and isolate only the faulty part of an electrical system. Figure 1 depicts the loss of discrimination where a fault between B and the transformer will cause A and B to trip. This is not acceptable because of the loss of electrical supply to the other healthy circuits. Correct discrimination is achieved when only B trips, isolating the fault and maintaining the continuity of electrical supply to the other healthy circuits.

Instantaneous trip or hi-set element used in overcurrent and earth fault protection provides fast tripping of the circuit breaker for high magnitude of fault current. However, these hi-set elements have caused loss of discrimination at the 22kV distribution voltage level of many consumers. This article provides an analysis of the problems, solutions and actual case history.



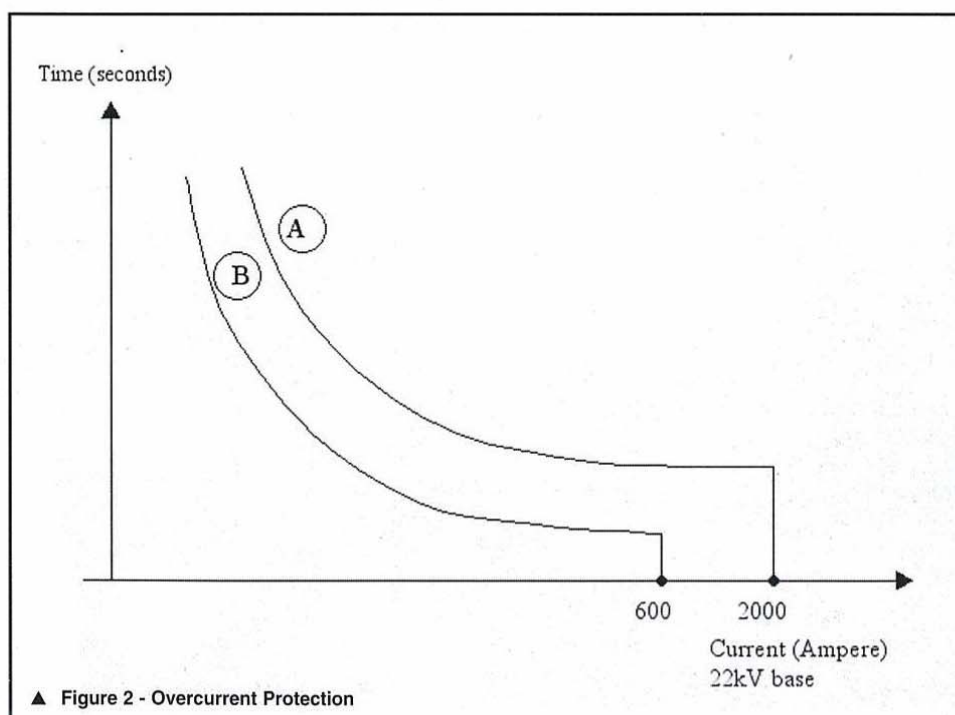
## Analysis of Problem

Referring to Figure 1, where a 3-phase fault between B and the transformer will lead to a loss of discrimination because both A and B will trip from their respective hi-set element of the overcurrent protection. From the relay co-ordination curve of Figure 2, there appears correct

discrimination for overcurrent protection between A and B. However, a hi-set of 600A and 2000A does not mean the fault current is limited to 600A and 2000A respectively. The fault current is totally independent of the setting of the hi-set element and its magnitude is close to 25kA for a 22kV system in Singapore. An actual fault of similar nature was recorded to be 22kA for a chemical plant in Jurong Island. The hi-set at A and B will pick up, and with no time delay between A and B, it is certain that both A and B will trip from their respective hi-set element. By the same analysis, an earth fault between B and the transformer will also cause both A and B to trip from their respective hi-set element of the earth fault protection.

## Solution

The solution is to disable all hi-set elements for the overcurrent and earth fault protection at the incoming circuits. Hi-set elements should only be used at the outgoing circuits. There are broadly two types of outgoing circuit, a transformer outgoing and a feeder outgoing.



## Transformer Outgoing Circuit

### Hi-Set for Overcurrent Protection

The difference of fault current at the HV and LV sides of the transformer is significant. This makes for easy setting of the hi-set for overcurrent protection at the HV side of the transformer.

For example:

2MVA, 22kV/400V, DyN11, 5% transformer

- Maximum through fault at 22kV

$$= \left( \frac{1}{0.05} \times \text{full load current} \right)$$

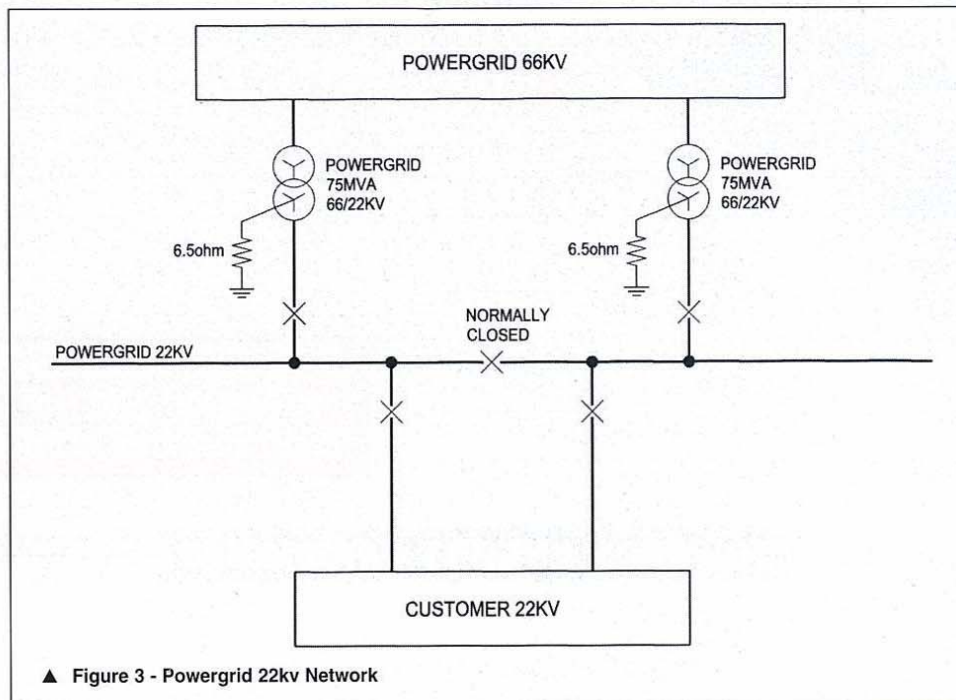
$$= 1050\text{A}$$

- Allow 20% safety factor for DC offset of the fault current.

- Setting for hi-set for 22kV overcurrent protection  
 $= 1.2 \times 1050\text{A}$   
 $= 1260\text{A}$

### Hi-Set for Earth Fault Protection

The magnitude of the 22kV earth fault current is limited by the PowerGrid 66/22kV transformer, where the neutral of the 22kV windings is connected by a 6.5 ohm resistor to earth. Figure 3 depicts the



typical arrangement. The maximum earth fault current will be 4000A when both transformers are in operation. The minimum earth fault current will be 2000A when one transformer is in operation.

Unlike the hi-set for overcurrent protection, there is no need for the hi-set for earth fault protection to co-ordinate with an earth fault at the LV side of the transformer. This is because for a DyN11 transformer, an earth fault

at LV star side is not reflected as an earth fault at HV delta side. The HV side will see a phase to phase overcurrent.

Hence, the hi-set only need be less than the minimum 22kV earth fault current. A reasonable setting is 500A.

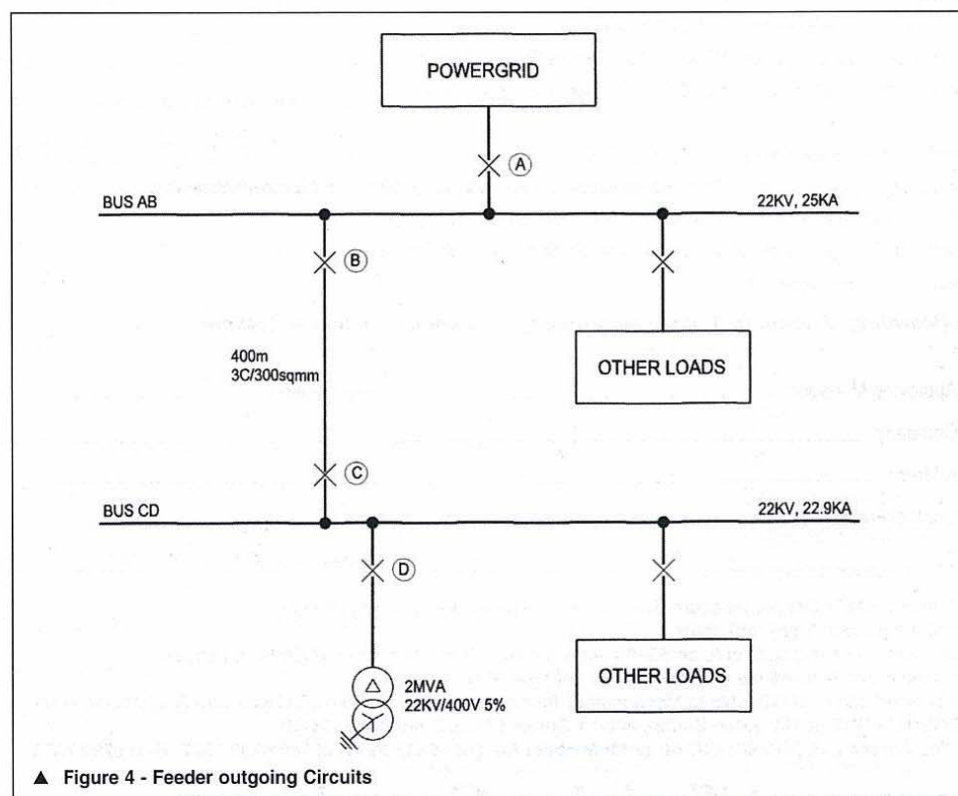
## Outgoing Feeder Circuits

### Hi-Set for Overcurrent Protection

Referring to Figure 4, based on the previous analysis, hi-set elements are disabled at incoming A and C. The hi-set for overcurrent protection at D is 1260A, based on the example in Section 3.1.1. The required hi-set for overcurrent protection at B will be 25kA, the maximum 3-phase fault current. However, protection relays have a maximum setting for the hi-set, 20kA a typical figure, and assume this value is used.

Hi-set Location	Setting
A	Disabled
B	20000A
C	Disabled
D	1260A

For a 3-phase fault between D and the transformer, the fault current will be about 22.9kA. B and D will trip from their respective hi-set of 20kA and 1260A. There is a loss of discrimination.





## Features

If the protection relay at B can provide a hi-set of 25kA, there will be correct discrimination for the same 3-phase fault between D and the transformer. However, at the practical level, the difference in 3-phase fault current will be small for various sections of the customer 22kV electrical installation.

For various length of the 3C/300mm<sup>2</sup> cable of Figure 4, the fault current at busbar CD is given as follows:

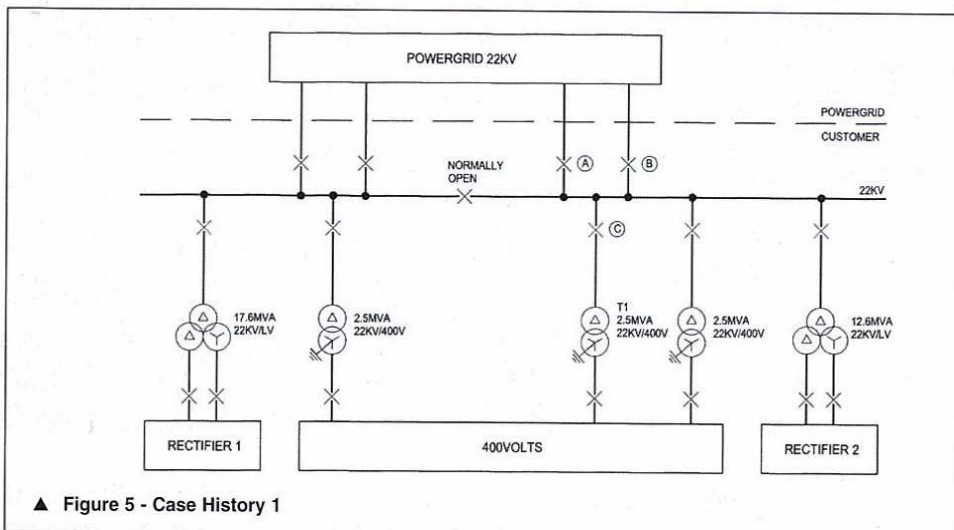
Length (m)	Fault kA at Busbar CD
50	24.7
100	24.4
200	23.9
300	23.4
400	22.9

Hi-set achieves discrimination entirely by fault current, and not by time because time delay is not a feature of hi-set. If there is no significant difference in fault current in the electrical system, hi-set for overcurrent protection should be used with care for outgoing feeder circuits.

### Hi-Set For Earth Fault Protection

As mentioned in Section 3.1.2, the 22kV earth fault current is limited by the neutral resistor at the PowerGrid 22kV system. There will be very little difference in earth fault current at all sections of the customer 22kV system. The difficulty is not the limitation of the maximum setting of the protection relay, since a maximum 4000A earth fault current is easily within the limit of the protection relay.

The difficulty is the almost



▲ Figure 5 - Case History 1

constant value of earth fault current at all locations of the customer 22kV system. Hence hi-set elements for earth fault protection should be used with care for outgoing feeder circuits.

### Case History 1 (Refer to Figure 5)

A failure of the 22kV heat shrink cable termination at the transformer T1 caused the tripping of A, B and C from their respective hi-set element of the overcurrent and earth fault protection. The plant has since disabled all hi-set elements at all the incoming circuits, and used hi-set elements only at all the outgoing circuits.

### Case History 2 (Refer to Figure 6)

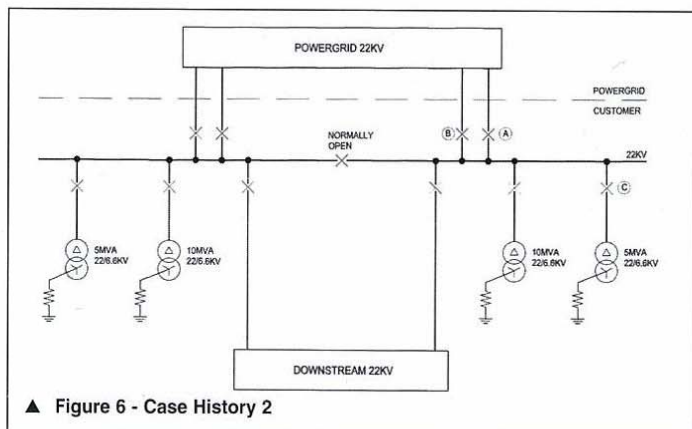
A failure of the 22kV capacitive divider for the neon light indications at switchgear C caused the tripping of A, B and C from their respective hi-set elements of the overcurrent and earth fault protection. The plant has since disabled all hi-set elements at all the incoming circuits, and used hi-set elements only at all the outgoing circuits.

### Case History 3 (Refer to Figure 7)

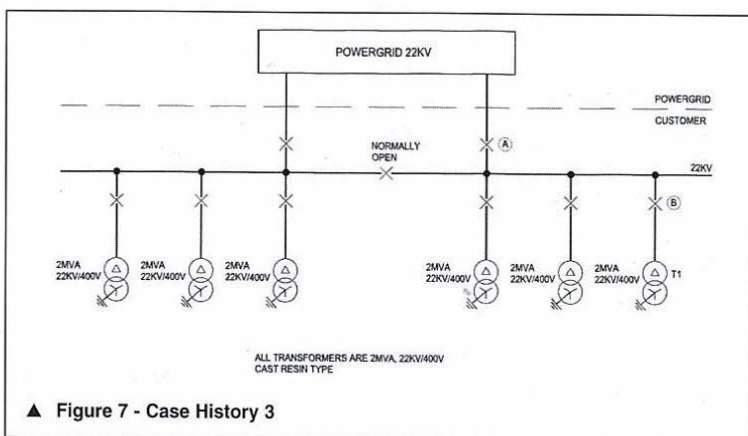
A failure of the 22kV windings of transformer T1 caused the tripping of A and B from their respective hi-set elements of the overcurrent and earth fault protection. The plant has since disabled all hi-set elements at all the incoming circuits, and used hi-set elements only at all the outgoing circuits.

## Conclusion

- Hi-set for overcurrent and earth fault protection should not be used at incoming circuits; otherwise, there is a loss of discrimination where the incoming circuit trips for a fault at the outgoing circuit.
- Hi-set for overcurrent and earth fault protection should not be used for outgoing feeder circuits because of small difference in fault currents at various sections of the 22kV system.
- Hi-set for overcurrent and earth fault protection are recommended at outgoing transformer circuits.



▲ Figure 6 - Case History 2



▲ Figure 7 - Case History 3