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Distribution Feeder Network Security Enhancement Using Improved Feeder Group Method

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Abstract: This study presents an innovative "Feeder Group" distribution network methodology which is developed for planning implementation in one of the power utilities in Hong Kong. The design concept s in feeder utilization, load transfer capabilities among Zone Substations as well as the security enhancement are presented. An improved "Hybrid Feeder Group" design concept is also proposed to reduce the outage time of power interruption due to cable fault. This network operation method is presented in the study with respect to its operational merits.

Key words: Distribution network design, load transfer capability, feeder automation

INTRODUCTION

In many countries including in North America, most of the distribution network is of radial feed design in which operational security is low. However, in the city center area, ring network in closed ring structure is used in which security is high but with low utilization of network (Filipec *et al.*, 1999; Taylor *et al.*, 1997; Kasim *et al.*, 1997; Brown *et al.*, 2001; Willis *et al.*, 1996, 1995; Willis, 1997).

In Europe, most of the rural area is of radial feed design. In city centre, open ring distribution system is adopted (Filipec *et al.*, 1999; Taylor *et al.*, 1997; Kasim *et al.*, 1997; Brown *et al.*, 2001; Willis *et al.*, 1996, 1995; Willis, 1997; Lakervi and Holmes, 1995). High security is achieved but only 50% utilization rate could be achieved.

In balancing the requirements of security and utilization of distribution network (Filipec *et al.*, 1999) the "Feeder Group" or "FG" network design is developed by one of the Hong Kong power utilities. The "FG" design could provide a reasonable utilization rate of the distribution network and could provide flexible load transfer capabilities among main zone substations.

"FEEDER GROUP" OR "FG" DESIGN CONCEPT

"FG" is made up of 4 feeders which normally come from different Zone Substations (Z/S) (Fig. 1).

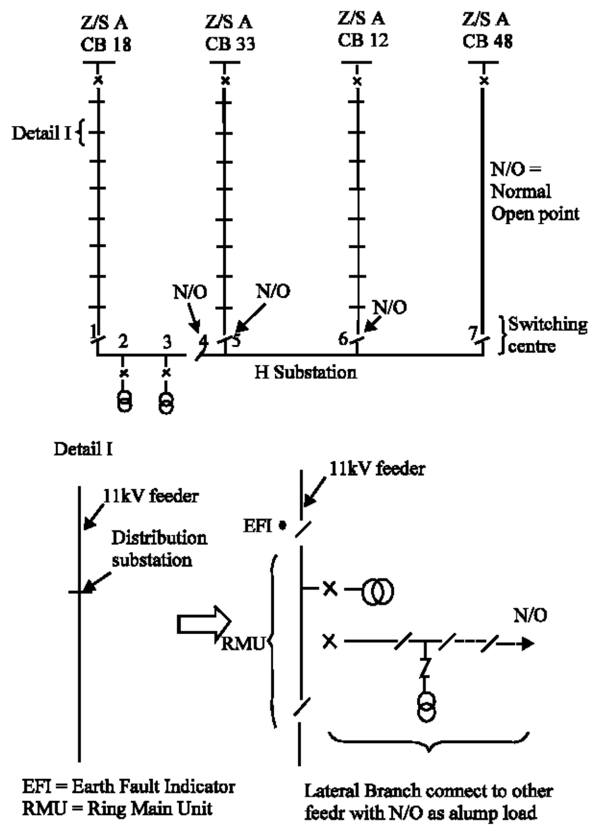

Fig. 1: "Feeder group" of 11kV distribution network

Characteristics of feeder group design

- A feeder group normally consists of 4 feeders, preferable from different zone substations, with 3 loaded feeders (Z/S A CB18, Z/S B CB33 and Z/S C CB12) and one clean feeder (Z/S D CB48).
- Under design loading, the loaded feeders can be loaded to 7.2 MVA with N/O placing at switching centre. That is,

Z/S A CB18 - N/O at Sw. 4 H S/S
Z/S B CB33 - N/O at Sw. 5 H S/S
Z/S C CB12 - N/O at Sw. 6 H S/S

The clean feeder Z/S D CB48 will be normally no load for backup one of the loaded feeder in case of fault.

- For a feeder group of 4, 25% reserve capacity was set. Utilization factor is 75%.
- Under zone substation contingency situation, e.g. Z/S A with more than one Zone Transformer outage which requires to shed load, Z/S A CB18 feeder of 7.2 MVA could be transferred to Z/S D through Feeder Group by closing Sw. 4 H S/S and opening Z/S A CB18. This applies to Z/S B and Z/S C.

Cable fault: Let us take an example to demonstrate the identification, isolation of fault and restoration of load after a cable fault at EHT 2914 (Fig. 2).

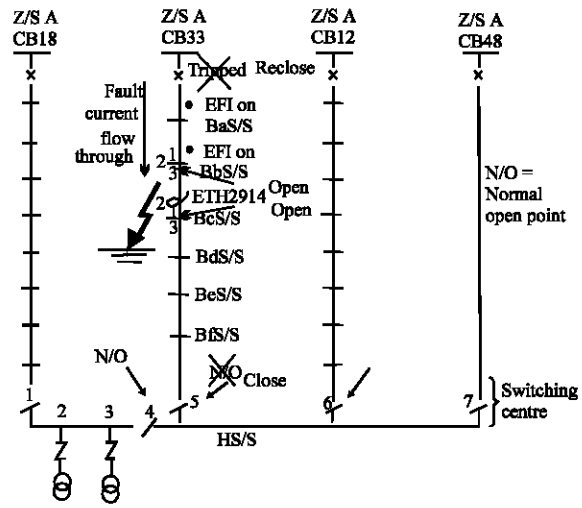

Fig. 2: Feeder group (under fault)

Fault identification

- Z/S B CB33 tripped.
- The substations at Z/S B CB33 feeder are out of supply. These are:- Ba, Bb, Bc, Bd, Be and Bf substations.
- Ba S/S and Bb S/S with Earth Fault Indicator (EFI) on.
- Bc, Bd, Be and Bf S/S on the same feeder have no EFI on indication.
- Confirm EHT 2914 connecting Sw. 3 Bb S/S and Sw. 1 Bc S/S is faulty.
- All these events can be seen at SCADA System Control Centre.

Fault isolation: By remote control, open Sw. 3 Bb S/S and Sw. 1 Bc S/S.

Load restoration

- Reclose Z/S B CB33.
- Close Sw. 5 H S/S.

As the above could be performed through SCADA system for cable fault identification, isolation and load restoration, it normally takes less than one minute to complete.

BENEFITS FROM "FEEDER GROUP" DESIGN

In conjunction with SCADA system remote monitoring and control on the distribution network, "FG" gives the following benefits:-

- High utilization rate: 75% for group of 4. Compare to open loop design of 50% of utilization rate.
- Load transfer capability among zone substations. With one clean feeder reserve capacity to cater for cable fault in the feeder group, the clean feeder can be used for load transfer among zone substations.
- The standardization of algorithm in cable fault identification, isolation and load restoration. Any cable fault in the feeder group, the switching algorithm would be the same by EFI to locate the faulty cable. This can be implemented to program at the SCADA system to fully feeder automation. Under the full feeder automation, the load restoration could be reduced to around one second.
- The loading of each feeder could be fed to System Control Centre for off-line calculation of minimum loss of feeder group in which the N/O points could be arranged to give minimum loss condition.

"HYBRID FEEDER GROUP" ("HFG" DESIGN)

Although there are a lot of benefits in using "FG" design, there is still a short duration of outage time (around one second if full feeder automation is implemented) in power interruption. It may not be well accepted by the important customer in Hong Kong.

A "Hybrid Feeder Group" or "HFG" design that incorporated the closed network design concept but with the benefits of feeder group design is proposed for consideration (Fig. 3).

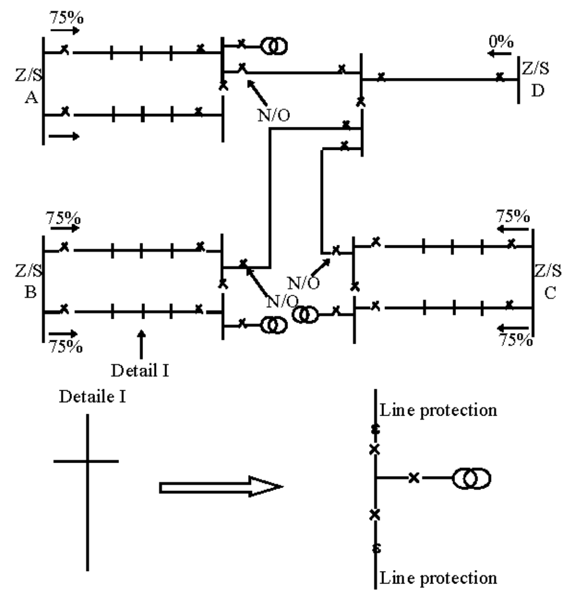

Fig. 3: Hybrid feeder group design

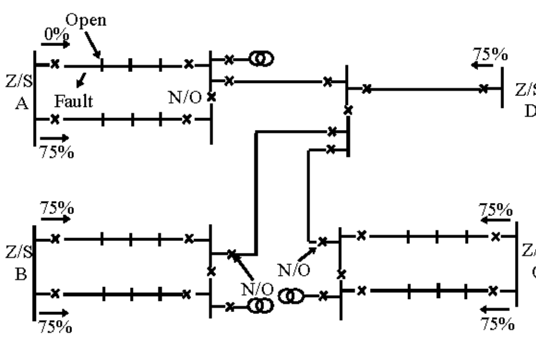

Fig. 4: Hybrid feeder group design (Under fault)

Characteristics of hybrid feeder group design

- 3×close loops + 1×clean feeder.
- Utilization factor = $\frac{6\times75\%}{7\times100\%}$ = 64%
- Cable fault at loop A, fault isolated by line protection. No power interruption due to the advantage of close loop.
- Under the worst case of Loop A cable fault, at the first section and peak load, Z/S A CB overloaded with 150% loading (less than 1 sec).
- As Z/S A CB overloaded, immediate switching through computer control as shown in Fig. 4 will be carried out. Overloaded situation can be relieved within 1 sec.
- Zone substation load transfer (75 + 75%) capability through distribution network is retained. Clean feeder can pick up 100% of load. The other 50% can be transferred through lateral branches to other feeder groups.
- The conversion of existing "Feeder Group" to "Hybrid Feeder Group" is not too difficult through network reinforcement. However, the replacement all existing (Switch-CB-Switch) RMU to (CB-CB-CB) RMU is a hugh effort.
- The design loading limit is set at 75%. It is to cater for lopsiding effect that in practise the load balance on a closed loop is not controllable. It depends on the cable parameters and loading of substations. This is the main disadvantage of close loop compared to open loop.

CONCLUSION

The "Feeder Group" design could provide reasonable balance between the security of distribution network and the utilization of network. The "Hybrid Feeder Group" Design further shortens the duration of power interruption time under cable fault condition. The decision in balancing the security level and the utilization of distribution network has been significantly reviewed under the new trend of deregulation of electricity market. Utility companies would consider the network design in a more business oriented way in coordination with the traditional engineering oriented way. The feeder group design and the proposed hybrid feeder group design are thus of value to enhancing power quality needs in the new power market environment.

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