An Integrated Protection and Control System for 10kV Electricity Distribution Networks Based on Package Transmission Communication Network

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Abstract—The application of a Wide Area Monitoring Protection and Control (WAMPAC) system in a 10 kV electricity distribution network (three 110 kV substations and nine 10kV ring main units) is presented in this paper. It provides current differential protection for 10kV feeders in order to meet the requirements of speed and selectivity of 10 kV feeder protection. The integrated protection and control system uses wide area information transmitted in Package Transmission communication Network (PTN) for feeder current differential protection, and to provide an auto-closing scheme for fast post-fault restoration of supplies. Laboratory tests and site trial have been done to prove the effectiveness of the system.

Index Terms—Electricity Distribution Network, Wide Area Monitoring Protection and Control (WAMPAC), Package Transmission Network (PTN), Feeder Protection

I. INTRODUCTION

The security and reliability of electricity distribution networks are important to customers due to the reason that it supplies to customers directly. For 10 kV distribution networks in China, the conventional time-graded overcurrent protection is normally applied. However sometimes it is difficult or impossible to achieve satisfactory time grading while maintaining a reasonable fast fault clearance time, particularly if the upper stream protection needs to co-ordinate a lot of down stream protections [1-2].

In recent years the number of distributed Renewable Energy Sources (RES) especially PVs have increased significantly. They are normally connected to 10kV distribution networks in China Southern Power Grid. With these embedded generations connected, it may cause the conventional overcurrent protection to mal-operate or fail to operate due to the change of direction of fault current flow and fault level. It is very difficult or impossible to apply the conventional overcurrent protection in the distribution networks with embedded generations [3-7].

Therefore this paper developed an integrated protection and control system for such distribution networks to provide fast current differential protection for 10kV feeders in order to meet the requirements of speed and selectivity of 10 kV feeder protection. The integrated protection and control system uses wide area information transmitted in Package Transmission communication Network (PTN) for feeder current differential protection, and to provide an auto-closing scheme for fast post-fault restoration of supplies.

II. ARCHITECTURE OF THE INTEGRATED PROTECTION AND CONTROL SYSTEM

The integrated protection and control system consists of a central unit which is normally installed at a 110/10 kV substation, and a local unit installed at each 10kV substation or at each 10kV ring main unit.

An integrated protection and control scheme has been developed for application in a 10 kV distribution network in China Southern Power Grid as shown in Fig.1.

Fig.1 Topology of the distribution network

As shown in Fig.1, a central unit is installed at the 110/10 kV substation Q and one local unit installed at each of the 9 ring main units (RMU #1 to #9). The normally open point is at RMU9.

The architecture of the WAMPAC system is shown as Fig.2. The local unit has the functions of sampling currents of each feeder and transmitting it to central unit, also receiving the trip and control commands from central unit. The central unit receives all the sampled currents, circuit
breaker (or load switch) status from all the local units. It integrates the current differential protection for all the 10 kV feeders, and knows the topology of the distribution network for auto-closing scheme.

If CB is installed at each RMU, the CB will be tripped directly by the local unit when it receives the trip command from central unit. If load switch is installed at each RMU, the CB at the beginning of the 10kV line will be tripped first when a power system fault occurs, then the two load switches which are closest to the fault will open by the local unit to isolate the fault.

RMU#4. After CB F03 opens to clear the fault, load switches in RMU#3 and RMU#4 open to isolate the fault, the central unit then send closing command to close CB F03 and load switch in RMU#9 to automatically restore the supplies to the rest of healthy circuits, as shown in Fig.4.

**III. PTN COMMUNICATION NETWORK DESIGNED**

Feeder current differential protection is simple and reliable, but it requires a reliable communication network and the time synchronization of the sampled currents obtained from all the local units. Therefore the PTN communication network is chosen for the application of the integrated protection and control system because the IEEE 1588 time synchronization can be easily applied in PTN for the synchronization of all the local units. The PTN communication network designed (using the existing optical fibers) for the application is shown in Fig.3.

**IV. FUNCTIONS OF THE INTEGRATED PROTECTION AND CONTROL SYSTEM**

Circuit breakers are only installed at the beginning of the 10kV feeders (i.e. CB F03, F07, F45 at the three 110/10kV substations), and there are load switches at each ring main unit, so the current differential protection for each feeder is used for fault location.

**A. Fault at f1**

If a power system fault occurs at f1, the feeder current differential protection locates the fault between RMU#3 and RMU#4. After CB F03 opens to clear the fault, load switches in RMU#3 and RMU#4 open to isolate the fault, the central unit then send closing command to close CB F03 and load switch in RMU#9 to automatically restore the supplies to the rest of healthy circuits, as shown in Fig.4.

**B. Fault at f2**

If a power system fault occurs at f2, the WAMPAC system will not start up because so far the system only covers from RMU1 to RMU9. After CB F07 opens to clear the fault, if RMU#9 does not detect any current, the central unit will send commands to open load switch RMU#9-1 and close load switch RMU#9-2 to restore the supplies to RMU#9, as shown in Fig.5. Then CB F07 will reclose, if there is a permanent fault, CB F07 will trip again, ring main units between CB 07 and RMU#9 will lose power supply. In the future, ring main units between CB 07 and RMU#9 will be upgraded to participate in the WAMPAC system.

**C. Multiple Faults**

Firstly a fault occurs at f1, after CB03 trips, RMU3 and RMU4 will open to isolate the fault. At this time if a fault occurs at f3, CB F07 opens to clear the fault, load switches in RMU#5 and RMU#6 open to isolate the fault, the central unit then send closing command to close CB F07 to automatically restore the supplies to the rest of healthy circuits, RMU#4 and RMU#5 will not get power supply, as shown in Fig.6.
rest of healthy circuits, as shown in Fig.8.

D. Communication Failure

If a power system fault occurs at f1, and at the same time if the local unit in RMU#3 has communication failure, the feeder current differential protection is not able to locate the fault between RMU#3 and RMU#4, so it will extend the protection zone to the line section between RMU#2 and RMU#3. After CB F03 opens to clear the fault, load switches in RMU#2 and RMU#4 open to isolate the fault, the central unit then send closing command to close CB F03 and load switch in RMU#9 to automatically restore the supplies to the rest of healthy circuits, as shown in Fig.7.

E. Local Status

If RMU#5 is switched to local status for maintenance, the load switches in RMU#5 will not be operated by the WAMPAC system, so it will extend the fault location zone to the line section between RMU#4 and RMU#6. When a power system fault occurs at f3, the feeder current differential protection locates the fault between RMU#4 and RMU#6. After CB F03 opens to clear the fault, load switches in RMU#4 and RMU#6 open to isolate the fault, the central unit then send closing command to close CB F03 and load switch in RMU#9 to automatically restore the supplies to the rest of healthy circuits, as shown in Fig.8.

F. Fault at the busbar in RMU

If a power system fault occurs at the busbar in RMU#5, the local unit in RMU#5 will locate the fault position, using current differential protection of bus bar. After CB F03 opens to clear the fault, load switches in RMU#4, RMU#5 and RMU#6 open to isolate the fault, the central unit then send closing command to close CB F03 and load switch in RMU#9 to automatically restore the supplies to the rest of healthy circuits, as shown in Fig.9.

G. Failure of Load Switch

If a power system fault occurs at f1, the feeder current differential protection locates the fault between RMU#3 and RMU#4. After CB F03 opens to clear the fault, load switches in RMU#3 and RMU#4 open to isolate the fault, but if the load switch RMU#3-1 fails to open, the central unit will send tripping command to the load switch RMU#3-2 and the load switch RMU#2-4 to open it, and then send closing command to close CB F03 and load switch in RMU#9 to automatically restore the supplies to the rest of healthy circuits, as shown in Fig.10.
V. APPLICATION OF THE INTEGRATED PROTECTION AND CONTROL SYSTEM

The protection and control scheme developed has been tested satisfactorily in laboratory, using real time digital simulator (RTDS) system. Now the WAMPAC system is being installed and commissioned on site, and it will be put in service shortly. It is hoped that the system will improve the supply reliability of the distribution network significantly after it is in service [8].

VI. CONCLUSION

Research and laboratory test of a WAMPAC system for application in a 10 kV electricity distribution network (three 110 kV substations and nine 10kV ring main units) has been carried out. The central unit integrates the current differential protection for all the 10 kV feeders, and knows the topology of the distribution network for auto-closing scheme. It is expected that, with the application of the WAMPAC system, faults in the 10 kV feeders can be located quickly. It shortens the outage time of the important load and improves the reliability of power supply significantly.

REFERENCES


Author Introduction

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