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REAL TIME LOCAL AUTOMATION IN REMOTELY CONTROLLED SUB-STATIONS

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1. INTRODUCTION

During preparations and design of interface for remotely controlled sub-stations with old protection solutions unavoidable question appeared: how to improve reliability of classic relay protection, with obsolete components and technical solutions. There are divided opinions on what kind and range of changes are necessary to achieve more reliable and modern technical solution. Each of the offered solutions has its price in work hours and equipment and also necessary time in which consumer is left without power. It must be emphasized that these sub-stations are in constant use, therefore power shutdowns must be minimized. Solution of choice must be a compromise to reconcile price of work and equipment and duration of service shutdown time, and at the same time provide safety, macro localization of failures and precise information on failure type which can be used to quickly localize and repair it.

Analysis of technical reports on failures in sub-stations and 35kV and 10kV power lines showed that, in cases where relay protection failed to prevent unwanted damage and power supply loss, most common reasons of failure are:

1. failure of output part of protection relay
2. failure of circuit breaker itself
3. failure of contacts on other relays used for switching off circuit breaker,
4. absence of DC voltage.

Based on conclusion of above mentioned analysis and years of experience it can be considered that measurement element is the most reliable part of protection relays because number of failures of protection equipment caused by measurement element is minimal and mainly due to failure of current transformer. This conclusion is base for local automation of sub-station.

Since we found that, in acceptable number of cases, each failure will be registered by measurement element of protection relay, we decided to keep existing protection relays currently in exploitation and use their measurement elements to register presence of failure. Signal from measurement element is brought to microcomputer devices which are placed on protection spots (feeders, transformers, relay consoles) and are integral part of sub-station interfacing. These devices will monitor workflow and provide solution for technical limitations of some protection relays and relay combinations. Devices function in two ways: locally, on level of individual feeders, and networked, by passing information to master device on supply line level, providing complete local automation function in sub-station.

This concept of interfacing to control remotely, in objects with electromechanical and static relays, keeps existing relay combinations and at the same time provides safer operation and acquisition of accurate information from supervised object, with minimal investment and fast setting up for remotely controlled operation.

2. GENERAL REMARKS

In further text we will, as illustration, use typical object – sub-station 35/10kV with static protection relay.

While performing installation of remote control interfacing in object, one must separate switch-off circuit of circuit breaker and lines for protection signals, on all points in object. Interfacing also includes forming of new circuit for manipulation of circuit breaker. This additional circuit can be used as backup line to switch off circuit breaker in case of failure of output part of protection relay.

Prepared object, with microcomputer devices in feeder cabinets and relay consoles, provides supervision of existing protection relays and commanding of circuit breaker. Operation of existing protection relays isn't changed. In case of failure protection relay registers it and gives command to switch off circuit breaker. After switching off circuit breaker, signal from measurement element is set back to inactive state which ends fault state. Local automation takes place in cases when circuit breaker fails to switch off.

3. SYSTEM OPERATION

Microcomputer devices in individual feeders are integral part of remote control system. Basic function of these devices is acquisition of local state and alarm signals and control of circuit breaker. Devices are connected via serial interface (RS485) in network with central microcomputer device. Such distributed concept allows less intervention in sub-station and less effort and material needed for wiring signals compared to standard, centralized interfacing scheme. Besides, this concept provides signal detection at point of origin, without unnecessary mediators, long conductors and relay combinations which increase unreliability. Finally, placing device in feeder cabinet enables additional features such as local automation and supervision of protection relay. Further in this paper we will explain this function in detail.

Individual devices in feeders supervise signals from measurement element of protection relay. In case of failure, i.e. activation of signal from measurement element, device waits for signal to be deactivated in preprogrammed time interval – time needed for protection to act. If signal isn't deactivated in programmed time, it is assumed that circuit breaker failed to switch off. Failure could be due to one of two main causes: failure of output part of protection relay or failure of circuit breaker. This situation is solved in two steps.

First step is attempt to localize problem. After detection of problem, local device, after given time, gives new switch-off command to circuit breaker. This command attempts to eliminate problem on output part of protection relay or intermediate relay which is often part of switch-off circuit. Successful switching off would eliminate problem, device would register failure of switch-off circuit and send information to distribution center. However, if circuit breaker failed to switch off and measurement element is not deactivated, it is assumed that circuit breaker is cause of problem. In that case, device registers failure of circuit breaker and instantly signals distribution center that failure of circuit breaker occurred. In first step, registered failure of circuit breaker is only signaled and monitored.

In second step registered information on circuit breaker failure proceeds to higher level device. Higher level device compares received information with monitored signals, and, by given logic, issues adequate commands. This command switches off some other (predefined) circuit breaker in order to eliminate problem. Information on performed action is sent to distribution center. Complexity of given solutions for local automation depends on operation of protection relay measurement element, as well as technical solution for sub-station to be adapted for remotely controlled operation.

4. OPERATION IN REAL SITUATION

Depending on place of installation and required level of local automation, devices can be put into four basic types :

1. 10kV feeder
2. 10kV transformer
3. 35kV transformer
4. 35kV feeder

We will discuss acting of each individual device type in real situations.

4.1. 10 kV feeder

Devices in 10kV feeder cabinets monitor overcurrent, short circuit and earth fault protection signals. These signals are acquired from measurement element. We will describe device operation for each protection type.

Overcurrent protection – if in given time (programmed time of protection acting) circuit breaker fails to switch off, device waits additional 0.2s, and, after this period elapses, issues command to switch off circuit breaker. In case of successful switching off, device signals failure of output relay and reports performed switching off. If circuit breaker fails to switch off again, device signals failure on circuit breaker and sends signal to device installed on 35kV transformer.

Short circuit protection – if in given time circuit breaker fails to switch off, device waits additional 0.05 seconds, and issues switch-off command. In case of success, device signals failure of output relay and reports performed switching off. If circuit breaker fails to switch off again, and sub-station doesn't have short-circuit protection of bus-bars and circuit breaker failure protection, instant command is issued for device at 10kV transformer to switch off its circuit breaker, and failure of circuit breaker is signaled to distribution center.

Earth fault protection – if in given time circuit breaker fails to switch off, device waits additional 0.2 seconds, and issues switch-off command. In case of success, device signals failure of output relay and reports performed switching off. If circuit breaker fails to switch off again, device waits additional time for backup earth fault protection to react. If circuit breaker still fails to switch off, instant command is issued for device at 10kV transformer to switch off its circuit breaker, and failure of circuit breaker is signaled to distribution center.

If monitored feeder signals any protection (overcurrent, earth fault or short circuit), and, in addition, there's signal 'no DC voltage', device issues instant command to switch off circuit breaker on 10kV transformer and signals failure of circuit breaker and loss of DC voltage to distribution center.

4.2. 10 kV transformer

Devices in 10kV transformer cabinets monitor short circuit protection of bus-bars, circuit breaker protection and react on commands issued by devices on 10kV feeders.

Short circuit protection of bus-bars - if in given time circuit breaker fails to switch off, device waits additional 0.03 seconds, and issues switch-off command. In case of success, device signals failure of output relay and reports performed switching off. If circuit breaker fails to switch off again, instant command is issued for device at 35kV transformer to switch off its circuit breaker, and failure of circuit breaker is signaled to distribution center.

Circuit breaker failure protection - if in given time circuit breaker fails to switch off, device waits additional 0.03 seconds, and issues switch-off command. In case of success, device signals failure of output relay and reports performed switching off. If circuit breaker fails to switch off again, instant command is issued for device at 35kV transformer to switch off its circuit breaker, and failure of circuit breaker is signaled to distribution center.

If monitored transformer raises short circuit signal, and there is also 'no DC voltage' signal, instant command is issued for device at 35kV transformer to switch off its circuit breaker, and transformer failure and loss of DC voltage is signaled to distribution center.

On command to switch off circuit breaker sent from device at lower hierarchical level (10kV feeder), device at 10kV transformer performs switching off of circuit breaker and reports on performed action to distribution center.

4.3. 35 kV transformer

Devices in 35kV transformer cabinets monitor overcurrent protection of 10kV feeders, backup overcurrent protection of transformer, earth fault protection of transformer, Buholtz protection, contact thermometer protection and differential protection.

If device at 35kV transformer receives signal for circuit breaker failure and failure of overcurrent protection to act on 10kV feeder, and, in addition, signal for transformer overload protection is raised, device issues command to switch off user defined 10kV feeder, in order to reduce transformer load. Report on performed action is sent to distribution center. At the same time, device monitors transformer temperature. If transformer load isn't reduced, device waits overload protection to execute. After defined time interval elapses, and protection didn't switch off, device waits additional 0.2s, and then switch-off command is repeated. If circuit breaker fails to switch off again, instant command is issued for device at 35kV supplying feeder to switch off its circuit breaker, and failure of circuit breaker is signaled to distribution center.

Backup overcurrent protection – if circuit breaker didn't switch off in given time, device waits additional 0.2s, and switch-off command is repeated. In case of success, device signals failure of output relay and reports on performed switching off to distribution center. If circuit breaker fails to switch off again, instant command is issued for device at 35kV supplying feeder to switch off its circuit breaker, and failure of circuit breaker is signaled to distribution center.

Earth fault protection - if circuit breaker didn't switch off in given time, device waits additional 0.2s, and switch-off command is repeated. In case of success, device signals failure of output relay and reports on performed switching off to distribution center. If circuit breaker fails to switch off again, instant command is issued for device at 35kV supplying feeder to switch off its circuit breaker, and failure of circuit breaker is signaled to distribution center.

Buholtz protection - if circuit breaker didn't switch off in given time, device waits additional 0.02s, and switch-off command is repeated. In case of success, device signals failure of output relay and reports on performed switching off to distribution center. If circuit breaker fails to switch off again, instant command is issued for device at 35kV supplying feeder to switch off its circuit breaker, and failure of circuit breaker is signaled to distribution center.

Contact thermometer - if circuit breaker didn't switch off in given time, device waits additional 0.02s, and switch-off command is repeated. In case of success, device signals failure of output relay and reports on performed switching off to distribution center. If circuit breaker fails to switch off again, instant command is issued for device at 35kV supplying feeder to switch off its circuit breaker, and failure of circuit breaker is signaled to distribution center.

Differential protection - if circuit breaker didn't switch off in given time, device waits additional 0.02s, and switch-off command is repeated. In case of success, device signals failure of output relay and reports on performed switching off to distribution center. If circuit breaker fails to switch off again, instant command is issued for device at 35kV supplying feeder to switch off its circuit breaker, and failure of circuit breaker is signaled to distribution center.

If monitored transformer raises any of above mentioned protections, and there's also 'no DC voltage' signal, instant command is issued for device at 35kV supplying feeder to switch off its circuit breaker, and transformer failure and loss of DC voltage is signaled to distribution center.

4.4. 35 kV feeder

Devices in 10kV feeder cabinets monitor overcurrent, short circuit and earth fault protection signals.

Overcurrent protection – if in given time (programmed time of protection acting) circuit breaker fails to switch off, device waits additional 0.2s, and, after this period elapses, issues command to switch off circuit breaker. In case of successful switching off, device signals failure of output relay and reports performed switching off. If circuit breaker fails to switch off again, device signals failure on circuit breaker.

Short circuit protection – if in given time circuit breaker fails to switch off, device waits additional 0.05 seconds, and issues switch-off command. In case of success, device signals failure of output relay and reports performed switching off. If circuit breaker fails to switch off again, instant command is issued for device at 35kV supplying feeder to switch off its circuit breaker, and failure of circuit breaker is signaled to distribution center.

Earth fault protection – if in given time circuit breaker fails to switch off, device waits additional 0.1 seconds, and issues switch-off command. In case of success, device signals failure of output relay and reports performed switching off. If circuit breaker fails to switch off again, device waits additional time for backup earth fault protection to react. If circuit breaker still fails to switch off, instant command is issued for device at 35kV supplying feeder to switch off its circuit breaker, and failure of circuit breaker is signaled to distribution center. Activating of switch-off command on 35kV supplying feeder will depend on position of sub-station on 35kV power line.

If monitored feeder raises any of above mentioned protections, and there's also 'no DC voltage' signal, instant command is issued for device at 35kV supplying feeder to switch off its circuit breaker, and feeder failure and loss of DC voltage is signaled to distribution center.

5. CONCLUSION

Discussed concept will provide solution for problems that occur due to failures of protection relays and circuit breakers. Described devices, connected in system on sub-station level provide signaling of failures of protection relays, exact localization of failure on protection relay or circuit breaker, prevent unnecessary circuit breaker trips in sub-station and acting of protections in supplying sub-stations which are not affected by failure. This helps dispatcher to easier make decisions and speeds up process of recovery of the power network.