

Dominant Practice Of Central European Electrical Utilities For Transmission System Protection

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PAPER MISSION

- The publication of the activities of the protection faculty of the System Protection and Dynamics Subgroup / Regional Continental Europe / System Operation Committee / ENTSO-E by means of one core working product, scoping the synergy through the widening of the collaboration of similar groups of other similar institutions

LINK TO THE SOURCE - Procedure

- ❑ Questionnaire distributed to TSOs (29 Companies at the CE regional area)
 - ❑ Introductory (2 Questions)
 - ❑ Protection principles (1 Q)
 - ❑ Protection Planning and Engineering (43 Q)
 - ❑ Protection commissioning, maintenance, analysis and auditing (4 Q)
 - ❑ Generalities (2 Q)
- ❑ Responses (by most of TSOs)
- ❑ Evaluation report
- ❑ Final Deliverable
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PAPER 'S CONTENT

- SELECTION OF SOME ESSENTIAL / EMERGENED ISSUES
 - INTRODUCTION
 - PROTECTION SYSTEM
 - Protection Principles
 - Protection of transmission lines
 - Line Differential protection vs the Classical Distance Protection
 - Redundancy Practices for Protection Equipment
 - Setting Criteria and Coordination Practices
 - Impact of new Generation Technologies on System Protection
 - Distance function (21) in double bus configuration substations
 - Differential relay (87) for transmission elements connected to wind farms
 - Phase overcurrent relays for transmission network transformers
 - CONCLUSIONS
 - ACKNOWLEDGMENTS
 - REFERENCES

II. INTRODUCTION

- ❑ protection practices for the transmission systems in central Europe
- ❑ redundancy practices, setting criteria and protection coordination methods
- ❑ comparison of the differential principle versus the distance principle
- ❑ differential scheme for line protection due to the increasing connection of power electronic devices
- ❑ The effect on dependability and security

II. INTRODUCTION # 2

- ❑ best practices for protection schemes considering security of supply and safety of persons and equipment
- ❑ to ensure system security across the interconnected European System at extra high voltage or high voltage
- ❑ reference for common principles, methods and procedures, concerning protection engineering

Protection Principles - Objectives

- ❑ Operational reliability (separate coils, supplies, double IEDs: 21+21, 21+50/67P-G...))
- ❑ Dependability (fast clearing, total coverage...)
- ❑ Security (allowance of maximum transmission capacity of the line)
- ❑ appropriate CBs with rapid tripping and arc quenching (less than 150ms fault clearing time)
- ❑ Additional functions, e.g. automatic reclosing (A/R), PSB/OOS, Commun. aided, residual voltage / current protection and logical controls)

Protection of transmission lines

- ❑ distance relays with teleprotection schemes (PUP, POP, AUP)
- ❑ maximum fault clearing time should be less than the critical fault clearance time
- ❑ Shorter fault clearing times will cause better system stability $\leftrightarrow$ shortening the time margins should not jeopardize the overall protection system security

Protection of transmission lines #2

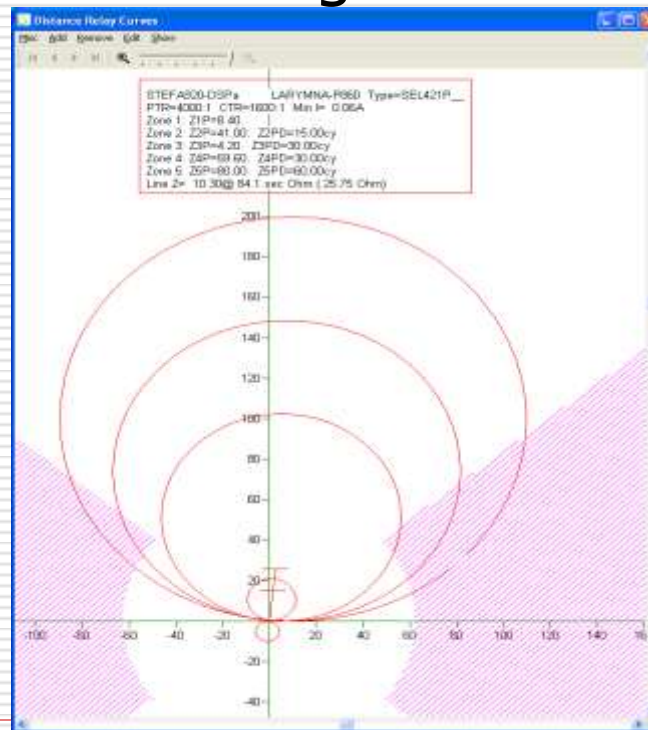
- Settings → short circuits in the grid will be detected and cleared selectively
- «protection limiting current» → current which can be transferred safely (without picking-up of starter elements and/or tripping of the protection system)
- The protection should be set not to trip under system transient conditions, which are not short circuits
- Total accumulated clearing time a concern (0.6+5 sec)

Protection of transmission lines #3

- strategy for determine the relay settings (operational limits, pre-defined conditions: minimum operating voltage, load area. equipment limit curves)
- Protection limiting current (of starter elements, reset ratios, measuring tolerances and additional safety factors)
- not to trip under system transient conditions, which are not short circuits

Load encroachment feature of distance relays

- maximum possible loadability of the protected equipment, without diminishing the clearing of anticipated faults according the simulation studies



Line Differential protection vs the Classical Distance Protection

- ❑ The line differential protection, associated with distance protection is considered a preferable protection technique for HV and EHV lines
- ❑ reliable telecommunication links
- ❑ resistive coverage of 150 Ohm
- ❑ current differential relay for 3-end circuits, tapped transformers, «short lines»- < 10 km, or < 20 % MIN-L and cables
- ❑ double current differential protection is decided to be used, for very specific and sound reasons, distance as back-up

Line Differential protection vs the Classical Distance Prot. # 2

- ❑ current differential protection should be a reliable type (preferably digital).
- ❑ The protection should be of the segregated phase type, i.e. it should be able to detect the phase in fault
- ❑ CT requirements
- ❑ protection of lines with tapped transf.: Specs
- ❑ The communication system for differential line protection should be based on fiber optic and any equipment should comply with the IEC 60834

Redundancy Practices for Protection Equipment

- ❑ The level of redundancy depends on the critical fault clearing time of the protected element
- ❑ Most important are the conditions for critical time calculation
- ❑ 2SP:• Primary protection system, which is the scheme that detects the faults in the power system tripping the element. The relay associated with the system is considered the main or primary relay
- ❑ • Main backup protection, which is the protection system redundant to the primary protection system that ensures that a failure of any element of the primary protection system is covered. This protection is called secondary or backup protection,
- ❑ • For EHV in particular there is no defined hierarchy between the two schemes. We can have two main protections, and they can include complementary principles.

Redundancy Practices for Protection Equipment # 2

☐	Tc L (ms)	Tc R (ms)	Tc LZI (ms)	Redundancy
☐	< 350	< 350	-----	2SP/2C
☐	> 350	< 350		2SP/2C
☐	> 350	(**)		2SP/1C
☐	> 350	> 350	-----	2SP/1C

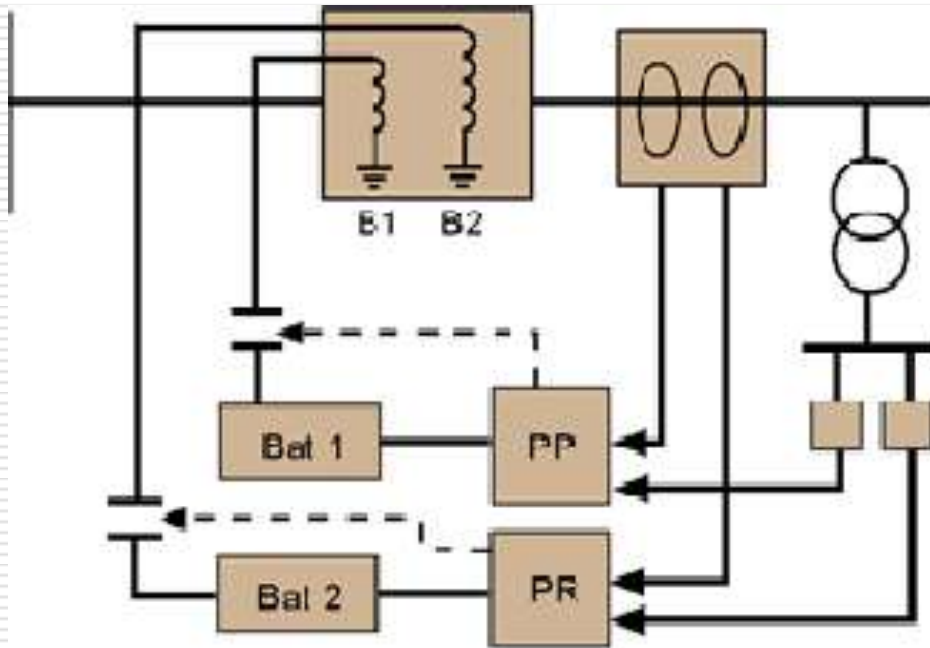
TABLE 1. DEGREE OF REDUNDANCY AND CRITERIA

Redundancy Practices for Protection Equipment # 3

For short circuit protection of a system element with a 2SP requirement the principle of dependability should be valid,. In terms of object's protection and for EHV level, we should have:

- Primary protection system, which is the scheme that detects the faults in the power system tripping the element. The relay associated with the system is considered the main or primary relay
- Main backup protection, which is the protection system redundant to the primary protection system that ensures that a failure of any element of the primary protection system is covered. This protection is called secondary or backup protection,
- For EHV in particular there is no defined hierarchy between the two schemes. We can have two main protections, and they can include complementary principles.

Redundancy Practices for Protection Equipment # 4



Full redundancy schemes for a protection system

Key note: Bat: Battery, PP: main Protection PR: Secondary protection

Setting Criteria and Coordination Practices

- ❑ Protection studies must have high quality, must guarantee the reliable operation and security of the system.
- ❑ Possible reasons for changing setting: new/cahnage equipment, topology, maintenance, lack of telecom, ...
- ❑ In meshed transmission networks, the coordination is especially difficult because of the short-circuit power variability and because of the intermediate infeed.
- ❑ Two network study cases should be considered: PEAK CASE, with all available generation connected, and OFF-PEAK CASE that considers the same topology, generation disconnected for power balancing and overhead lines outage («N-1» criterion

Setting Criteria and Coordination Practices # 2

- generation-transmission-distribution → cleared coordinated and with selectivity. The selectivity is not required in the case of radial feeders. A safe margin between primary and next back-up stage and zone is considered between 0.2(digital relays) and 0.3 to 0.5 sec (older generations of relays).
- Importance of models, non-conventional generating units, transients/subtransients, saturated/non-saturated etc
- only overcurrent and distance relays are considered as responsible for clearing the faults.
- Not involved at coordination differential protection
- faults with a reasonable fault resistance should be examined
- the complete path: generation-transmission-distribution must be considered as an interlinked entity and faults passing through different voltage levels must be cleared coordinated

Impact of new Generation Technologies on System Protection

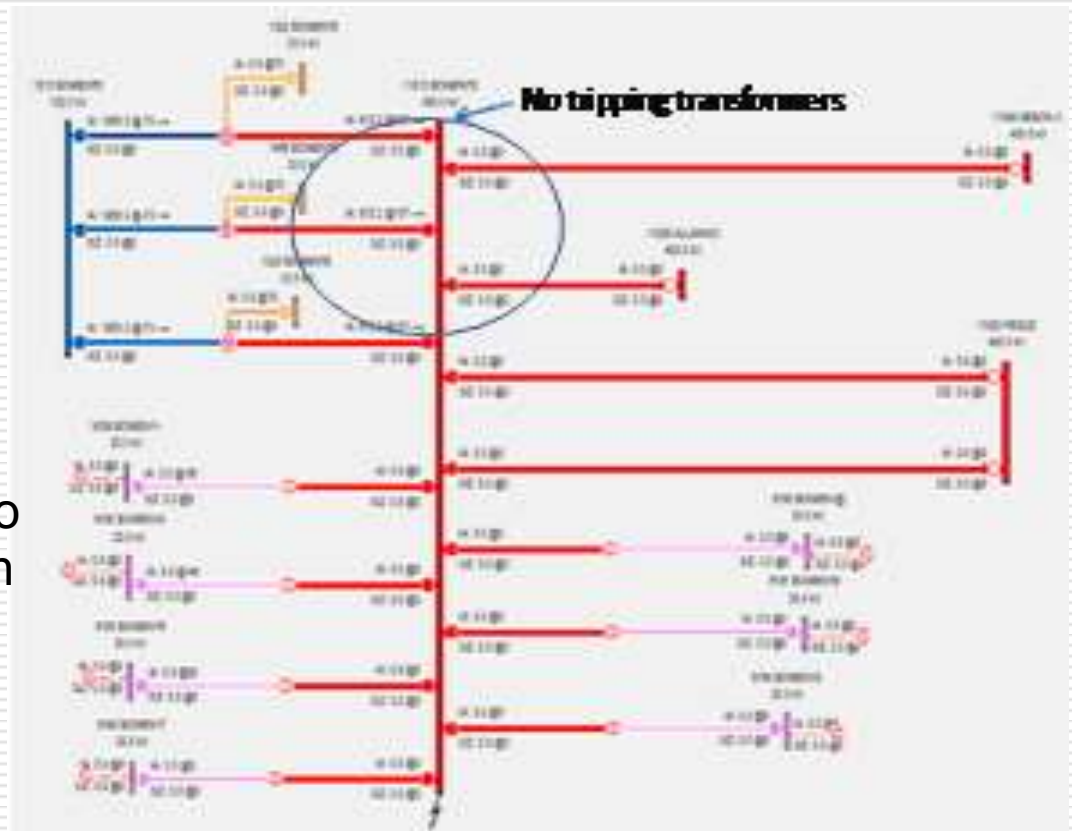
- ❑ The low values of short circuit currents supplied by modern wind farm generators can adversely impact on the performance of the HV transmission system protective relays when in a particular electrical area or at specific generation scenarios, the doubly fed induction machines or the full converter synchronous machines are extensively used instead of classical generation
- ❑ Most of modern digital distance relays require a minimum value for phase current, in order to be able to operate. it means that low short circuit currents I_{SS} supplied by the doubly fed and full converter wind farm generator, could not be high enough to distance relays to operate under faulty conditions by zone 2 or zone 3.

Impact of new Generation Technologies on System Protection #2

- the short circuit current supplied to the fault is coming from squirrel cage inductor generators, the distance relay will not operate in its step 2 zone or zone 3, since the short circuit current after the typical delayed time for zone 2 (0.35~0.45 s) is surely lower than I_{MIN} (actually close to 0).
- differential current value will normally be into the operation area that is set in the differential relay and therefore line differential will be able to clear the fault when RES is feeding the short circuit.

OC relay (51) for transmission elements connected to wind farms

Problems arise when one or two voltage side of transformer is only fed from wind farm generators. 51 OC functions will not detect the faults in the busbar where transformers are connected. Therefore OC functions are not adequate in EHV transmission systems when RES are connected.



IV. CONCLUSIONS

- ❑ Basic principles of protection followed
- ❑ System safety, security, reliability, integrity
- ❑ Exploitation of other available functions of protection relays in favor of system improvement and reliability
- ❑ Tools assuring the security of the protection
- ❑ Distance protection vs. differential
- ❑ Difficulties with non conventional generating plants for zone 2 or zone 3 backup distance functions
- ❑ In case of high penetration of RES current line differential protection must be used in any line
- ❑ Where RES are feeding short circuit, OC functions are no able to detect and clear faults. So avoid those functions in EHV transmission systems.

Credits

- Credits are expressed to other colleagues or entities, for their contribution related to present issue:
 - Members of the SPD SG
 - Members of the «Line Protection» AhT of the SPD SG
 - TSOs, who responded to the Questionnaire

Thank you for your attention