ANALYSIS OF POWER SYSTEM COLLAPSE RISK

Eleschová, Ž., Beláň, A., Cintula, B. Smitková, M.
Faculty of Electrical Engineering and Information Technology, Slovak University of Technology in Bratislava
zaneta.eleschova@stuba.sk

Annotation
In this paper are analysed the initialization events with considering different scenarios and their impact on the power system transient stability. As an initialization event is considered a short circuit at various places of power line. In each scenario are considered protection failures (backup protection), circuit-breaker failures (breaker failure relay activation). The individual states are analysed and the power system collapse risk assessed based on the simulation experiments results

Keywords
Power System Collapse, Transient Stability, Breaker Failure Relay, Backup Protection.

1 INTRODUCTION

In the project supported by the Slovak Research and Development Agency APVV-0337-07 was solved issue of the power system collapse risk assessment with considering different initialization events and defined scenarios. Based on transient power system stability simulation was assessed the state of power system after the initialization event (IE). As initialization events were considered: short circuit on the power line in Transmission System of Slovak Republic, bus short circuit in Transmission System of Slovak Republic, outage of high power unit, power line outage and load outage. There were also considered scenarios involving protection failures, and circuit-breaker failures. All scenarios of failure conditions were analysed based on the simulation results. The risk of power system collapse was further assessed using the PSA method. There was created a reliability model of power system elements and for all events and scenarios were created the event trees.

Based on simulation results it can be concluded that the worst initialization event is a short circuit. Failures of power unit or load are not significant events for the Transmission System of Slovak Republic parallel operation with the European power system.

At present, this project continues with extended assignment.

In this paper are presented results and assessment for the initialization event - short circuit on power line.

2 POWER SYSTEM STATE ASSESSMENT AFTER INITIALIZATION EVENT WITH CONSIDERING THE SCENARIO

Based on the results of transient power system stability simulation for power system state assessment were suggested following definitions of power system states after the IE:

Definition 1 – Power System is stable
Power system is stable, if after IE simultaneously is applied:
- will be not lost any power source in the power system after the IE,
- will be not overloaded transmission lines,
- no 400 kV substation will be without power supply from the transmission system due to IE,
- no reduction in power supply.

Definition 2 - Power System of Slovak Republic is stable with limitation
Power System of Slovak Republic is stable with limitation, if after IE simultaneously is applied:
- will be not lost any power source with total power higher than 880 MW
- no more than 2 substations (400 kV) will be without power supply from the transmission system due to IE,
- no significant reduction in power supply from the transmission system due to IE.

Definition 3 - Power System of Slovak Republic is in an emergency state
Power System of Slovak Republic is in an emergency state, if after IE is applied:
- will be lost power sources with total power higher than 880 MW due to IE,
  or
- more than 2 substations (400 kV) will be without power supply from the transmission system due to IE,
  or
- there will be significant reduction in power supply from the transmission system due to IE.

Definition 4 - Power System of Slovak Republic is unstable
Power System of Slovak Republic is unstable, if after IE simultaneously is applied:
- will be lost power sources with total power higher than 880 MW due to IE,
- more than 2 substations (400 kV) will be without power supply from the transmission system due to IE,
- there will be significant reduction in power supply from the transmission system due to IE.

Definition 5 - Power System of Slovak Republic is unstable in bulk
Power System of Slovak Republic is unstable in bulk, if after IE the power system will get in a complete loss of voltage (power system blackout).

3 DEFINED SCENARIOS AFTER INITIALIZATION EVENT

For initialization event - short circuit on power line, were validated by transient simulation following scenarios:

1 [a = bp, b = bp]
At the beginning ("a") and at end ("b") of the line where the short circuit was; it is considered distance protection failure. The short circuit tripping is provided by backup protections (bp) on other lines.

2 [a = bp, b = BFR]
At the beginning of the line, where the short circuit was; it is considered distance protection failure, at the end of this line; it is considered the circuit breaker failure. On one power line side is the short circuit tripping provided by backup protections and on the bus at the end of the line is considered breaker failure relay (BFR).

3 [a = BFR, b = bp]
At the beginning of the line, where the short circuit was; it is considered the circuit breaker failure, at the end of this line; it is considered the protection failure. On one power line side is the short circuit tripping provided by backup protections for and on the bus at the beginning of the line is considered breaker failure relay.

4 [a = bp, b = p]
At the beginning of the line, where the short circuit was; it is considered distance protection failure - the short circuit tripping provided by backup protections at the end of this line is the tripping provided by the distance protection in fast zone (short time of tripping).

5 [a = p, b = bp]
At the beginning of the line, where the short circuit was; the tripping is provided by the distance protection in fast 1st zone - short time of tripping (p), at the end of the line is considered distance protection failure – the tripping provided by backup protections.

6 [a = BFR, b = BFR]
On both power line sides are considered circuit breaker failures and on both buses is considered breaker failure relay activation.

7 [a = BFR, b = p]
At the beginning of the line is circuit breaker failure – tripping by breaker failure relay activation, at the end of the line is the tripping provided by the distance protection in fast 1st zone (short time of tripping).

8 [a = p, b = BFR]
At the beginning of the line is the tripping provided by the distance protection in fast 1st zone (short time of tripping), at the end of the line is circuit breaker failure - tripping by breaker failure relay activation.

As in the model were also included substations with three breakers per two branches, the scenarios were supplemented for power lines from these substations with considering of circuit breaker failure:
1. side circuit breaker failure
2. middle circuit breaker failure
3. both circuit breakers failure.

The events scenario after initialization event (short circuit) for one of the lines is possible to depict of flowchart in Fig. 2. This flowchart is for the short circuit in the middle of the line. In Fig. 3 is a flowchart for a short circuit position, which is beyond the first zone distance protection.
There is important thing to mention namely the power lines are protected by distance protections and for the further development of considered scenario is the location of short circuit on the power line very important. Distance protection behavior is describing the sequential type tripping characteristic. The first protection zones reach cannot be set to the total impedance value of the protected power line Z_{L1}. The main reason is that the protection impedance measuring element has measurement errors and typical value is ± 5% of the impedance reach. Therefore, the protection could operate non-selectively. Therefore, the 1st zone Z1 where distance protection operates in fast time (short time of tripping), is reduced to 80% to 90% of power line length. Therefore, the short circuits out of the first zone (at the end, respectively at the beginning of the line) are not tripped immediate, but with the delay in the second zone.

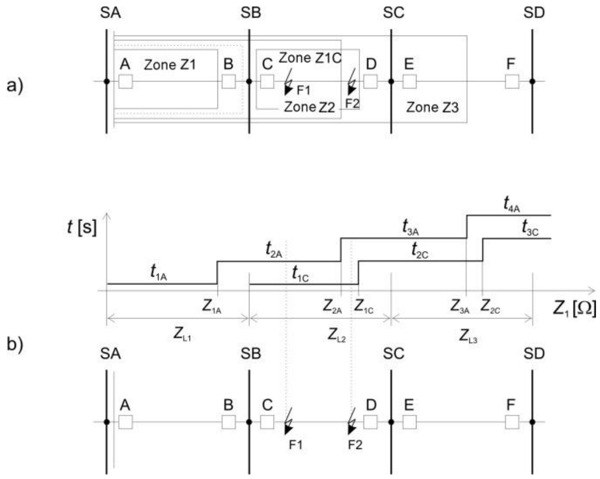

Fig. 1 . Power line protection by distance protection;
a)protection zones, b) sequential tripping characteristic

In terms of reliability assessment by probabilistic model is in the flowchart included also protection communication. Failure of this communication then influences the risk assessment in terms of probability.
In these flowcharts is given development of events in substations with one bus operation. The scenario with considering the circuit breaker failure, i.e. breaker failure relay activation, it is an important method of substations operation. Significant and positive roles have substations with two bus operation, where the splitting of substation is possible and that means "saving" a few branches. Even more positive roles have substations with three breakers per two branches.

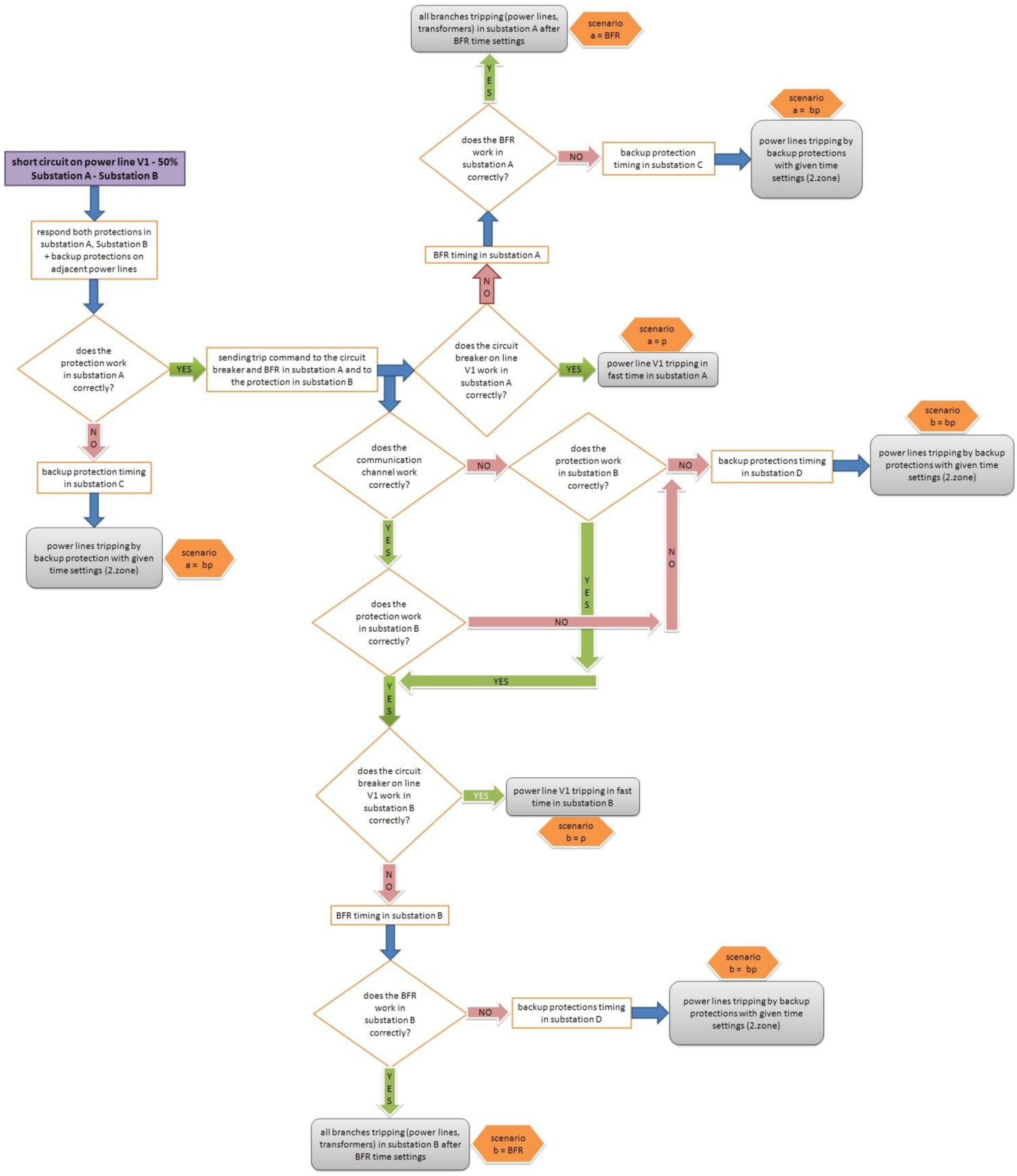

Fig. 2. Flowchart of short circuit in a half of length of power line

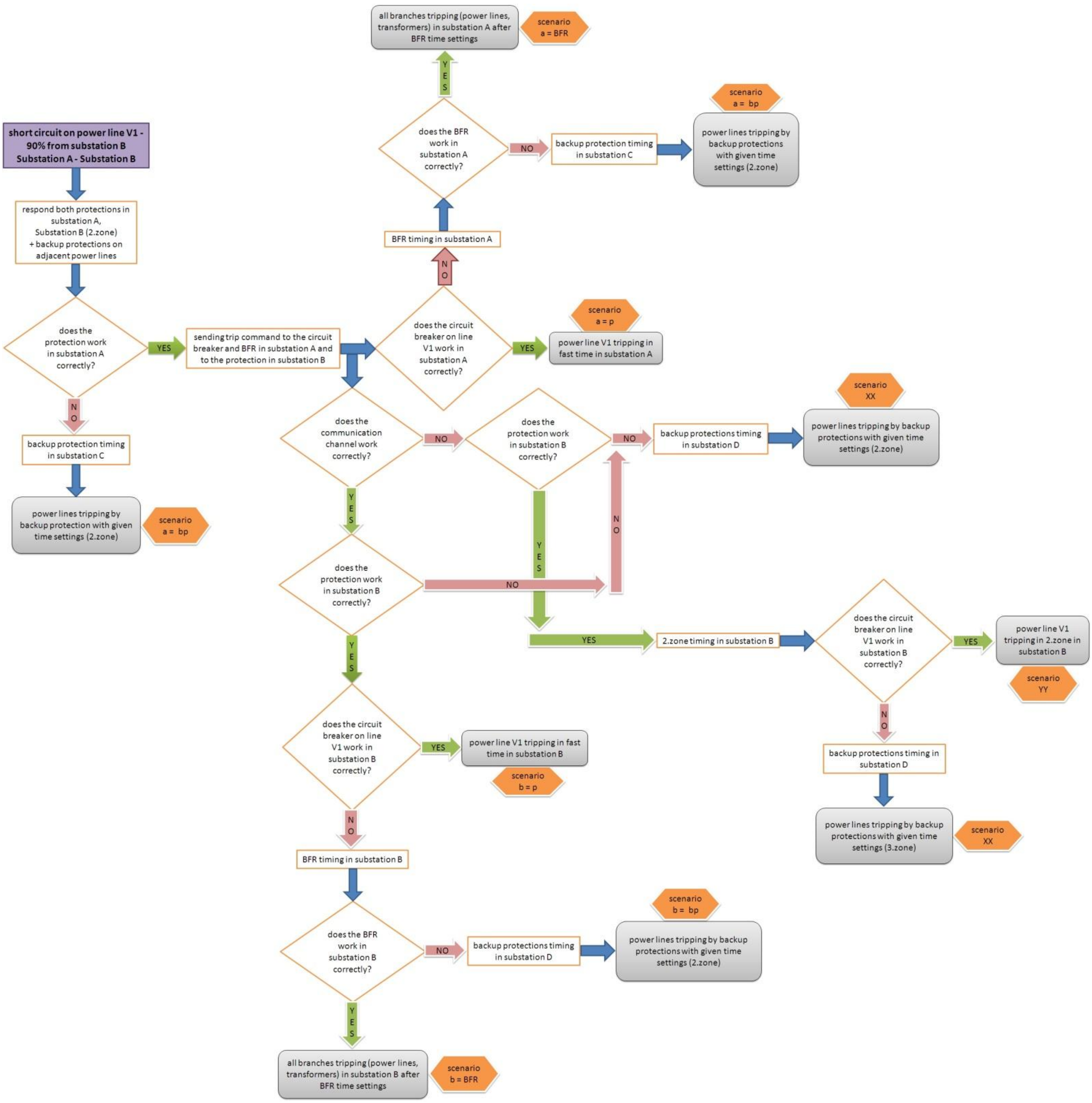

Fig. 3. Flowchart of short circuit position on power line beyond the first zone distance protection

4 EXPERIMENT RESULTS EVALUATION

Considered scenario with protection failure or circuit breaker failure means more serious risk for Power System of Slovak Republic, what confirm most experiments of short circuit on 400 kV power line without tripping in fast 1st zone (short time of tripping). Particularly short circuits on power lines from substations, where the high power of generator units is exported with considering appropriate scenarios are assessed as D3 (Definition 3) and D4 (Definition 4). Scenario with considering circuit breaker failure (BFR activation) have important and positive role substations with two bus operation (possibility of substation splitting), respectively substation with three breakers pre two branches. Considering the transient stability of synchronous generators is also important BFR time and backup protection time setting.

In any modeled case, there has not been the complete blackout of Power System of Slovak Republic.

Considering the topology of Transmission System of Slovak Republic (where dominate particularly 400 kV power system and all power units are connected only into this voltage level), the short circuit on 220 kV transmission lines under any scenario has not the serious impact on Power System of Slovak Republic and does not threaten its stability.

5 CONCLUSION

In this paper are given results of the power system collapse risk assessment with considering initialization event: short circuit on power line with considering given scenarios included protection failures and circuit breakers failures. Based on simulation experiment results; the individual states are analysed and the power system risk collapse assessed.

It is clear that probability of these events in real power system operation is very low. The aim of the project, which partial results are given in this paper, is a different point of view on power system and its reliability. Based on the results, it is possible in the further development of the power system to take certain decisions, e.g. about methods in operation of important substation, power lines or protections strengthening. Therefore, research in this field can bring to the further development of the transmission systems and method of their operation new knowledge.

ACKNOWLEDGEMENTS

This work was supported by the Slovak Research and Development Agency under the contract No. APVV-0337-07.

These publications are the result of implementation of the project: “Increase of Power Safety of the Slovak Republic”(ITMS: 26220220077) supported by the Research & Development Operational Programme funded by the ERDF.

REFERENCES

[1] Final report of project APVV-0337-07.

[2] JANÍČEK, F., CHLADNÝ, V., BELÁŇ, A., ELESCHOVÁ, Ž.: Digitálne ochrany v elektrizačnej sústave. Vydavateľstvo STU, Bratislava 2004. s. 360 ISBN 80-227-2135-2