

Chapter 12

Fault Tree–Based Root Cause Analysis Used to Study Mal–Operation of a Protective Relay in a Smart Grid

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ABSTRACT

This chapter presents how root cause analysis based on fault tree technique can be used to study mal-operation of protective relay in a smart power grid. This approach is used to identify disturbances first and root cause of mal operation of protective relays which may lead to unnecessary tripping and hence to blackout. Once the critical root causes are identified, mitigation measures first such as blocking protection functions and digital filters may be used in view of increasing the reliability of the considered protection system. The proposed approach has many advantages as it allows obtaining an important quantitative figure (security). These permits to strongly strengthen the elements of the protecting system which are most likely appropriate to failure and hence the impact on the overall system's cost is significant. Another main advantage is that it takes into account the reliability of the software part of the system which is considered to have a significant contribution in the overall reliability of the protecting system.

INTRODUCTION

A protection system is a vital part of any electric power system and plays an incredible role in maintaining high availability required in present day. The mal-operation (false trip) of one relay of the protective scheme to operate as intended may place at risk the stability of the whole power grid and hence may lead to blackout.

In this chapter, Root Cause Analysis (RCA) based on Fault Tree Analysis (FTA) is used to identify disturbances first and root cause of false trips of protective relays which may lead to unnecessary tripping in cascading and then to the bulk blackout. Once the critical root causes are identified for this mal-

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operation of these relays, mitigation measures such as blocking functions and digital filters may be used for increasing the reliability of the considered protection system. Some research works (Chena, J. et al, 2005; Jonsson, M., & Daalder, J., 2001; Lin, X. et al, 2008; Su, B., et al, 2005; Jiao S., et al 2001; Rao, J. G., & Pradhan A. K.; 2012) proposed some efficient solutions (based mainly on digital filters) to obtain accurate and disturbance-free phasor measurements. As a result, the reliability of the measuring block of the protection system can be significantly improved. However, this improvement concerns one term of the reliability (the dependability) of the protection system. In the present chapter, how RCA based FTA is used to improve the reliability of the global protection system. This proposed approach has many advantages compared to those published in previous works as it allows obtaining an important quantitative figure (security). This permits to strongly strengthen the elements of the protective system which are most likely appropriate to failure and hence the impact on the overall system's cost. Another main advantage, it takes also into account the reliability of the software part of the system which is considered to have a significant contribution in the overall reliability of the digital /numerical protective system.

A Cigré study found that 27% of bulk power system failure (blackout) resulted from false trips of protection system. Besides, an analysis of 17 years data provided in NERC reports revealed that 63% of major disturbances are protection related protective relays which suffers from two types of mal-operation: unnecessary tripping (false trip) and fail to operate (Rao, J. G., & Pradhan A. K., 2012; Sachdev, M.S., & Baribeau M. A., 1979; Tziouvaras, D., 2007).

Major power system disturbances are more likely to be caused by unnecessary tripping rather than by the failure of a relay to take action (Jonsson, M. & Daalder, J.; 2001). In fact, a major cause of power system instability is due to the relative long time delay for fault clearance of zone three backup relays in distance relay that may used to protection the power transmission lines. In order to overcome the drawbacks of these relaying systems, many mitigation techniques have been developed such as a blinder that blocks the relay to operate during the power swing (Bentarzi H., Ouadi A., and Maun J.C., 2014). A more advanced new blocking and unblocking function based on power swing detector using Phasor Measurement Units (PMUs) has been proposed. In addition to the local phasors information, the proposed scheme uses remote phasors information from different locations for power swing detection, which can be provided at high speed by PMUs. These measurements are used for calculating the apparent power absorbed by power line and the difference in phase angles of voltages that may be used for detecting power swings and faults. Hence, the proposed scheme blocks tripping signal during the power swing and unblocks it during fault condition (Ouadi, A. Bentarzi, H., Chafai, M.; 2016).

The second order of major causes of instability of the power system is due to the magnetization current in differential relay used to protect the power transformers. In order to overcome the drawbacks of these relaying systems, many techniques have been developed such as an introduction of delay that blocks the relay to operate during the inrush phenomena (Sonnemann, W.K., Wagner C.L., & Rockefeller G.D., 1958). The mal-operation of this differential relay is generally due to not only unnecessary tripping during inrush current that reduces the security of protection system and hence its reliability but also unnecessary tripping when external fault occurs accompanying an overexcitation (Kennedy, L. F., & Hayward, C. D., 1938). Also this latter action may affect on a security of the relay and hence its reliability. Many techniques have been developed to block the operation of the relay during the saturation associated with an external fault condition such as a harmonic restrains (Hayward C. D., 1941). A more advanced new blocking function based on fourth harmonic detector using digital signal processing has been proposed (Guzman, A., & Zocholl S., 2001; Bouderbai, R., Bentarzi H. Ouadi, A., 2011). In addition to the second harmonic magnitude information, the proposed system uses other harmonic orders

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