CHAPTER 7

CONCLUSION

7.1 Conclusion

The proposed adaptive comprehensive protection schemes (CAP-1 and CAPS-2) for the distribution system with DGs provide the coordinated protection of relays in variable operating modes, where an operating mode can change due to grid-connected mode, islanding mode, feeders' reconfiguration, increment and decrement in the sizes of DGs, and DG's connections and disconnections during normal and faulty conditions. Different stages of protection including sensing of the fault, detection of the faulted zone, determination of pickup setting, selection of relays hierarchies, and coordination of relays have been analyzed and investigated considering different protection factors: variable operating modes, increasing proliferation, information loss due to unknown pre-fault failures of relays and their communication links, and unpredictable nature of the operating mode. In this respect, from Chapter-2 to Chapter-5, for each protection stages, problem formulations and corresponding solution methods or algorithms have been proposed. In each of these chapters, different case studies have been performed to show the significance and advantages of the individual algorithms, where the comparative performance has been validated by using the test system results.

After that, in Chapter-6, the applications of the proposed algorithms of different protection stages in developing the proposed protection schemes, CAPS-1 and CAPS-2, have been demonstrated. The comparative test results show that each algorithm has its own significant contribution in making the proposed protection schemes faster. The advantageous features of

each proposed algorithms, as discussed ahead, make the proposed protection schemes robust, reliable, faster irrespective of the above-mentioned protection factors.

- In the proposed hybrid approach (Hybrid_algo) for determining the pick settings, a relay not only uses the measurements of phase current's magnitude but also uses the measurements of other electrical parameters to sense the fault. This hybrid approach works independently of the level of fault currents, and as a result, makes the protection schemes capable of sensing the fault irrespective of the grid connected mode or islanding mode, network configuration, type and size of DG, and type of fault. With this approach, there is no need to switch protection modules for every change in the operating mode. Moreover, rather than using different protection characteristics such as inverse-time and definite-time for different protective relays to clear the faults of different levels, this algorithm assists in providing the same scale of inverse-time based protection characteristics for all protective relays. This, consequently, not only makes the coordination easier in a fault situation that may have different fault current levels at different network locations, but also provides fine selectivity due to using the inverse-time characteristics.
- The proposed algorithm (DFZD_algo) determines the faulted zone by taking only a few binary bits from the system's advanced relays. This method is capable of detecting the faulted zone irrespective of the change in the fault current level with the operating mode and absence of the information flow due to the FRC events. This algorithm makes the scheme partially independent of the communication systems and capable of discriminating whether the relays get picked up due to either non-faulty condition or faulty condition.
- One of the major reasons behind the failure of the existing protection schemes is the requirement of the new hierarchy levels for relays as operating mode changes.

Predetermined based relays' hierarchy (RHs) levels (stored in a lookup table) can provide the adaptive relays' settings but may fail to provide the coordinated protection if any unknown operating mode appears in the system. The proposed algorithm (RHs_algo) for determining the adaptive RHs is based on the calculation of few online pickup-signals (PS) binary bits of the relays. This algorithm not only makes the schemes adaptive to the unknown operating modes but also adjusts the relays hierarchies by utilizing the information of FRC failed relays (from the DFZD_algo) to make the protection faster and efficient.

- In this work, a constraint reduction relay coordination (CRRC) approach has been proposed which releases a significant amount of burden of the constraints from the coordination optimization process while determining the relays' TMS settings for all the possible operating modes. Apart from this, an expanded version of the CRRC, named SCRRC has been proposed, The SCRRC method, by utilizing few gathered information from the system, lessens the complexity in coordinating the relays in the environment of the increasing number of both DGs' connections and operating sizes of DGs.

The cumulative performances of the proposed algorithms in CAPs-1 and CAPS-2 show that each algorithm has its own significant contribution in making the proposed protection schemes faster, robust, and reliable. The results manifest that, compared to the conventional overcurrent protection approach, the proposed protection approach provides a very significant amount of reduction in the total fault clearing time such that the online delays added by the online algorithms are inconsiderable.

7.2 Future Scope of the Work

The proposed work can be further extended to the following aspects:

- The scheme is based on online algorithms and can adapt the prospective advancements in the technologies (protective devices, sensors, communication systems). It is flexible and programmable and can be re-designed for new types of inputs.
- The logic of relaxing the numerous constraints by using the CRRC and SCRRC can be implementable for the other types of protection schemes (differential protection, distance protection, etc.).
- This work presents effective solving approaches for different protection stages (sensing of the fault, faulted zone detection, selection of relays hierarchies, and relays coordination) for the varying operational status of the distribution systems with DGs. Where the inclusion of each proposed algorithm contributes to making the protection faster and robust. Any of the online algorithms can be easily incorporated into the other protection schemes to enhance the performance of the relays. Where the individual contribution of an algorithm can be further examined for the other types of protection schemes.
- The proposed protection approach possesses the capability of taking the protection decision in the presence of the information loss due to pre-fault failures of relays and/or their communication links. This protection approach can be further extended with the different types of information loss such as due to bad data detection and cyber-attacks.
- The proposed algorithms can be implementable for the decentralized communication assisted protection schemes as well.

- The penetration of DGs has a direct impact on the protection coordination. The proposed relay coordination study can be extended to determine the maximum DGs' penetration level, and sizing and sitting of the DGs by including the new constraints in the relay coordination study. This combined study by taking the different types of constraints may have a good scope in achieving more penetration of the DGs while prevailing the relays coordination during a faulty situation.
- The proposed protection stages can work with different existing wide-area-monitoring and protection strategies.
- The presented studies can be expanded with different cyber-attack-solution strategies, and bad-data detection algorithms.
- Can be redesigned for the systems with and without communication facilities, and with and without DGs.
- The proposed CAPS-1 scheme can be utilized as an emergency protection scheme for an unknown or undetected operating mode and fault condition.