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REVIEWING BREAK POINT SET METHODS IN RELAY PAIR CONFIGURATIONS: A CRITICAL ANALYSIS

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Abstract

This paper presents an overview on determination of Break Point Set for the coordination of Directional overcurrent relays in protection system. Efforts have been made to include all methods that are used for the determination of Break Point Set, such as Linear programming, Integer programming and Genetic Algorithm based optimization techniques as well as other conventional methods such as graph theory approach. This paper presents a review of earlier works carried for the determination of break point set and its relevant issues.

Index Terms: *Break Point Set (BPS), Relative Sequence Matrix (RSM), Particle Swarm Optimization (PSO)*

1. INTRODUCTION

The main objective of protective device coordination in power system is to select their suitable settings so that their vital and most essential protection function is fulfilled along with requirements of sensitivity, selectivity, reliability and speed. Abnormal conditions in power system lead to the power supply interruption and equipment damage. It compels the protection engineers to design a reliable protection scheme for power system. In order to make the system more reliable, secondary protection is also provided along with primary protection. The secondary protection acts as back up protection in case of primary protection failure. The process of coordinating the relays of a protection system involves setting relays one by one. During this procedure, at each stage, the relay being set must be coordinated with all of its primaries, so it can back up their protection operations. When this process is carried out on a transmission system with loops, each relay may serve as the primary relay in some primary-backup pairs, and as a backup relay in some other pairs .Hence, the setting for each relay must be chosen such that it operates ahead of certain faults, as well as operate after certain other relays for certain other faults, This problem makes the coordination procedure iterative for multi loop networks.

For the proper coordination of relays, the identification of primary back up relay pair is essential. There are numerous methods to find primary back-up relay pair The process of coordinating a system of directional relays involves setting the relays one by one until the relay being set coordinates with all its primary relays. For proper relay pairing, the identification of Break Point Set (BPS) is necessary. To overcome and identify efficient ways of addressing this problem, Break Point Relays, which are a minimum set of relays that can break all the loops in the system in both directions, are found.

2. CONVENTIONAL METHODS OF BREAK POINT SET FOR RELAY PAIR

The basic conventional idea of the coordination of relays is to determine a proper set of relays to start the coordination procedure. The set or pair of relays that can break all the loops in the system is termed as break point set and each relay in break point set is termed as break point. Figure 1 shows the schematic for the conventional approach. The idea of break point sets (BPS) to reduce the complexity in relay coordination was first introduced by Knable in [1, 2]. The sequence of all the other relay pairs will be determined to reduce the number of iterations in the process and to accelerate the convergence of the coordination process. The sequence for setting the relays is displayed by a relative sequence matrix (RSM) [3]. Once the break point set is determined, the relative sequence in which the directional over current relays in the system should be set is computed by using Relative Sequence Matrix (RSM). In setting a relay, determining which relays will be backed up by this relay is necessary. The set of all primary and backup relays sorted by the backup relays is the set of sequential pairs (SSP) [3-5]. The simple and straightforward methods are those based on the graph theory, as in [7, 8]. Finding a break point relay in a small network with a limited number of buses and loops is not too complex. However, with the increase in the number of buses and loops in the system, the problem of finding the suitable BPS is practically complicated [7]. Some of the inefficiencies in the earlier approach of [3] have been addressed in [8]–[10]. As in [10-12], the proposed approaches are based on functional dependency, which applies heuristic method for selecting BPS.The concept of functional dependency has been applied in to the topological analysis of the graph [10, 11, 12] .The computation of all possible loops in the circuit is not required [13]. This method obtains a minimal BPS, in a time period which is a polynomial function of the number of relays. A minimal BPS is defined as a BPS in which all of its members are essentials. In [10], the authors have applied the concept of functional dependency to the topological analysis of the graph. This did not require the computation of all possible loops in the circuit and also did notrequire exponential time but settled for suboptimal solutions. This approach is extended by Madani and Rijanto in [15] and [16]. In [16], Madani and Rijanto have tried to improve their algorithm by using the concept of partitioning graphs into the forest. Madani presents the topological analysis of protection system in which primary backup relation among relays by a directed graph which is refer to dependency diagram. This converts the BPS determination into Feedback Vertex Sets (FVS) using graph theory .The method approaches a minimum or a near-to-minimum BPS step by step, choosing the best relay as a break point at each step, then RSM is found. It can be applied to both directional as well as non directional relays. Another topological analysis using loop opener diode which contains only directional relays. In this, each BP relay is replaced by a set of diode which opens all loops of network in both directions. This further converted into partitioning of a graph into induced trees in graph theory.

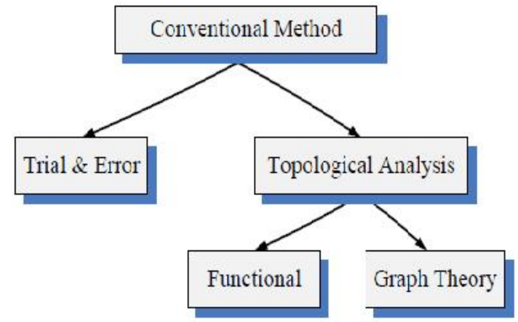

Fig. 1: Conventional method approach.

Bapeswara Rao and Sankara Rao [9] proposed a method for determining the minimum break-points set (MBPS) of a power system network and manipulation of matrix L'. However, determination of the complete loop matrix L' can be time consuming for large power networks. In [9], the MBPS problem was mapped to find the minimum cover of relays such that their span is the whole set of directed loops. However, the minimum cover problem is the set-cover problem which is known to be NP complete. Using Boolean functions and Boolean algebraic manipulations, the authors in [9] manage to obtain the minimum BPS. At the same time, an exponential time computational effort (which is expected as the problem to which the MBPS problem was mapped is NP complete) is required. This is in contrast to earlier approaches such as [3] where a minimal and not a minimum set were obtained. Prasad et al. suggested a faster method for BPS determination based on simple loops matrix. Although, this method has a good advantage compared to the previous ones; it needs to consider the whole system at the beginning stage to compose a simple loops matrix and it cannot determine the minimum set as well as the network parameters which were not considered[13]. Jamali and Shateri in [18] have tried to take advantage of the network decomposition ideas introduced in [17] and take a polynomial time approach but can end with rather suboptimal results. It may be noted that most of the approaches do not give the optimum set but rather a suboptimal one. Askarian Abyaneh et al. developed an efficient computer program for the determination of BPS based on graph theory [20]. In this method, network reduction is made first, and then the appropriate loops are composed, while in the traditional graph theory approach the composition of the matrices loops are made on the original network. Here simplifying the network yields to reduce the mass of equations but the obtained BPS is not the minimum one and the network parameters such as pilot protection or important loads are not considered.

Sastry in [19] has tried a heuristic approach where a bus with the highest degree is chosen and all the relays on that bus are removed. This process is carried out until no more loops are left in the system. Though the proposed algorithm is polynomial in time, the solution is not guaranteed to be exact. The authors in [18] have also developed a heuristic technique. Their approach can be summarized as; at each step, a bus, which participates in maximum number of coordination loops, is chosen. Subsequently, all the relays on that bus are selected in the BPS and the relevant coordination loops are opened. The procedure is repeated until there are no coordination loops left in the network. Recently, in [23], Yue et al. tried to circumvent the problem of enumerating all of the loops and solving the problem in polynomial time but ended up with suboptimal results. In their work, a set of primary relays is considered initially. This set is referred to as Primary Relay Dependency Set (PRDS). Its cardinality is referred to as the Primary Relay Dependency Dimension (PRDD). Now, choose a relay with maximum PRDD and add it to an MBPS. Thereafter, this relay is removed from all of the sets. In this process, if the PRDS associated with any other relay also reduces to the null set, then the process is repeated with this relay also. However, this relay is not added to the BPS. This process is repeated until all sets are reduced to null set. As is evident, their approach is a greedy algorithm. It may be noted that the approach in [22] is also a greedy approach but gives much better results than [23]. On the other hand, it has to pay the price of being an exponential time algorithm compared to the approach in [23], which is a polynomial time algorithm. Xiongping Yan et al proposed a method based on the theoretic analysis of converting mesh network into radial network for determination of break point set (BPS) for directional relay coordination grounded on analysis of breaking loop is proposed, which is implemented easily within the adjacency matrix of power network [24]. Donghua Ye et al presents a simple and effective approach based on two dynamic matrixes of Node Relay Matrix (NRM) and Relay Incidence Matrix (RIM) to determine minimum break point set (MBPS) for coordination of the directional relays. Firstly, the NRM and RIM are defined and their calculation methods are developed. Then, some optimization operations for network reduction and special structure are presented to update the NRM and RIM and the detailed flowchart is provided [25]

3. OPTIMIZATION METHODS FOR BREAK POINT SET FOR RELAY PAIR

Many authors reported the use of optimization techniques to determine break point set for multiloop system. The optimization techniques used for the determination of BPS reported in literature are shown in figure 2. The main aim is to minimize the objective function (OF) which is the number of break points for the relay pair. Joymala et al proposed an optimization technique based on Particle Swarm Optimization (PSO) to calculate BPS. The process follows the enumeration of loops considering an arbitrarily starting relay location and relay sequence set Firstly, network is reduced for parallel or three end nodes, then loops are found and then the problem is formulated as a set covering problem and finally BPS is determined using PSO technique [26]. Hossein Askarian Abyaneh et al presented an expert system for protection coordination in power systems. The rules of the expert system for the determination of BPS include network configuration, protection systems, and fault levels [27]. Sharifian et al proposes a method based on Expert System and Genetic Algorithm where two approaches are considered one is the effects of fault level, network configuration, pilot protection and other protection systems. The second one defines protection relay dependency dimension (PRDD) for finding MBPS. By comparison of PRDD in a multi-loop network, the MBPS can be determined, and the process of comparison will not stop until the MBPS of the network is discovered. It can also generate a new MBPS after each coordination process. [28].

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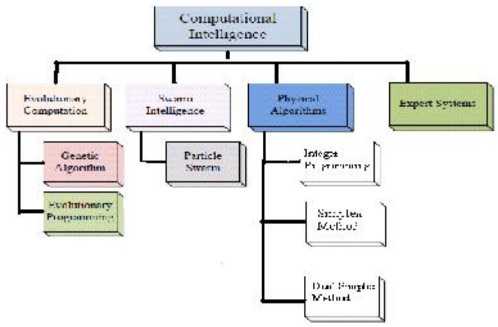

Fig. 2: Optimization Technique proposed by the researchers for finding break point set (BPS).

First, the network is reduced if there are any parallel lines or three-end nodes. Second, all the directed loops are enumerated to reduce the iteration. Finally, the problem is formulated as a set-covering problem, and the break point set is determined using the zero-one integer programming technique. Arbitrary starting relay locations and the arbitrary consideration of relay sequence to set and coordinate relays result in navigating the loops [29].

4. CONCLUSION

A comprehensive review on determination of break point set has been studied. Many methods and techniques are proposed and implemented for the past four decades. To meet present day requirements, methods such as linear programming, integer programming and GA based optimization techniques seem to be reliable and fast. A graph theory approach is studied and seems to be optimal for the determination of break point set. This is an effort to present author's works on the subject of techniques used in determination of break point set; the presence of oversight is bound to be there. Future work will be to determine the break point set for relay coordination using other optimization techniques which are still unexplored.

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