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Review of The Optimal Coordination of Directional Overcurrent Relay Using Moth Flame Optimization

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***Abstract*-A comprehensive review of different optimal coordination methods like seekers algorithm, fire fly algorithm, hybrid genetic algorithm, hybrid PSO, artificial bees colony, flower polliation ,CMA-ES algorithm, GANLP for mitigate the relay problem. Relay coordination is essential to ensure quick operation of relays in order to avoid the excessive damage to the equipment's and end users consumers. As the probability of shunt fault occurring in the network is higher comparatively so protection is done accordingly. Relay coordination means coordination of proper relaying operation with certain insight between primary and back-up relays pair connected in the network.**

***Keywords*-Direction overcurrent relays, optimal coordination, Improved Moth-flame optimization,**

I.INTRODUCTION

Reliable operations of the power grid are becoming importance nowadays more than ever, due to the embedding of electric powered technology in all human activities. Protection of the electric grid against interruptions caused by different faults occupies the priority of power system researchers concerns [1].

Planning of protection schemes accurately is required to guarantee reliability, speed and selectivity of protective relays to insulate the parts under faulted conditions from the rest of the network. Protection issues have become more complex with evolving of the distribution networks (DNs) toward the vision of distributed generations (DGs). Additionally, the growing of the DGs connections introduced extra challenges with the concept of micro-grids (MGs). To obtain the maximum advantages from these upcoming power generation technologies with maintaining the existing power system infrastructure, there are main protection issues required to be taken into considerations which are false tripping, binding tripping recloser malfunctions, binding, nuisance (sympathetic) and undesired islanding [2].

Traditional distribution system is radial in nature. The protection of these networks is relatively simple protective devices such as overcurrent (OC) relays, fuses and reclosers [3]. An OC relay is a device that determines whether sending signal or not to open a circuit breaker by measuring the current which pass through it [4]. There are other relays kinds such as directional relays, definite time OC relays and distance relays.

II.OPTIMAL COORDINATION OVERCURRENT RELAY DESIGN VARIABLES

Relay coordination task is considered of great importance for the operation of power systems. The optimal coordination of relays is supposed to guarantee that faults in the protected zones are cleared firstly by the corresponding primary relays, and if they fail, the corresponding backup relays act after a coordination time interval (CTI). With the development of relays, directional overcurrent relays (DOCRs) have been applied to the design of economical alternatives for the primary and backup protection of power systems.

The operating times of DOCRs are decided by two design variables as time dial setting and pickup current setting or plug setting. Optimal coordination between the operating times is able to maintain the reliability of the overall protection system. Mathematically speaking, this coordination problem is a highly constrained optimization problem, which can be modeled in three ways as follows, according to the nature of the design variables:

- (i)Linear programming (LP)
- (ii)Nonlinear programming (NLP)
- (iii)Mixed integer nonlinear programming (MINLP)

Firstly, when the DOCRs coordination problem is formulated as an LP problem, the value of or is assumed to be fixed; hence, the operating time of each relay is calculated as a linear function of . Even though LP is a simple formulation, it requires experts for setting the initial values of or and it easily gets stuck in local minima [5]. Secondly, when formulated as an NLP problem, both andare considered as design variables and calculated to optimize the relay operating time , where and take continuous values. By NLP, the total operational time of the primary relays can be reduced and the coordination can be maintained well. Thirdly, when formulated as an MINLP problem, both and are calculated and optimized. The difference between NLP and MINLP is that the parameter of takes discrete values in MINLP, while takes continuous values in NLP.

III.PROBLEM FORMULATION OPTIMIZATION TECHNIQUES

Modern optimization algorithms were used to solve the DOCRs coordination problem. Genetic algorithm (GA), Hybrid GA, and Hybrid GA-NLP were used in [2–4]. Modified DE algorithm (MDEA) and opposition-based chaotic DE (OCDE) were used in [5, 6]. Two modified particle swarm optimization (PSO) algorithms were used in [7, 8], where the repair algorithm and a nonrandom technique for initialization were introduced to the standard version, respectively. Teaching learning-based optimization (TLBO) and modified adaptive TLBO (MATLBO) were used in [9, 10]. Firefly algorithm (FA), chaotic firefly algorithm (CFA), and modified swarm firefly algorithm (MSFA) were used in [11–13]. Biogeography-based optimization (BBO) along with a new hybrid BBO with linear programming (BBO-LP) was used in [14]. Furthermore, Jaya algorithm [15], seeker optimization algorithm (SOA), simulated annealing-based symbiotic organism search (SASOS), and improved group search optimization (IGSO) were used in [15].

Regardless of the variety of these algorithms, exploration (diversification) and exploitation (intensification) phases are two common phases that should always be considered. In the exploration phase, the optimizer should be able to promote its randomized solutions as many as possible to thoroughly explore the whole space. In the exploitation phase, only the solutions with better fitness values are searched further on its neighborhood to intensify the searching quality. These two phases should be made balanced reasonably; otherwise, the optimizer would be trapped in local optima or suffer from immature convergence drawbacks.

Recently, a number of nature-inspired modern algorithms were proposed to effectively balance the exploration phase and exploitation phase by Mirjalili, such as grey wolf optimizer (GWO) [9], whale optimization algorithm (WOA) [2], ant lion optimizer (ALO) [1], and moth-flame optimization (MFO) [22]. They have achieved good results. Then, in 2019, a new nature-inspired technique named Harris' Hawks Optimizer (HHO) is proposed by Heidari et al. [3], with the same purpose to make fine balance between exploration and exploitation. The main idea of HHO is inspired from the cooperative behaviors of one of the most intelligent birds, Harris's hawks, in hunting escaping preys (rabbits in most cases). Different mathematical models are constructed to mimic different stages of hunts used by Harris's hawks; then, a new stochastic metaheuristic algorithm is proposed and designed based on the constructed models to tackle various optimization problems.

IV.LITERATURE REVIEW

A.Rathinam , "Optimal Coordination of Directional Overcurrent Relays using Particle Swarm Optimization Technique": The main function of the protective devices in the power system is to detect and remove the selected faulty parts as fast as possible. Directional over current relays are commonly used for the protection of interconnected sub transmission systems, distribution systems, or as a secondary protection of transmission systems. For the systems having more than one source connected, that is meshed or looped networks, directional over current relays become the suitable choice for better selectivity, since directional relays operate only when the fault current flows in the specific tripping direction desired. The most vital task when installing directional relays on the system is selecting their suitable current and time settings such that their fundamental protective functions are met under the requirements of sensitivity, selectivity, reliability and speed.

The problem of setting Directional Over Current Relay(DOCR) is a highly constrained optimization problem that has been solved as a linear programming problem. The calculation of the time dial setting (TDS) and pick up current (IP) setting of the relays is the core of the coordination. This paper calculates the TDS by choosing one of the available pick up current settings as the predetermined value. The simplex two phase method is used to determine the optional TDS of the relays. Improvement in the solution is brought by using the particle swarm optimization technique to the co-ordination problem for reaching the global optimum value with less computational time. Sample 3 bus and 8 bus systems are utilized for comparing the results obtained by PSO with that of the simplex method. The optimization method used in the recent times minimizes the operating time of the relays much, when compared to the other methods. This method also enhances quicker solution of coordination process.

Rahul Dhiman, "Moth-Flame Optimization Technique for Optimal Coordination of Directional Overcurrent Relay System": The protection devices have an important role in modern power system. The operation of electric power system network majorly depends on combinatorial working of relays, circuit breakers and other protection devices. The power system reliability is improved majorly by installing two types of relays i.e., primary and backup relays. Initially, the primary relay operates for any faulty condition to give fast response. For any condition primary relay fails to trip, then backup relays perform same task after some time interval. The coordinated operation of primary and backup relay is important to prevent any malfunctioning due to time gap. The coordination between primary and backup relay is a nonlinear optimization problem. In this dissertation work, optimal coordination of directional over current relay is achieved using moth-flame optimization algorithm. The moth-flame optimization is population-based technique applied for calculating optimal settings of the relay with faster convergence for primary relay and better performance coordination with backup relays. Relays setting configurations includes time multiplier settings, plug settings multiplier and pickup current settings. Relay coordination is done using continuous decision variables i.e., time multiplier settings and pickup current. The technique is implemented on IEEE 8-bus test system without external grid and results are compared to other techniques results.

Ahmed Korashy, "Optimal Coordination of Standard and Non-Standard Direction Overcurrent Relays Using an Improved Moth-Flame Optimization": In this paper, an efficient optimization technique, called improved moth-flame optimization (IMFO) is proposed to improve the performance of conventional Moth-flame optimization (MFO). Then, both of MFO and IMFO are applied to solve the coordination problem of standard and non-standard directional overcurrent relays (DOCRs). In the proposed IMFO, the leadership hierarchy of grey wolf optimizer is used to improve the performance of conventional MFO with the aim of finding the best optimum solution. The major goal for optimal coordination of DOCRs is to minimize the total operation time for all primary relays as well as satisfy the selectivity criteria between relay pairs without any violation in the operating constraints. The performance and feasibility of proposed IMFO are investigated using three different networks (8-bus network, 9-bus network, and 15-bus). The proposed IMFO is compared with conventional MFO and other well-known optimization techniques. The results show the effectiveness of the proposed IMFO in solving both standard and non-standard DOCRs coordination problems without any violation between primary and backup relays. In addition, the results show the power of proposed IMFO in finding the best optimal relay settings and minimizing the total operating time of relays which its reduction ratio reaches more than 28% with respect to the conventional MFO. Furthermore, the reduction in the total operating time of primary relays reaches more than 50 % with the usage of the non-standard relay curve.

ASHIS SONI, SHASHANK KUMAR SIMARDEEP KAUR SHIMPY RALHAN, "OPTIMAL COORDINATION OF DIRECTIONAL OVERCURRENT RELAY USING MOTH FLAME OPTIMIZATION ALGORITHM": Over current relays are commonly used in distribution system whose function is not only to provide primary protection but also secure and accurate back up protection also. The overcurrent relays must be optimally coordinate among them to reduce the total operating time so that fault clearing time will be increased. In this paper, a Moth Flame optimization technique is proposed in order to minimize the total operating time of the overcurrent relays. The proposed method is tested on the data obtained from two widely adopted distribution system. Comparison assessment with other techniques shows the efficiency, accuracy, and speed of the proposed algorithm.

Dhiman, Rahul, "Moth-Flame Optimization Technique for Optimal Coordination of Directional Overcurrent Relay System": The protection devices have an important role in modern power system. The operation of electric power system network majorly depends on combinatorial working of relays, circuit breakers and other protection devices. The power system reliability is improved majorly by installing two types of relays i.e., primary and backup relays. Initially, the primary relay operates for any faulty condition to give fast response. For any condition primary relay fails to trip, then backup relays perform same task after some time interval. The coordinated operation of primary and backup relay is important to prevent any malfunctioning due to time gap.

The coordination between primary and backup relay is a nonlinear optimization problem. In this dissertation work, optimal coordination of directional over current relay is achieved using moth-flame optimization algorithm. The moth-flame optimization is population-based technique applied for calculating optimal settings of the relay with faster convergence for primary relay and better performance coordination with backup relays. Relays setting configurations includes time multiplier settings, plug settings multiplier and pickup current settings. Relay coordination is done using continuous decision variables i.e., time multiplier settings and pickup current. The technique is implemented on IEEE 8-bus test system without external grid and results are compared to other techniques results.

Mohammad Shehab, Laith Abualigah, Husam Al Hamad, HamzehAlabool, Mohammad Alshinwan& Ahmad M. Khasawneh, "Moth–flame optimization algorithm: variants and applications": This paper thoroughly presents a comprehensive review of the so-called moth–flame optimization (MFO) and analyzes its main characteristics. MFO is considered one of the promising metaheuristic algorithms and successfully applied in various optimization problems in a wide range of fields, such as power and energy systems, economic dispatch, engineering design, image processing and medical applications. This manuscript describes the available literature on MFO, including its variants and hybridization, the growth of MFO publications, MFO application areas, theoretical analysis and comparisons of MFO with other algorithms. Conclusions focus on the current work on MFO, highlight its weaknesses, and suggest possible future research directions. Researchers and practitioners of MFO belonging to different fields, like the domains of optimization, medical, engineering, clustering and data mining, among others will benefit from this study.

ThiramuniSisitha Sameera Senarathna and KullappuThantrige Manjula UdayangaHemapala, "Optimized Adaptive Overcurrent Protection Using Hybridized Nature-Inspired Algorithm and Clustering in Microgrids": Microgrids have been popularized in the past decade because of their ability to add distributed generation into the classic distribution systems. Protection problems are among several other problems that need solutions in order to extract the full capability of these novel networks. This research follows the branches of two major solutions, namely adaptive protection and protection optimization. Adaptive protection implementation with a novel concept of clustering is considered, and protection setting optimization is done using a novel hybrid nature-inspired algorithm. Adaptive protection is utilized to cope with the topology variations, while optimization techniques are used to calculate the protection settings that provide faster fault clearances in coordination with backup protection. A modified IEEE 14 bus system is used as the test system. Validation was done for the fault clearing performance. The selected algorithm was effective than most other algorithms, and the clustering approach for adaptive overcurrent protection was able to reduce the number of relays' setting groups.

Ahmed R. Abul'Wafa, Bahaa S. Mahmoud, Aboul'Fotouh A. Mohamed, "Analytical Method for Directional Overcurrent Relays Coordination in Microgrids": Microgrids are consisting of interconnected loads and distributed generators which can operate with and without utility. The significant implementation of microgrids challenged the protection engineers especially in designing protection microgrid schemes. This challenge comes from the bi-directional fault current variation and the dynamic behavior of microgrids. The implementation of artificial intelligent (AI) techniques for coordinating the directional overcurrent relays (DOCRs) in Microgrids (MGs) is a promising solution. However, all the (AI) techniques estimate the solutions and achieve the objective function after an extensive number of iterations. This paperwork proposes an analytical method for solving the coordination of (DOC) relays in meshed Microgrids which operates in grid connected mode. The proposed analytical method needs a lesser simulation time than the (AI) techniques to find the proper settings for the coordinated directional overcurrent relays (DOCRs). A file code is written using MATLAB software to implement and test this methodology.

A.R. Abul'Wafa1, B.S. Mahmoud proposed four metaheuristic optimization techniques (Genetic algorithm (GA), Moth-Flame Optimization (MFO) Algorithm, Grey Wolf Optimizer (GWO), and the Salp Swarm Algorithm (SSA)) for solving the problem of Directional Overcurrent Relays Coordination. The authors found that the Moth-Flame optimization algorithm achieves the best simulation results [5].

A.Sharma and B. K. Panigrahi proposed a metaheuristic technique based differential evolution (DE) algorithm for solving the coordination problem of (DOC) relays. T. Amraee proposed a Seeker optimization Coordination of Directional Overcurrent Relays coordination, this algorithm mimic the behavior of human searching considering its experience, social learning, memory, and uncertainty reasoning. A.S. Noghabi, J. Sadeh, and H.R. Mashhadi proposed hybrid technique which combined both Genetic Algorithm (GA) and the Linear Programing (LP) to improve the efficiency of GA for solving the directional overcurrent (DOC) relays coordination problem.

M.M. Mansour, S. F. Mekhamer, and N. El-Kharbaweproposed a modified particle swarm optimizer for the coordination of directional overcurrent relays. S. Kar, D. Jati, and S.R. Samantaray proposed an effective relay coordination using Genetic Algorithm (GA) considering a different topology and operating modes of the micro-grid. Y. Damchi, M. Dolatabadi, H. R. Mashhadi, and J. Sadeh proposed a mixed integer linear programming (MILP) approach for optimal coordination of directional overcurrent relays in interconnected power systems.

Z. Moravej, F. Adelnia, and F. Abbasi proposed a nondominated sorting genetic algorithm (NSGA-II) for the optimal coordination of directional overcurrent relays. As mentioned before, the relay pairs identification is a mandatory requirement for (DOC) relay coordination. Different techniques are proposed in for relay pairs identification.

V. MICROGRID PROTECTION CHALLENGES

The microgrids have accumulated a considerable amount of interest within the past years and turn out to be an indispensable asset in the power industry. The capability to incorporate renewable power generation into the distribution system is one of the vital reasons for microgrids recognition. A broad array of distributed generation (DG) technologies such as sustainable micro-turbine generation, including wind generation, photovoltaic generation, and energy storage systems, make the microgrid more feasible in both islanded and grid-connected modes [1]. There are several technical disputes to be confronted when trying to access the entire potential of microgrids, and protection is one of those challenging areas [2]. Many solutions were presented, influenced by the improvement of protection techniques. Microgrids containing DG can cause variations in short circuit levels, which is one of the main reasons for these protection challenges. The ability of microgrids to operate islanded of the main utility can make these variations more drastic. Also, the existence of different operating topologies makes the protection selectivity more complicated. The existence of DG and different operating topologies mainly causes the technical challenges that microgrids face. Protection challenges can be identified as a major area that requires specialized solutions in order to manage efficient running microgrids. A few of the main protection challenges can be identified as follows.

Short-circuit capacity variation due to utility grid connection and disconnection needs to be addressed by changing the relay threshold values accordingly [3]. Microgrid DG penetration can introduce bi-directional power flow which will also cause the fault current to change its direction. They can create protection problems such as unnecessary tripping, relay under reach, and relay overreach [4]. The protection scheme needs to account for the above grid condition changes in order to provide reliable protection against faults.

VI. CONCLUSIONS

There are several adaptive protection schemes proposed. A scheme that updates the relay settings based on the topology of operation. This method only included utility connection and DG connection contingencies. Researchers have been using fuzzy-based systems to identify faults in micro-grids. Voltage and current phasor measurements are fed into the fuzzy inference systems to identify the faults. These methods are mainly used for fault identification and classification, where a separate system is required for fault clearance. More advanced artificial neural networks (ANNs) have been used for fault classification in adaptive scenarios of micro-grids. This method requires extensive processing to obtain the results, and the researchers have only presented the scheme in an algorithmic state.

Most of the literature did not consider multiple topologies. Consideration of topology clustering for protection optimization was not considered by any previous authors. Protection optimization was mainly applied in a linear formulation, which considers only a single variable. The proposed method covers all the areas, namely considering multiple topologies, performing non-linear optimization, using a novel hybrid optimization algorithm, and utilizing topology clusters.

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