A Survey on the Development of Real-Time Overcurrent Relay Coordination Using an Optimization Algorithm

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Abstract

The current work is a survey on the development of real-time overcurrent relay coordination utilizing an optimization approach. Overcurrent relays are a safeguard commonly used in transmission and distribution networks owing to their low cost. Depending on the operating conditions and the location of the faults, load or fault currents in a mesh system may loop in or out of the protective zone of the overcurrent relay. As a result, directional overcurrent relays are employed to determine whether the fault is inside or outside the protective zone. The goal of overcurrent relay coordination is to find settings that minimize operating time for failures within the protective zone. In addition to this it provides scheduled backup for relays in neighbouring zones that has been pre-specified. As an outcome, the highest possible fault current observed by the relay must be greater than maximum fault currents in its protective zone detected in zones close by.

Key Words: Overcurrent Relay, Real-Time Coordination, Optimization Algorithm, Protective Zone.

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Introduction

Electrical power system protection is frequently employed in generation, transmission, sub-transmission, and distribution voltage levels. Overcurrent relays are commonly used in sub-transmission and distribution systems due to their low cost. Loads or fault currents may enter and leave the overcurrent transmission area in a mesh system. As a result, overcurrent directing transmission is used to differentiate between protected zones. The goal of coordinating overcurrent relays is to reduce fault operation time within the protective zone while providing timely backup for relays in nearby zones. So, the relay's protective zone's maximum fault current must be bigger than the neighbouring zones' maximum fault current. In radial, one source, and two source loop network systems with symmetrical sources, the criterion is satisfied. However, owing to the variety of operating setups, the preceding requirement is not always satisfied. Since the systems cannot function without protection, impedance relay protection is utilized. The overcurrent protection concept is thus considered to be out of range or has reached its protective limit for particular mesh system active configurations. Coordinating overcurrent relays in distribution systems must fulfil basic criteria of sensitivity, selectivity, dependability, and speed. However, to meet the rising demand for electricity, additional lines and contracts are built.

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This contributes to the dynamic distribution system. So coordination is harder. Overcurrent relay coordination using a real-time optimization technique resulted in quicker fault extinction, less false tripping, and improved season-to-season fault extinction delay.

Literature Survey

Various optimization strategies have been used recently to solve the directional overcurrent relay coordination issue. Originally, before computers, optimization issues were manually computed using big and sophisticated computations, which increased both time and error. Some metaheuristic techniques are now used, making the answer more precise and dependable. The working time of the relay must be reduced to ensure reliable network functioning. This need prompted researchers to work on it.

Abdelhamid, M. et al. (2021) [1] proposed an improved Bonobo optimization algorithm (IBO) to solve the problem of directional overcurrent relay (DOCR) optimal coordination. This issue impacted power grid security. It's a nonlinear, restricted optimization problem. IBO uses Levy flight distribution and three leader chooser to enhance the original Bonobo optimization method (BO). BO and IBO were used to create two DOCR solutions. With the operational restrictions, the fifteen bus and thirty bus test networks were employed to verify BO and IBO. They compared the IBO algorithm's findings to the BO algorithm, as well as other well-known algorithms. The findings proved the suggested IBO algorithm's superiority over existing methods in reducing total relay operating time for optimum DOCR coordination.

Ahmadi, S.A. et al. (2016) [2] investigated to find the evolutionary algorithm which generates Time Setting Multipliers (TSMs). They thought the overcurrent relays' properties would help TSM and coordination. The coordination difficulty was overcome using artificial intelligence. The HSS algorithm was used to choose the overcurrent relays' TSMs. The HSS result was compared to the genetic algorithm utilized in earlier research. Greater coordination is shown by HSS and relay characteristics in the sample network simulation.

Alam, M.N. et al. (2018) [3] An online adaptive protection coordination scheme based on numerical relays for directional overcurrent (DOCRs) and a commercial AMPL based IPOPT solver was proposed. The suggested methodology employs Intelligent Electronic Devices (IEDs) and a communication channel that can provide real-time system data and relay configuration. The provided technique can manage load, generation, and line losses in a system. Miscoordination caused by DG injections is also clarified. The suggested technique was tested on the IEEE 14 - bus system (with and without DG). The proposed technique increased overall system dependability by lowering the amount of energy not provided. They were matched up against the GAMS-based Sparse Nonlinear Optimizer (SNOPT) solver, the OPTI Toolbox-based Interior Point Optimization (IPOPT) solver, the interior-point technique based on MATLAB, as well as the metaheuristic genetic algorithm and differential evolution. The suggested coordination strategy produces excellent results in a short period and so is suited for the adaptive protection system.

Alam, M.N. et al. (2016) [4] presented interior-point method-based protection coordination schemes for coordinating directional overcurrent relays. A novel objective function (NOF) was also designed to reduce the working period of main and backup relays. On two test systems, the suggested solution techniques and objective function were evaluated (one small and one large). For the defined objective function, the performance of the suggested method is compared to that of the genetic algorithm, differential evolution, and two-hybrid algorithms. NOF's protective coordination outcomes outperformed those of other objective functions that have been compared in the literature.

Al-Roomi, A.R. et al. (2016) [5] developed a new hybrid algorithm with some additional sub-algorithms to solve the IEEE 6 bus test system. They also investigated electromechanical and static DOCRs numerically. For convenience, all investigations in the literature were confined to DOCRs that were numerical, static, or electromechanical. It is possible to utilize electromechanical or static relays as a second wall of defence instead of merely tossing them in the worst-case scenario, every bus would have two primary DOCRs that also functioned as backup DOCRs for other buses. That is, the problem's dimension is doubled, making an efficient solution difficult.

Asadi, M.R. et al. (2009) [6] used a new approach for optimal coordination of OC relays based on a particle swarm algorithm. They optimised the overcurrent relays' TSM (time setting multiplier) and PSM (plug setting multiplier). Because most over current relays only accept discrete values like

TSM and PSM, final responses are altered to the discrete form. Their approach included quantizing the replies as part of the optimization process, resulting in optimized discrete TSMs and PSMs. The paper's originality was handling miscoordination difficulties for both continuous and discontinuous TSM and PSM. The findings were positive and proved to be a valuable tool for coordinating OC relays.

Bakhshipour, M. et al. (2021) [7] proposed based on phasor measurement units (PMUs) data, a novel protective logic for optimal coordination of overcurrent relays measure optical sequence power at two small stations hundreds of miles apart, which are synchronised with a GPS satellite system. Control centres and/or sub-channels collect accurate time tags added to samples. The phasor information can be extracted from these measurements at any node in the power grid where PMUs are deployed. This enables improved estimation of state, management, as well as security. In addition to voltage and current, information on phasors was used to make decisions in these relays. The method was tried out on IEEE 8 bus and 14 bus systems.

Bedekar, P.P. et al. (2009) [8] presented a genetic algorithm (GA) overcurrent (OC) method for relay coordination. The goal was to establish an optimal relay setup that minimized relay operation time while avoiding relay malfunction. The GA approach was used to optimize OC relay coordination in a ring-fed distribution system. The fitness function was penalized to add constraints. The GA approach was used to design computer applications (using MATLAB).

Birla, D. et al. (2005) [9] looked upon the problem of coordination from different considerations by making use of computer aids. Coordinated or selected means that two protection devices deployed in series have features that offer a certain operation sequence. Coordination of directed overcurrent relays is a major issue in contemporary linked power system networks. Several attempts have been made to automate the relay coordinating process. This article summarizes major achievements in time-overcurrent relay coordination utilizing various strategies and methodologies. This study helped future scholars identify appropriate references to further their studies.

Bottura, F.B., et al. (2014) [10] presented a Hybrid Genetic Algorithm (HGA) for the transmission of direct transmission to a real-time power system, which was part of the Brazilian power transmission system. The HGA uses a combination of linear programming and genetic algorithms to identify optimal relay configurations. Minimizing relay operating time accomplished coordination. For short circuit experiments, the power system was simulated using CAPE software. The HGA solutions are comparable to those from Discrete Particle Swarm Optimization (DPSO), a modified alternative to standard particle upgrade. Finally, the DPSO says that HGA gives excellent results for the coordination of the test system's overcurrent relays.

Bouchekara, H.R.E.H., et al. (2016) [11] used a new metaheuristic method called the Backtracking Search Algorithm (BSA) to resolve the DOCR's coordination issue. For all main relays, the coordination issue is an optimization problem. The technique has been examined on three different networks: six bus, eight bus, and fifteen bus. A credible method for comparing the proposed BSA's findings with other well-known metaheuristics have also been devised. In DOCR coordination difficulties, BSA outperforms other techniques.

Chabanloo, R.M. et al. (2011) [12] presented a new objective function (OF) within the genetic algorithm (GA) to resolve the issue of the efficiency of combining overcurrent and distance relays. The existing target function of the OC relay link was upgraded and expanded to integrate OC with the data transmission distance. Various OC transmission elements are analyzed by GA to achieve optimal interaction. The approach was tested on two power system networks. Les résultats de simulation confirment the method's feasibility and effectiveness in real-world power system networks.

Chabanloo, R.M. et al. (2018) [13] proposed the concept of setting groups (SGs), an adaptive protection scheme for increasing system reliability. The existing target function of O/C relay coordination was upgraded and expanded to encompass O/C and distance relay coordination. Various O/C relay features are analyzed by GA to achieve optimum coordination. The approach was tested on two power system networks. Les results de simulation conferment the method's feasibility and effectiveness in real-world power system networks.

Chaitanya, A.V.K. et al. (2017) [14] presented the optimum time coordination of overcurrent relay in distribution network solved using the Differential Evolution method and Dual Simplex method. The existing target function of O/C relay coordination was upgraded and expanded to encompass O/C and distance relay coordination. Various O/C relay features are analyzed by GA to achieve optimum coordination. The approach was tested on two power system networks. Les results de simulation conferment the method's feasibility and effectiveness in real-world power system networks. Chelliah, T.R. et al. (2014) [15] developed and applied a set of two algorithms named opposition-based chaotic differential evolution ($OCDE_1$ and $OCDE_2$). The developers approached the coordination of directional overcurrent relays (DOCR) as an optimization problem, employing a variety of optimization techniques. Many algorithms have been presented throughout the decades to cope with these issues. To find the most suitable solution, both types used opposition-based learning and a chaotic scale factor. The approach was tested in four situations. They compared the findings to previously suggested algorithms in the literature and found the proposed strategies to be fairly competent.

Costa, M.H. et al. (2019) [16] presented A new approach to improve the robustness of directional overcurrent relay coordination. Initially, the anticipated relay parameters were discovered utilizing a matheuristic method on the basis of Linear Programming, Differential Evolution, and local search strategies. On the other hand, in single line dropping circumstances, undesired load shedding was mitigated by using the algorithm's answer as a source to a framework for re-optimization (N-1 criterion). The technique was tested on a true looped network, an IEEE – thirty bus, an IEEE – 118 bus, and an IEEE – three hundred bus. There were 590 relays and 1044 primary/backup connections.

Costa, M.H. et al. (2017) [17] proposed a matheuristic algorithm to provide coordination of directional overcurrent. The method employed both Differential Evolution and Linear Programming. To deal with both discrete and continuous relay systems, two local search algorithms were also provided. In 5 cases, the proposed technique produced results that were comparable to, or superior to those previously published in the literature at a far reduced computing cost. Also, the method may directly manage robust coordination by considering probable system modifications.

ElSayed, S.K. et al. (2021) [18] presented a new hybrid The Harris hawks optimization algorithm with sequential quadratic programming (HHO-SQP) for best results transmission of over-directed coordination to obtain the right transfer settings. The SQP approach was used in hybrid algorism to enhance the original HHO method's performance. The optimization problem was described as a optimization problem that is non-linear and severely constrained to reduce overall main relay working time while maximizing backup relay running time. The created goal function was subject to coordination limitations, such as no coordination between the primary and backup relays. The performance of the proposed algorithm was evaluated on two test systems. The suggested algorithm's findings were compared to other current meta-heuristic approaches. Overall, the novel hybrid method beats other previous meta-heuristic algorithms.

Gupta, S. et al. (2020) [19] employed a Random Walk Grey Wolf Optimizer (RWGWO) an algorithm based on search improvement for advanced wolves in the old GWO algorithm in order to overcome issues withstanding up to greater local discovery and early meeting while solving indirect and complex operational challenges the RW-GWO method was used to discover the best configuration for the directional overcurrent relay issue. The findings for traditional GWO were also given, with comparisons to alternative optimization techniques. The RW-GWO outperforms other optimization approaches in getting the best configuration for appropriate overcurrent relay coordination.

Hussain, M.H. et al. (2013) [20] presented an overview of protection systems and protective relays, optimal overcurrent relay coordination is required. Efforts have been made to cover all overcurrent relay coordinating mechanisms. They include artificial intelligence (AI) and Nature Inspire Algorithm (NIA) along with other traditional overcurrent prevention technologies. The use of AI and NIA to safeguard overcurrent relays was highlighted over the use of traditional approaches. They supplied a list of all relevant articles and a short synopsis of the research activity.

Kahraman, H.T. et al. (2021) [21] conducted an in-depth study to evaluate the effectiveness of the advanced dFDB method of selection and evaluation of the developmental effects of the DOCRs problem. The test is performed in two phases. To evaluate the performance of created dFDB technique and optimization algorithm, three benchmark test suites with varying issue kinds and dimensions were used. The experimental results obtained were evaluated utilizing non-parametric statistical methods approaches to find the best successful optimization strategy. The created approach was used to optimize the DOCRs issue. The suggested technique for solving the DOCRs coordination issue was assessed on five test systems: IEEE three - bus, IEEE four - bus, IEEE eight - bus, IEEE nine - bus, and IEEE thirty - bus. They compared the created algorithm's numerical outcomes to previously suggested methods. The suggested solution minimizes the relay operating time for optimum DOCR coordination.

Kalage, A.A. et al. (2016) [22] presented a modified adaptive teaching learning-based optimization algorithm to overcome the disadvantage of traditional heuristic techniques. To find the best time multiplier setting (TMS) and plug setting (PS) for DOCRs, they structured the coordination problem as a restricted problem of nonlinear optimization. The first TMS solution was derived heuristically using the most frequent TMS value range. The first initial solution with the highest TMS value replaces the TMS range's the upper acceptable limit. The new top limit was clearly lower. The following optimization phase used the improved TMS range for the teaching phase iterations. After the teacher phase from the existing solution, a new upper limit was established, and the learner phase iterations were optimized. This was repeated to find the best answer. PS fixed range was employed to get selectivity. Iteratively updating the upper limit of the TMS range outperforms approaches that use a fixed TMS range. This method was proven to be more successful on various networks. The suggested approach is shown in four examples. To alleviate the effect of distributed generation (DG), superconducting fault current limiters were used in the third case study.

Karegar, H.K. et al. (2005) [23] presented a method for reducing the number of issues and finding those that make overcurrent transfer preparation impossible. Reducing the number of limits increases the likelihood of preparation and reduces the system's operating time. The optimum coordination approaches reduced the operation times of the relays within the goal function subject to what are known as coordination constraints They devised a novel strategy for optimal protective relay coordination based on restrictions. They developed pre-processing reduction limitations for efficient overcurrent relay coordination. The novel strategy was backed up by data from a typical test network and a real-world power system network.

Kheirollahi, R. et al. (2014) [24] functionally elaborated on the Bat Optimization Algorithm (BOA) and the issue of complete integration of overcurrent transfer controls, as part of the effort to reduce algorithm development time, some new changes have been made to the algorithm, to improve the exactness of the output results. The method was tested on two conventional power system networks. The suggested improved Bat Optimization Algorithm outperforms prior research on optimum overcurrent relay coordination.

Khurshaid, T. et al. (2019) [25] proposed the recently developed meta-heuristic technique known as Firefly The flashing behaviour of fireflies is imitated by an algorithm (FA). The suggested approach has been used to tackle Directional Overcurrent Relay (DOCR) difficulties. This work's major goal was to discover the optimal Time Dial Setting (TDS) settings to reduce operation time of relay. The initial FA was modified to address DOCR coordination difficulties. The original FA was enhanced with an experience-based learning strategy (IFA) and a self-adaptive weight. To alter the tendency to move the best answer and ignore the worst, IFA introduced a self-adjustment weight. Also, an experiential learning system was developed to maintain population diversity and enhance exploratory potential. On IEEE six and thirty bus systems, as well as on IEEE nine bus systems for numerical DOCRs, the IFA has been evaluated against various optimization strategies. In comparison to other meta-heuristics approaches, the IFA gives efficient and promising outcomes. The IFA has been implemented successfully in MATLAB.

Kida, A.A. et al. (2016) [26] proposed a high-performance hybrid algorithm (HPHA) to find the best way to coordinate OCRs in radial distribution systems. The optimum co-ordination issue is nonlinear in mixed integers (MINLP). They used the following choice variables: Ip, TDS, curve type and relay type. The HPHA employed a genetic algorithm as well as a heuristic algorithm (EHA). The HPHA determines the best comparison of Ip, TDS, curve types, and relay types to provide a preference for multiple fault levels. The suggested technique uses discrete Ip and TDS variables. As shown by the simulation results, the suggested approach increases coordination by reducing OCR operating times.

Kida, A.A. et al. (2020) [27] proposed a hybrid technique entitled simulated annealing-linear programming (SA-LP) to achieve better DOCR co-operation. The proposed method was tested on five systems for testing (IEEE three bus, six bus, eight bus, fifteen bus, and thirty bus). The SA-LP outcomes were compared to other optimization approaches documented in specialist literature. By improving monitoring, communication, and grid control, the proposed approach outperformed adaptive coordination.

Korashy, A. et al. (2021) [28] proposed an optimization algorithm called modified evaporation rate water cycle algorithm (MERWCA) to find the optimal solutions for the directional overcurrent relays (DOCRs) coordination problem. It enhances the performance of an existing evaporation rate water cycle algorithm by balancing the phases of exploitation (local search) and exploration (global search). To prevent landing on the local optimum and enhance the convergence rate, MERWCA added evaporation rate water cycle algorithm and Opposition Based Learning (OBL). The proposed MERWCA's performance was compared to 10 other popular metaheuristic algorithms using the CEC'2017 test suite (MAs). They were tested on non-traditional and standard relay curves. The MERWCA approach was evaluated utilizing the IEEE - 39 bus system of meshed distribution testing. Characteristic relay curves, both conventional and non-conventional were successfully solved by the MERWCA without any miscoordination between DOCR pairs. Moreover, MERWCA reduces overall operating costs by 46% compared to ERWCA and 66% when employing non-conventional relays. This was done using DIgSILENT Power Factory.

Krstivojević, J. et al. (2016) [29] solved the problem of overcurrent transmission communication in the distribution network has been speculating that during operation, due to the failure of some of its components, the network's configuration may change. First, several network topologies for the investigated distribution network were determined, and then each network topology was coordinated separately. Coordination is a nonlinear issue with several restrictions and criteria that must be met concurrently. The differential evolution approach was used to determine the optimal settings for overcurrent relays. The pickup current relay settings and time dial settings were both real variables, while the tripping properties were integer variables. The suggested method's efficiency has been proven and its deployment yielded good results.

Maleki, M.G. et al. (2019) [30] proposed three approaches based on mixed-integer linear programming (MILP) for OC-OC and OC-D relay coordination. In the OC-OC relay coordination challenge, two of the suggested systems used MILP-based calculating algorithms to the pickup-current and time settings. The challenge of relay coordination in OC-OC and OC-D was solved using these specified procedures. A novel MILP-based technique with fewer variables was also offered. This novel method can provide the best outcome in a short simulation period. A linear term with one continuous variable and two binary variables must replace a cubic term. So, a new linearization approach was proposed. Three techniques were tested on IEEE 8 - bus and IEEE 30 - bus networks. The novel suggested strategy outperformed the existing in terms of simulation time and objective function, particularly for extensive networks. Thus, the novel suggested technique might be used in computer software as an efficient relay coordination mechanism.

Mitra, S. et al. (2018) [31] proposed a smart algorithm for adaptive settings of digital OCR to guarantee proper harmonization among OCRs. The emulation results clearly showed this. Implemented on an embedded platform, the suggested hardware-friendly algorithm has the potential as an Intelligent Electronic Device (IED).

Moirangthem, J. et al. (2013) [32] proposed an effective approach based on the adaptive differential evolution (ADE) algorithm to resolve the coordination issue. Overcurrent relays may be used to effectively coordinate a linked system. Since time multiplier setting and pick up current configurations are discrete, the overcurrent relay coordination was framed as a non-linear issue. The ADE findings are viable, resilient, and efficient when compared to other methods on various model test systems.

Momesso, A.E. et al. (2019) [33] proposed Fuzzy Logic flexible protection system for adjusting the current relay's pick-up currents by time-varying units based on current voltage. The technique included two variables: pre-fault current and current variation, which define multiple pick-ups, and current classes. This trait allows for adaptive behaviour by accepting changing actuation curves. The Alternative Transients Program - Electromagnetic Transients Program was used to model and simulate (ATP-EMTP). The approach's flexibility allowed for new logic or decision adjustments, resulting in an adaptive method that performed well by automatically following changes in system operating conditions and enhanced the sensitivity of the overcurrent protection. The distribution system with Distributed Generator (DG) was tested with various short-circuit impedances.

Moravej, Z. et al. (2015) [34] presented a new method of cross-linking transmission of direct orientation to minimize the timing of primary transmission and secondary transmission relays, using random filtering of the genetic algorithm II (NSGA II). To develop a dependable protection system, significant discrimination times and a coordination time delay must be avoided (CTI). Their approach was unusual in that it reduced main and backup relay discrimination times while increasing their working time. Comparatively, the suggested technique does not need weighting elements to convert multi-objective functions into comparable single objective functions. The suggested formulation of a problem evaluated the implications of both local as well as far-end faults. The optimization method also considers multiple overcurrent relay characteristics to determine the best for each relay. Test examples for the proposed approach were 3 bus, 8 bus and 30 bus networks. The findings were compared to other approaches.

Ojaghi, M., et al. (2012) [35] proposed a fully adaptive technique for configuring all overcurrent (OC) relays in high-voltage (HV) substations This method may be utilized online without a communications infrastructure. It used an analogous power grid circuit at the sub-station to estimate needed short-circuit currents. An example 230/20kV substation with a 9-bus grid using the complete adaptive approach to adjust its OC relays. Comparing the findings revealed significant benefits of the suggested strategy over the standard setup method. The approach was also refined to address issues caused by dispersed generation. This adaptive setup approach led to self-adjustment OC relays.

Rivas, A.E.L. et al. (2019) [36] performed optimal coordination of directional overcurrent and distance relays collectively in a scheme of mixed protection. This was a mixed nonlinear programming (MNLP) issue of high mathematical difficulty. Variables in the mixed scheme were zone - 2 time set (tZ2), time dial setting (TDS) and plug setting (PS). To produce mixed optimum coordination, this model analyzes all fault sites. This optimization issue was solved using an ant colony optimization with an extended continuous domain (x-ACO) method and a hybrid approach (conventional ACO with LP solver). ACO's first solutions were created at random. However, the iterative ACO procedure narrows the space for investigation. There are four transmission systems (IEEE - 3, 6, 8, and 30 Bus) that confirm the suggested approaches' correctness and efficacy.

Rodporn, S. et al. (2012) [37] proposed a study of the good coordination of the current direct transmission. The relay connection problem is not a line. It usually has two sets of flexible controls (Dial Time Setup: TDS and Plugin Setup: PS). In all fault instances, the primary relay's operating time was the goal function. To find the best relay coordination solutions, differential evolution (DE) was used. It was a random model that found the answer. The structure is simpler than the Genetic Algorithm (GA). The test system used was a 9-bus system. Compared to GA and BFGS, the DE found the best solution for optimum relay coordination difficulties.

Saldarriaga-Zuluaga et al. (2021) [38] proposed a novel approach to fully connecting over-current relays (OCRs) to microgrids with three parameters into account for the development of each transmission: plug setting current curve, time-adjustment setting, and feature. To demonstrate the effectiveness of the method, the IEC benchmark microgrid and the IEEE 30 bus inspection system were used. The optimum coordination issue was solved using a particle swarm optimization (PSO), genetic algorithm (GA), and optimization based on the teaching and learning (TLBO) approach. Its applicability and efficacy were shown by comparison with other coordinating models presented in the specialist literature.

Shah, J., Khristi, N. et al. (2017) [39] evaluated the performance of different OFs on IEEE 30-bus system using Sequential Quadratic Programming (SQP). The comparison study was carried out to discover the optimal OF for DOCR coordination. The operating duration of relays was decreased by preserving coordination requirements between the primary and secondary relay pairs (P/B) to achieve optimal relay coordination, researchers have created a variety of Objective Functions (OFs) with varied weightings.

Shih, M.Y. et al. (2019) [40] proposed an unparalleled tunnel method developed to adapt to multi-purpose evolution (ESA-DEMO) for cross-link transmission communication. The proposed method avoids the use of common single-purpose functions, requiring tuning parameters, avoids algorithm parameters, minimizes key time intervals, cache, and link, and breaks connectivity barriers on a large connected network. The algorithm's durability and consistency have been tested on highly linked 6 bus, 14 bus, and 30 bus systems. An analysis of close - and far - end (optimum and lowest) defects were also carried out. For protection coordination, ESA-DEMO was compared to prominent genetic algorithms and multi-objective algorithms.

Shih, M.Y. et al. (2021) [41] presented a two-stage development method for resolving multiple network errors and resetting of overcurrent relays based on the Adaptive Protection Scheme concept (APS). The first step involves upgrading the Fault Current Limiters (FCL) to rebuild error currents flowing through the Circuit Breaker (CB) hot volume. The second step involves coordinating flexible defences to reset the Directional Overcurrent Relay (DOCR) in front of FCL and DG. This was critical because FCL can cause fault current over-limitation during low-load operation, affecting DOCR performance. The DEMO method was used to solve the FCL size and placement issue as well as the DOCR coordination challenge. As a result of the suggestion, errors exceeding the thermal limit of a circuit breaker, miscoordination of DOCR, and FCL over limitation have resulted in decreased performance.

Shih, M.Y. et al. (2014) [42] studied the coordination of directional overcurrent relays based on fixed network mesh electrical system topology. In addition, modern electrical systems tend to operate near boundary conditions to satisfy the clients. As a consequence, DOCRs lose speed and sensitivity. This work's main goal was to execute online directional overcurrent relay coordination to improve speed and sensitivity. The second goal is to construct differential evolution and compare it to genetic and ant colony algorithms. In order to achieve the aims, an online algorithm was created.

Shih, M.Y. et al. (2017) [43] presented an enhanced differential evolution algorithm (DE) for solving the problem of coordination with directional overcurrent relays (DOCRs). They compared several DE versions for DOCR coordination in bigger, linked power networks. To evaluate, number of infractions, the fitness value, and standard deviation are used. The excellent DE algorithm's four components were improved: elitism, dial reduction and mediocrity, mutation index renewal, and population reduction. Compared to the other algorithms studied, the enhanced-DE (eDE) had the best execution speed, quality of results, resilience, and convergence ability. The suggested technique was tested on IEEE 14 bus and 57 bus systems. On the IEEE 57 bus network, eDE outperformed DE when it comes to execution time, fitness value, and standard deviation.

Singh, M. et al. (2018) [44] proposed user-perverted time as opposed to excessive integration in combination with the flexible feature of zone-2 working-time upgrade of backup DOCRs. The suggested combined distance & DOCR coordination technique performed well in hardware in loop simulations. The suggested algorithm's sensitivity was tested for various phases and ground fault resistances, and it was shown to be very resistant for various fault circumstances.

Sulaiman, M. et al. (2018) [45] presented the solution of directional overcurrent relay (DOCR) Symbiotic Organism Search Simulated Annealing Problems. The problem's the goal function was to reduce the sum of all main relay operation times. The DOCR issue was nonlinear and restricted by two decision variables: TDS and plug setting (PS). They studied the IEEE 3, 4, and 6 bus versions of the issue. They used SASOS to tackle the issue and compared the results to other techniques in the literature.

Thakur, M. et al. (2016) [46] studied crossover exponential and power conversion (BEX – PM) in the Real Coded Genetic Algorithm (RCGA) was used to determine the proper directional overcurrent relay settings (DOCRs). Optimum configurations were found to reduce total primary relay action time and eliminate backup/primary relay miscoordination. The team also sought to minimize the discrepancy between backup and primary response times. The outcomes were compared to other methodologies in the literature. The findings show the strategy's compliance with difficult real-world optimization issues and the results' application.

Thangaraj, R. et al. (2010) [47] studied the optimization of the directional overcurrent relay (DOCR). The optimization model for the problem was non-linear and severely constrained, with two settings for each relay as decision variables and as an the primary function, the sum of all primary relay operating times. The research investigated three models: IEEE 3, 4 and 6 bus. They used five novel DE variants dubbed modified Diversions to tackle the issue (MDE1 to MDE5). The updated Dealgorithms outperform or perform as well as the other algorithms when compared numerically.

Xu, K. et al. (2018) [48] proposed a novel solution for flexible online communication of overcurrent transmission takes into account the critical load variability and the variability of renewable production in systems with increasing combinations of renewable energy sources. Overcurrent relays (OC) were commonly employed in power distribution systems to safeguard them. The difficulty of overcurrent relay coordination in protective systems is to pick settings that meet sensitivity, selectivity, reliability, and speed criteria. Existing optimal coordination approaches mainly assume fixed DG output and steady distribution load, which was the distribution system's static situation. When the distribution system's load or generation varies, the optimum coordination approaches fail to discover the optimal overcurrent relay coordination.

Yang, H. et al. (2013) [49] investigated the problem of connecting a secure relay to distribution systems with relay guides taken as an example and constructed as a problem of complete unbalanced integrated systems. The issue was initially described mathematically and then solved using the well-known differential evolution method. Finally, a sample system was employed to illustrate the method's practicality and efficiency.

Zanjani, M.G.M. et al. (2018) [50] proposed a new application of micro-phasor measurement units (μPMUs) for overcurrent relays in microgrids that are coordinated adaptively. Their research suggested a method to identify online uncertainty. Then the microgrid overcurrent relays were coordinated. Both transmission network and microgrid uncertainty approaches were employed. The topological changes, such as line outages, were identified by monitoring the impedance estimate produced by PMU measurements. Signals transmitted by PMUs located across the microgrid were used to identify uncertainties. All data were collected and analyzed in phasor data concentrators, and then overcurrent relay coordination was updated.

Proposed Methodology

Construct an algorithm that updates the network topology in real-time (Y_{bus}) and another algorithm that coordinates the operation of overcurrent relays using an optimization approach, and combines them into a single system. First, the data in the system will be updated in response to changes in components and network configuration. The Y_{bus} will then create or change objects using the data it has collected, using the Incident technique and the Inspection method's inverse, respectively. Following that, a list of "Relay Names" and a list of "Coordination Pairs" will be automatically generated. Once this is completed, the load flow analysis will be performed employing the Newton-Raphson technique or another approach. The Z_{bus} will then be created or changed using the Block construction technique and the Partial Inversion Motto. Finally, Thevenin's technique or Symmetrical Components will be used to do the fault analysis. The validation of algorithms is carried out utilizing an academic or real-world network as a testing system. The real-time algorithm is linked to the DOCRs by the design algorithm will update the login data (network topology, flow conditions, and error currents) to find the development algorithm. This will improve network monitoring, assuming that the hardware has already been built and that it requires the installation of a real-time algorithm.

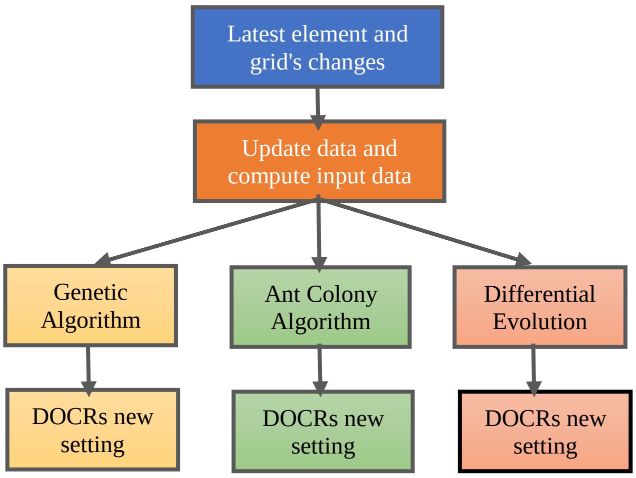

Fig. 1. Flow Diagram of Real-Time Coordination

The comparison of the three methods, as well as the construction of the real-time algorithm, will be the most significant contributions of this study endeavour. Real-time coordination will improve the sensitivity of the system as well as the operating time. As systems for testing, the IEEE 14 and 30 bus systems will be employed, respectively. The development of the "Real-Time Coordination Algorithm" will be the primary goal of this effort.

Conclusion

The transmission and distribution systems of the power system are the most complex and dynamic. Thus, a cost-effective protection strategy is required. The DOCR is the perfect answer. Despite its simplicity, the coordination of DOCRs is complex when short circuit currents and load demands of the linked system are involved. But sub-transmission and distribution networks are unavoidable. Thus, computing resources should substitute human labour in this time-consuming job. Algorithms are the computational resources here.

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