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OPTIMAL PROTECTION COORDINATION OF RELAYS IN PRESENCE OF DISTRIBUTED GENERATION USING WHALE ALGORITHM

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Abstract

This paperis proposes a novel nature-inspired meta-heuristic optimization algorithm, called Whale Optimization Algorithm (WOA), which mimics the social behavior of the humpback whales. The algorithm is inspired by the bubble-net hunting strategy which is good comparing to others. WOA is tested with 29 mathematical optimization problems and structural design problems. Optimization results prove that the WOA algorithm is very competitive compared to the state the of art meta heuristic algorithms as well as conventional methods

Keywords—Relays

INTRODUCTION

The modern electrical power system under normal operation involves the transfer of electrical energy from the generating power stations to variety of consumers through different processes, namely, generation, transmission, and distribution. The distribution of electrical power begins when generated electrical power reaches a substation via the transmission network. In an electrical distribution networks, each substation is connected to the consumers via one or more primary feeders. Most of the distribution feeders are radial in nature meaning that there is only one direction for the flow of electrical power from the substation to the consumers [1]. The distribution feeder includes various components such as in line transformers, loads, shunts capacitor banks, switches and over current relays (OCRs). The line feeder may be laid in underground or overhead configuration. Most of the lines are overhead configuration because of the financial advantages. The distribution feeder comprises of a 4 wire 3-phase circuit, and laterals that connect to three-phase or single-phase lines. The majority of the feeder's loads are situated on the laterals. The feeder is the inherently unbalanced because of the unequal (unequality) spacing of the laterals and uneven distribution of the single phase loads[2].

The current built up very quickly because of shunt faults in power system. The rise in magnitude of current indicates the existence of fault. The feeder and the power system equipments connected to it must be protected against the abnormal current due to the fault. The directional over current relay (DOCR) is used in the distribution system for overcorrect protection. The DOCRs plays a vital role

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in distribution feeders. Protection system is designed in such a way that relay operates Protection system is designed in such a way that relay should operate when a failure occur in the primary zone of protection. The secondary or backup relay should take over tripping only if the main relay fails to operate fails to operate. The relay may get mal operated if backup relays are not properly coordinated [1, 2].The purpose of relay coordination is to ensure that in the event of a power system failure, the protective relay is required to isolate only the faulty part of the power system from the healthy network and should operate as quickly as possible to keep the healthy network of the system in normal condition. Optimal relay coordination can be achieved by selecting optimal relay settings, namely Plug Setting (PS)and Time Multiplier Setting (TMS). The primary and backup relay pairs are determined first in traditional approach for configuring for setting of Time Multiplier Setting and Plug Setting. The relays are then set through an iterative process to ensure coordination. Conventional relay coordination process has some limitations. The settings of other relays in the power system depend on the initial guess of settings of the first relay. Therefore, conventional coordination process does not necessarily provide a guarantee of optimal relay settings. Heuristic Algorithms, due to their random nature and ability to perform a parallel search for a number of potential solutions, offer a possibility for optimal relay coordination.

METHODOLOGY

Introduction to Whale Optimization Algorithm (WOA)

Whales are magnificent animals. A fully-grown whale may reach a length of 30 meters and a weight of 180 tons Whales are primarily or firstly thought of as predators. Whales are fascinating animals because they are said to be very intelligent and emotive. Spindle cells are found in specific regions of the whale's brain that are comparable to those seen in humans. Human judgment, emotions, and social actions are all controlled by these cells. To put it another way, our spindle cells set us apart from other animals. The fundamental reason for whales' intelligence is that they have twice as many of these cells as human. Whales are learnt to shown to learn, communicate, think andevaluate, and yet feel emotional in the same way as humans do, although with a considerably lower degree of intelligence. Whales (particularly killer whales) have been observed to create their own vernacular. Humpback whales are few among the largest baleen whales. The range of a humpback adult whale is comparable to that of a school bus. Krill and tiny fish herds are their preferred prey. The best captivating characteristic of humpback whales is their exceptional hunting technique. This hunting method of humpback whales for scavenging is called bubble-net hunting. Bubble-net hunting is a model where Humpback whales run-after krill schools or small fish near the facade by swaying all around them in a constricting loop and forming separate bubbles along a circle or making a "9"-shaped route for foraging. This huntingprocess is a typical conduct of humpback whales, making this optimization exclusive amongst other nature-inspired optimization methods. Prior to 2011, barely surface observations were used to assess this phenomenon. Goldbogen et al. [65], on the other hand, used tag sensors to examine this behavior. They logged 300 feeding episodes of nine different humpback whales using a bubble-net feeding system generated from tags. They discovered two bubble-related movements and called them "upward-spirals" and "double loops," respectively. Bubble-net feeding is a typical activity observed just in humpback whales, and it's worth discussing here.

The Whale Optimization Method (WOA) is proposed by Mirjalili. It's a nature-inspired optimization approach of Directional Over current Relays for Optimal Coordination in Power

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Systems. Mostly used to resolve difficulties correlated to engineering and various numerical optimization concerns.

WOA is a population-based method. The Whale Optimization algorithm is becoming popular these days in engineering applications because.

i. It is based on a uncomplicated notions and is easy to execute.
ii. It does not necessitate gradient information.
iii. It has the ability to circumvent local optima.
iv. It can be used to solve a wide range of problem from a variety of areas.

The implied WOA possesses exceptional evaluation ability and speed when contrasted to other meta-experiential techniques. The primary goal of our proposed WOA is to determine the best TDS and PS values for reducing DOCR running time under backup and relay configuration constraints. By tackling 29 mathematical optimization complexities and six structural optimization obstacles, the efficacy of the WOA algorithm developed in this work is evaluated.WOA is a most recent algorithm that replicates the intuitive hunting behavior of the humpback whales. WOA has unique characteristics and requires few controls, for example, because it incorporates only two key core restrictions to be balanced: low execution and high-level adaptability.WOA computation may simply move between exploration and exploitation based on just one parameter. During the exploration phase, instead of using the best search agent found so far, the locality of the search agents (solutions) is updated by a randomly picked search agent. Despite using a logarithmic winding capacity, the algorithm covers the border area in the search space due to the ease of WOA computation in execution and the reduced reliance on parameters. The bubble-net hunting process has three parts to establish the mathematical paradigm of WOA. The encircling of the prey is the first phase, followed by a spiral bubble-net feeding action, and finally, the search for prey. All the steps are detailed below.

Application of Whale Optimization Algorithm

The recommended optimization technique is used to search the fittest search agent's neighborhood thus far to make sure that it's far the nearby optima and to select search retailers from the population since it offers all individuals a hazard to be decided on. A nature-stimulated whale optimization algorithm (WOA) became utilized in a radial and multi loop energy gadget to pick out the pleasant DOCR coordination. The quest agent suggests the layout variables (ps and TDS). The tiers of playstation and TDS are furnished for every take a look at machine. This new release system is sustained till the criteria of convergence met and the coordination standards constraints (ps, CTI, TDS) for maximum relay putting is executed. The counseled WOA has been examined on six IEEE numerous check systems to decide its overall performance.”The optimized minimal objective characteristic values for every take a look at case observe provide perception into the WOA's overall performance. in this work, WOA optimization algorithm is applied to obtain the optimal relay settings and the over modern relay coordination problem among the number one and backup relays is solved by using the MATLAB. The proposed algorithm is carried out to diverse popular take a look at structures and compared with different met heuristic algorithms.

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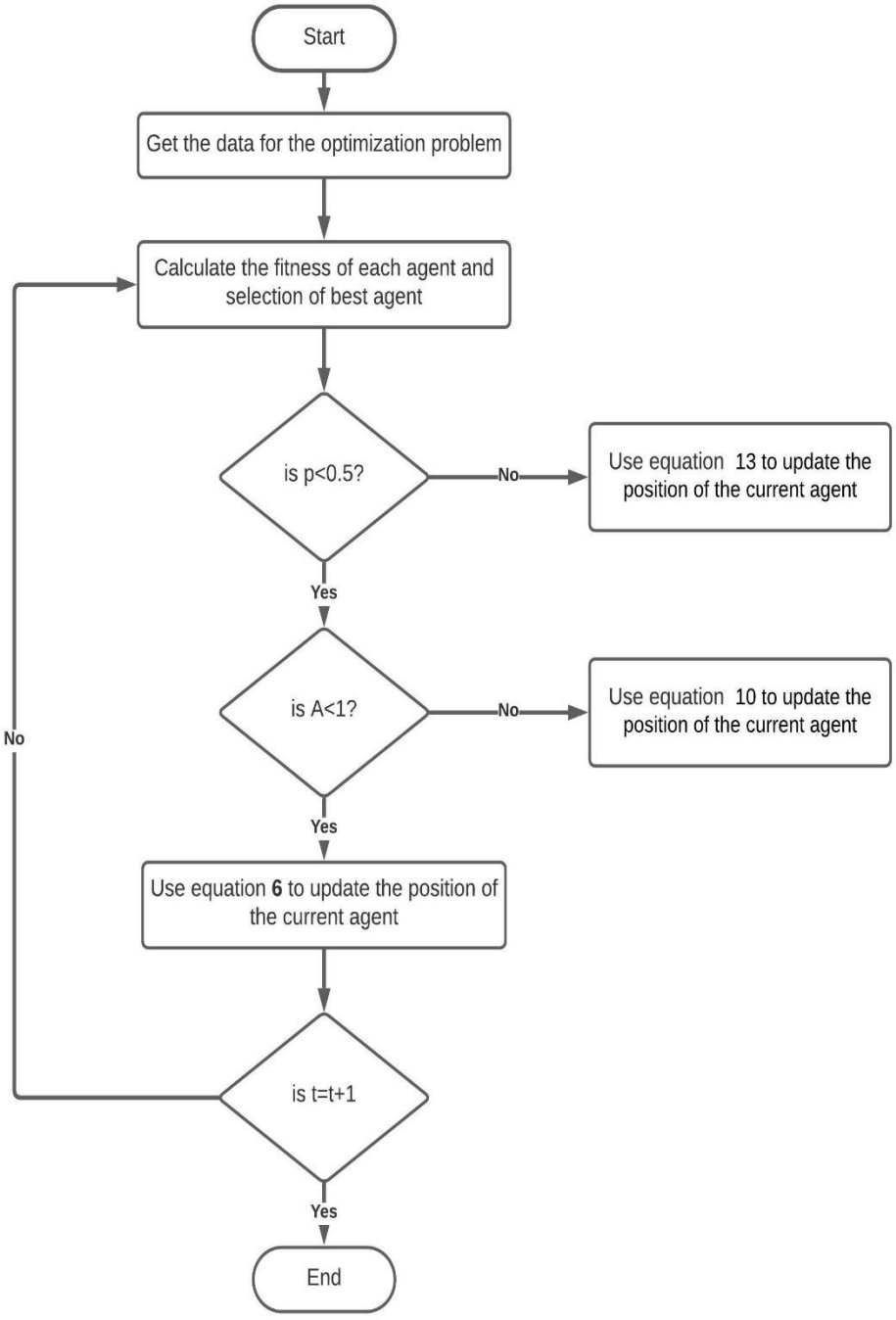

Figure: Flow chart of WOA Algorithm

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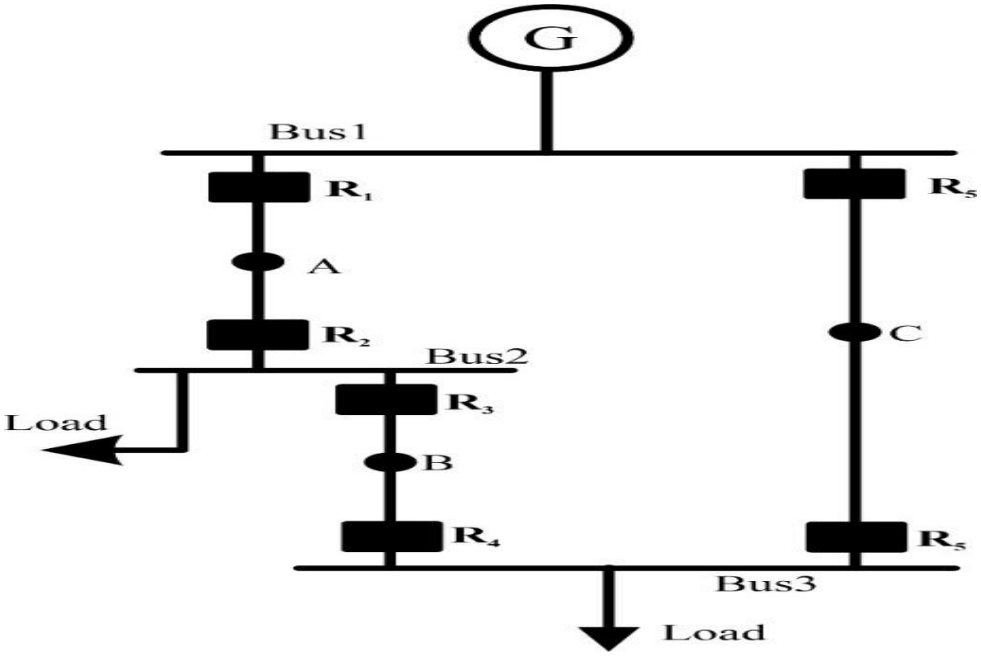

Fig : Single loop 3 Bus distribution system

Fault Location	Fault current seen by Relays in Amps					
	1	**2**	**3**	**4**	**5**	**6**
A	6579	313	-	1565	1565	-
B	2193	-	2193	2193	2193	-
C	1095.6	-	1096.5	-	5482.5	1827.5
D	1644.7	-	1644.7	-	2741.2	-

Table of : Current seen by relays at different fault locations

Relay No	Optimum TDS	Optimum PS
R_1	0.0849	0.5
R_2	0.05	0.9399
R_3	0.0726	0.5
R_4	0.05	0.5
R_5	0.3731	0.5
R_6	0.05	0.5

Table of Optimum values of TDS and PS

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Fault Location	Primary Relay	Back up Relay	Relay Operating time in seconds		CTI
			Primary Relay	Backup Relay	
A	R_2	R_4	0.2875	1.243	0.9556
B	R_3	R_1	0.3389	0.7897	0.4508
	R_4	R_5	0.2332	0.5332	0.3
C	R_6	R_3	0.2665	2.3554	2.0889
D	R_3	R_1	0.2333	18.2494	18.0161

Table of Relay operating time and CTI

	WOA		**TLBO**	
Relay No	Optimum TDS	Optimum PS	Optimum TDS	Optimum PS
R_1	0.0849	0.5	0.0706	0.9761
R_2	0.05	0.9399	0.0503	0.6001
R_3	0.0726	0.5	0.05000	0.6567
R_4	0.05	0.5	0.0500	0.8036
R_5	0.3731	0.5	0.0744	0.9947
R_6	0.05	0.5	0.0500	0.6266
Operating Time	**1.353 seconds**		**1.7139 seconds**	

Table of Comparison with other algorithms

TDS range	**0.05-1.10**		**0.05-0.50**		**0.05-0.25**	
Relay No	TDS	PS	TDS	PS	TDS	PS
1	0.0706	0.9761	0.114	0.705	0.057	0.572
2	0.0603	0.7001	0.051	0.642	0.051	0.412
3	0.05	0.7567	0.054	0.575	0.051	0.442
4	0.05	0.9036	0.051	0.597	0.05	0.572
5	0.0744	0.9947	0.071	0.552	0.053	0.551
6	0.05	0.6266	0.058	0.563	0.05	0.535
Total operating time	**1.8943 seconds**		**1.5606 seconds**		**1.1488 seconds**	

Table of Optimum TMS and PS with different TMS range

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CONCLUSION

This chapter outlines the whale optimization technique that was used to evaluate the DOCR coordination problem. These algorithms develop new population for TMS, which eliminates worst solutions with new potential solutions for TMS. The proposed technique has a high search capability and convergence rate in comparison to other algorithms, these distinguishing characteristics make the search agents of whale optimization algorithm more discriminative in obtaining the best results. The various optimization methods, as shown in the literature, were used to assess the standard test cases in this chapter, and the suggested WOA algorithm produced a more optimal solution compared to the other algorithms. The whale optimization algorithm has been implemented to five IEEE test systems including the standard IEEE three-bus, with DG and without DG.

The problem of DOCR coordination is largely a noticeably optimization hassle with quite a few constraints. because the recommended Whale Optimization set of rules can remedy the optimization troubles of limited and unconstrained“the hassle of over modern-day relay coordination has been transformed into an unconstrained optimization trouble with the aid of declaring a brand new goal characteristic and via the use of the restrictions at the TDS and playstation (and obstacles at the relay running time) because the limits of the variables This chapter gives a way for remodeling a relay coordination hassle into an optimization problem. A MATLAB program has been advanced to perceive the most reliable time coordination of DOCRs the use of the advised WOA technique. The MATLAB application used to decide the nice timing for DOCRs in a machine with any wide variety of over modern relays and primary-backup relationship. the total running time of number one relays TDS and playstation acquired for all take a look at case research through the cautioned WOA method ensured that the DOCRs will spark off within the minimum feasible amount of time for a fault at any point inside the device The graphs of convergence feature taken all through simulations shows that the convergence is faster and achieves a advanced solution for the high-quality fitness feature in fewer iterations.

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