DWT-Differential Analysis Optimization technique Used in the protection of Microgrid

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Abstract: ***This paper process DWT-differential analysis for optimal relay coordination issue for the microgrid. This solution works for grid-connected as well as the disconnected mode of operation. Coordination among relays of the microgrid is a complex part to handle, as the insertion of DG causes a bidirectional flow of current. Advanced protection methods involving DWT analysis of fault current can provide intelligent and smart ways of protection. Previous work has been applied with the differential algorithm on grid-connected and islanded mode, but one major deficiency is an increase in operating time of primary and secondary relay, which further decreases the reliability of Microgrid. The proposed system relies on DWT-differential Analysis based approach, which removes all unwanted noise and bandwidth from fault signal and differential analysis helps to select the best pair of a relay. The problem is formulated as a Non-linear programming constraint to minimize overall operating Relay time. The Scheme is tested with IEEE-9 bus system. The comparative analysis is carried out with two traditional methods, the result shows that it achieves a remarkable reduction in operating time in the primary and backup relay.***

Keywords: Differential Analysis; Microgrid Protection; Relay coordination.

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1. Introduction

The Protection of the power system is necessary to identify and remove the defective locations as quickly as possible. There is always a risk of a major failure in security, so a backup plan is mandatory. To maintain synchronization, both primary and Secondary relay attributes must meet that constraint. The relay must travel within its self-protective zone to avoid any misuse of the protective devices like circuit breakers and switches. The key role of the protection system is, the relay should not work other than its zone unless and until backup protection fails. the synchronization between primary and secondary relay should establish in such a way that the primary relay should operate before the secondary relay. Most reliable and low-cost protection in the power system is overcurrent relay protection [1-3]. Microgrid such as 108 bus, 34 bus, 18 buses have large no of relays present in the distribution system. To minimize the operating time of relay, we should minimize two basic parameters such as TDS (time dial setting) and PSM (plug setting multiplier) [4]. To protect an area that is not affected by the short circuit current, the protection system should be strong enough to isolate only the faulty area [5].

Authors A. Chowdhury and D. Koval [6] suggest that a hybrid-GA interval linear programming method for relay coordination, the main deficiency found is that the algorithm takes a lot of time to solve iteration, which adds to the operating time of the relay. Autors S. T. P. Srinivas and K. S. Swarup [7] cited the use of Superconducting Fault Current Limiter (SFCL), also with directional overcurrent relays (DOCRs) to solve the protection coordination problem in distribution systems, which include distributed Generator (DG); but the addition of one more device in the system increases cost and compactness of the system. N. K. Choudhary, S. R. Mohanty and R. K. Singh [8] suggest a fuzzy-based GA to optimize the operating time of relay, the addition of weight factor in algorithm increases the complexity of the system. D. Solati Alkaran, M. R. Vatani, M. J. Sanjari, G. B. Gharehpetian and M. S. Naderi [9] present a smart online adaptive optimum coordination method for overcurrent relays using a genetic algorithm for distribution systems when there are variations of load and distributed generation outputs, the main difficulty found in using the SCADA system. Online enabled SCADA needs users to remotely monitor and control remote sites via a web browser Security is the biggest issue. K. Xu and Y. Liao [10] present a genetic algorithm (GA) method for the coordination of overcurrent (OC) relays. Short circuit current use for analysis is not preprocessed hence the presence of noise and unwanted data will increase the operating time of the relay.

This paper proposes a hybrid and versatile overcurrent and differential protection plan to manage the extreme changes in the microgrid. The information mining model-based on the DWT differential intelligent protection scheme for the microgrid network has been proposed. The proposed plan creates protection work for the microgrid working at various topologies such as grid-connected and islanded modes. The differential highlights inferred at individual feeders are utilized to fabricate the information discretization, which is utilized for a final relay decision.

2. Problem Evolution

The Operating time of relay is mainly varied with two components that is TDS (Time dial setting) and PSM (Plug setting Multiplier). Whereas PSM is the ratio of short circuit current to Pick up current .operating time of relay varies inversely with short circuit current. Researchers P. P. Bedekar, S. R. Bhide and V. S. Kale [11] and H. H. Zeineldin, H. M. Sharaf, D. K. Ibrahim and E. E. A. El-Zahab [12] present an optimal coordination program minimizes the total operating time of relays and eliminates the miss-coordination between primary and backup relays. The protection coordination issue is commonly defined as an advancement issue where the fundamental target is to limit the general relay working time

$$t_{ij} = TDS_i \frac{\alpha}{\left(\frac{I_{SCij}}{I_{pi}}\right)^{\beta} -1} \quad (1)$$

Where i is the relay identifier and j is the fault location identifier. α and β are the constants that control the (time/current) characteristic of the relay. In this paper, α and β are chosen to be 0.14 and 0.02, respectively, to represent the characteristics of a standard inverse time overcurrent relay. There are different types of OCR with different characteristics, α and β vary as per Table 1; here IDMT relays are used. Different values of α and β generate nonlinear characteristics, which result in the formation of nonlinear programming problem with constraint.

The objective is to optimally coordinate dual setting relays to minimize the total relay operating times for both primary and secondary (backup) operation considering both modes of system operation: grid-connected and islanded configuration. The objective can be stated as follows,

$$\text{Minimize } T = \sum_{c=1}^{c}\sum_{i=1}^{N}\sum_{j=1}^{M}\left(t_{fw\_cij}^{p} + \sum_{k=1}^{k} t_{rv\_cij}^{bk}\right) \quad (2)$$

Where c is the configuration identifier, and it takes a value of 1 for the grid-connected configuration and 2 for the islanded configuration. N is the total number of relays. M is the total number of fault locations. $t_{fw\_cij}^{p}$ is the primary relay i operating time, in the forward direction, for fault at j for configuration c. $t_{rv\_cij}^{bk}$ is the backup relay i operating time, in the reverse direction, for fault at j for configuration c. The identifier k denotes the total number of backup relay for a fault at j. Primary protection in any power network has its backup to ensure a reliable power system. It is necessary to coordinate the two protective systems (primary and back-up). Coordination Time duration (CTD) is the criteria for coordination to be considered. It is a predefined time interval of communication, which depends on the type of relays. CTD for IDMT relays varies from 0.2 to 0.5 [13]. To ensure proper working of the protective system, the back-up scheme should not come into action unless the primary (main) fails to take the appropriate action [18]. Only when CTD is exceeded, the backup relay should come into action.

$$t_{rv\_cij}^{bk} - t_{fw\_cij}^{p} \geq CTD \quad (3)$$

In this paper, CTD is taken to be 0.2 s. where k is the backup relay identifier. P. E. F. Zanjan, K. Mazlumi and F. M. Bayat [19] suggest about the values that TDS and I_p can take, must also be set.

$$I_{pi\_min} \leq I_{pfwi}, I_{prvi} \leq I_{pi\_max} \quad (4)$$

$$TDS_{i\_min} \leq TDS_{fwi}, TDS_{rvi} \leq TDS_{i\_max} \quad (5)$$

The estimation of I_{pi_min} is picked with the end goal that it is bigger than the evaluated load current by a noteworthy edge. In this manner, the accompanying requirements are characterized. Where I_{pi_min} and I_{pi_max} are the minimum and maximum limits for relay i's forward and reverse pick up current setting and they are based on the load current calculations. TDS_{i_min} and TDS_{i_max} are the minimum and maximum limits for relay i in forward and reverse Time Dial Setting which will depend on the relay manufacturer values.

3. DWT-Differential Analysis

3.1 DWT Analysis

DWT is an effective tool to detect small disturbances that occur in the microgrid as it is a transient sensitive way for processing any signal. The Proposed research pre-processes short circuit current signal through DWT to extract the most significant feature to detect the location of the fault and to remove all noise factors from the signal, which ultimately helps to reduce the time of the operating relay.

Short-circuit current I_{sc} is sampled with frequency 6 Khz, the based value used is 20 MVA and 480 V for per unit calculation. There are 4 detailed coefficients (DA1-DA4) obtained after analyzing the signal as shown in fig. 1.

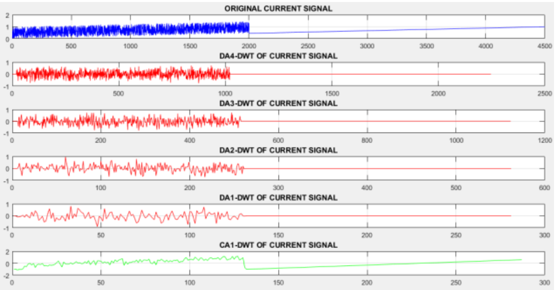
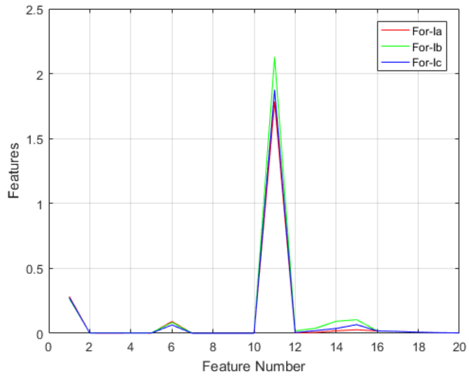


Figure 1: DWT analysis of fault signal

Current Signal I_{abc} is decomposed using DWT. Four level decomposition of current with DWT. Current measured at relay 21 and 1 is decomposed with DWT. DWT approach automatically adjusts window width to give good time resolution. J. A. Hoyo-Montaño *et al.* [17] suggest for decomposition, we used Daubechies Wavelet (db4) with four-level decomposition.

Extracted features are then used for fault classification purpose. R. Storn and K. Price [15] suggest that short-circuit current I_{sc} is fed directly to optimization algorithm which contains noise and high pass and low pass content in a waveform which increases the operating time of the relay. Fig. 2 shows extracted DWT features for fault measured at location R21 and R1 for I_a, I_b and I_c.



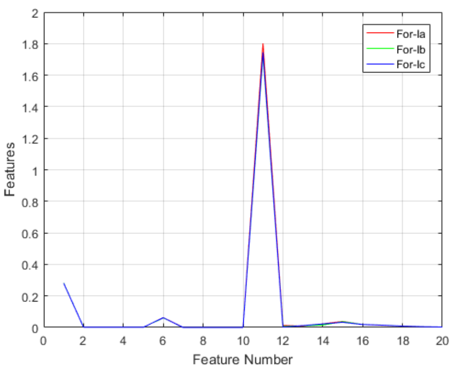


Figure 2: Fault signal at Location 1 and 21

3.2 Algorithm

Step 1: Initialization of all parameters, like population size, no of generation, cross over probability and scaling factor, etc.

Step 2: Generate first iteration.

Step 3: Generate a random target vector set of P-size corresponding to the variables which have to be optimized. Target vector set: $X_{i,G}$; $i = 1,2,3,\ldots,P$.

Step 4: Using these target vectors, calculate Objective function against unsatisfied constraints.

Step 5: Mutation: For a given vector set $X_{i,G}$, generate 3 random distinct vectors ($X_{r1,G}$, $X_{r2,G}$, $X_{r3,G}$ and $X_{r4,G}$. Generate mutant vector for target vector.

$$V_{i,G}=X_{best,G}+f_1\left(X_{r1i,G}-X_{r2i,G}\right)+f_2\left(X_{r3i,G}-X_{r4i,G}\right) \quad (6)$$

Step 6: Crossover: Obtain a trial vector set by replacing some of the mutant vectors by target vector based on crossover probability.

Step 7: Selection: Merge trial and target vector set. Compare the merged vector set and sort the vector set in ascending order (following the minimum objective function value). Sorted vector set is of doubled population size Select vector set of P-size (optimum values) and discards the rest values.

Step 8: In sorted vector set of p size if maximum generation is reached then Select Vector (variable value) which results in the minimum value of the objective function. Obtain X best individual and stop the process and if maximum generation is not reached then sorted vector set for the next generation and increment generation by 1 and directly jump to step 3 and repeat the algorithm. Relay use wavelet technique in the detection of a fault. Different conditions like healthy and faulty are checked within the microgrid. short-circuit signal from the faulty line is input to the intelligent relay.

The energy with the help of the wavelet coefficient is calculated and this featured is used by the decision tree to decide fault detection and classification. Flowchart of Algorithm and survival of fittest are shown in shown in fig. 3 and fig. 4.

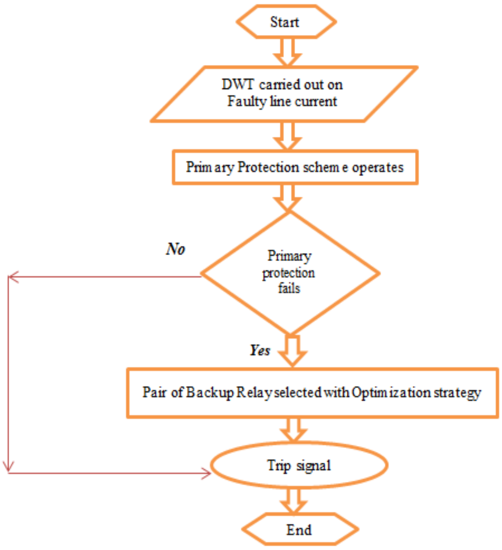


Figure 3: Flow chart of Algorithm

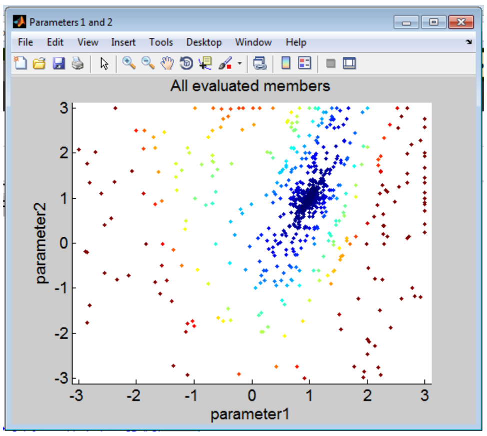


Figure 4: Survival of fittest

4. IEEE-9 bus System

The practical IEEE-9 bus test system is converted to a hybrid microgrid by connecting two solar one wind and one diesel generator set. A. Sharma and B. K. Panigrahi [16] give the source models are taken from standard MATLAB Simulink blocks and examples. The normal grid is fed with two feeders having rating 115 kV, X/R ratio=6, MVA=500MVA. The line impedance is 0.1529+j0.1406 Ω/km, all lines are 500m long. The transformer connected to point of coupling is with rating 20 MVA, 115kV/12.47kV. Ratings of DG1, DG2, DG3, DG4 are 480V, 20 MVA, x_d' = 0.11 with transformer rating 20 MVA, 12.47kV/480V. Load capacity is given by 2 MVA, 0.9 systems. When DGs were not consolidated with this 9-bus structure, the system was radial and single pair overcurrent relay that is primary relay on each line was sufficient for guaranteeing the protection. In any case, with the consideration of DGs at different buses, the radial structure directly has been changed over into a complicated network, on account of which, there is a bi-directional current stream in the network. Efficient working pair of relay required for protection. F1 to F8 are different fault locations on each bus and R1 to R21 are relays in fig. 5.

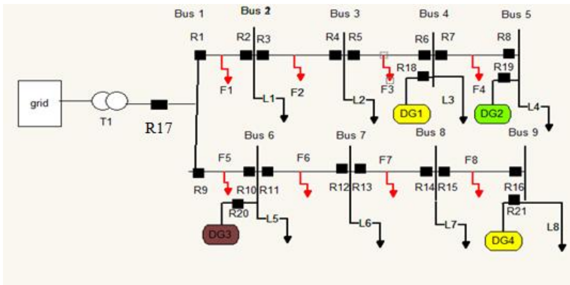


Figure 5: The IEEE-9 bus system

5. Results and Comparative Analysis

As shown in fig-5 when fault F1 creates on system R1 and R2 are a primary relay for the system. R10, R17 and R4 are secondary relays for the system. If primary relay fails to operate by any chance secondary relay operates within some time interval (CTD). Values for CTD 1 are 0.0176 and 0.894 CTD 2 value is 0.00868. It can be observed that all the CTD values are equal to or greater than 0.2 sec and all the primary relays are operating before backup relays. This shows that the coordination between relays is going smoothly.

To evaluate performance of proposed method, a comparative analysis is carried out between the Differential evolution (DE) algorithm method as done by A. Sharma and B. K. Panigrahi [16], with respect to different parameters such as Plug setting multiplier (PSM), Time Dial setting (TDS), first primary relay working time (PR1-T), second primary Relay working time (PR2-T), first backup relay working time (BU1-T) and second back up relay working time (BU2-T). PSM result is improved with respect to the reference method. As PSM decreases less will be operating time. The value of TDS is calculated by taking different short circuit currents at different locations of faults and choosing the different value of CTR (current transformer ratio). Operating time of primary and backup relay reduced by a great percentage as compared to the reference method. CTD is the difference between backup and primary relay operating time, which also causes a huge change in value. All comparison results convinced the proposed method ultimately reduces the operating time of relay helps to improve the reliability of the Microgrid.

Table 1: CTD Comparison

Faults	CTD-1		CTD_2	
F1	t_{10-1} 0.0176	t_{17-1} 0.894	t_{4-2} 0.00868	
F2	t_{1-3} 0.031		t_{6-4} 0.003219	
F3	t_{3-5} 0.008119		t_{8-6} 0.0491	t_{18-6} 0.0928
F4	t_{5-7} 0.04339	t_{18-7} 0.1332	t_{19-8} 0.00374	
F5	t_{2-9} 0.00811	t_{17-9} 0.1128	t_{20-10} 0.2017	
F6	t_{9-11} 0.0077	t_{20-11} 0.108	t_{14-12} 0.001403	
F7	t_{11-13} 0.00252		t_{16-14} 0.007281	
F8	t_{13-15} 0.00156		t_{21-16} 0.00458	

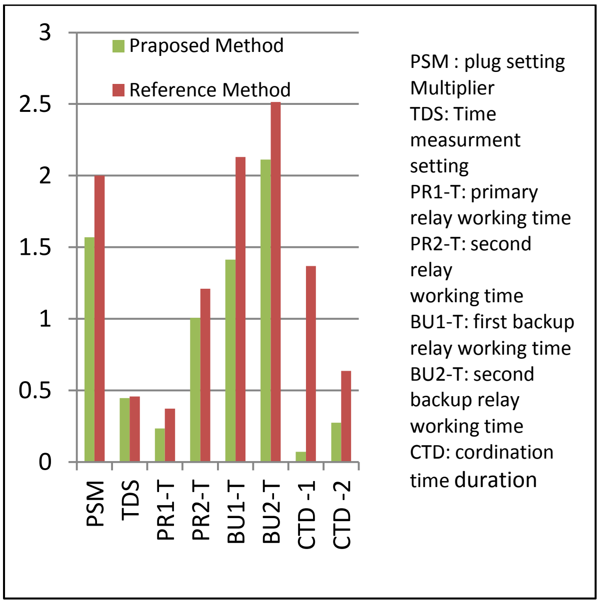


Figure 6: Comparative Analysis

6. Conclusion

The integration of DGs in the system brings various operational and planning related issues. This focuses on the protection related issues arise from the introduction of microgrids. There is a significant short circuit current difference during grid-connected and islanded modes of operation. The optimized settings which have been obtained in this tackles the issue of relay miss-coordination arrived due to the difference of fault current level during both modes. The optimized relay settings are obtained using a meta-heuristic technique based DWT-Differential algorithm. The research proposes, convincing discrete relay setting which are feasible for numerical relays. The optimized discrete relay settings result in the accurate and coordinated operation of relay is both modes of operation of the microgrid.

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