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Integrated Dwt-Differentiation Algorithm for Fault Detection and Relay Coordination in Micro Grid

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Abstract: The Bidirectional flow of current makes it difficult to detect fault in the microgrid. The level of fault current changes continuously with change in load, it leads to selectivity and sensitivity issue of relay. In this paper integrated DWT-differentiation algorithm is proposed for fault detection and relay coordination, the input waveform of fault current is proceed with discrete wavelet transform. Time scale function of DWT used to extract exact feature from signal which helps in further effective analysis. The Optimization function of relay is mainly depends on PSM (plug setting multiplier) and TDS (Time dial span). The Fault current used to calculate this parameter are already analyzed from DWT. Standard 9 bus IEEE system is used as reference. Fault is detected at 21 different locations; initially primary protection is activated and secondary protection operates only if first selected pair of relay fails to operate .The differential algorithm select best pair of backup relay and relay coordination is carried out resulting in reduction of operating Time.

Keywords: Keywords: Microgrid protection; Relay coordination; fault detection; differential algorithm.

I. INTRODUCTION

Non-renewable energy sources are disappearing step by step consequently need for the microgrid is expanding. The entry of sustainable power sources and Distributed generators (DGs) in network decrease the greenhouse effect and offer the answer for high demand requests of consumption of artificial power [1-4]. The microgrid gives plenty of power to a wide range of loads such as businesses load, everyday load in the country and urban areas [4].In remote regions where power doesn't come because of natural disasters and the environment issue, the microgrid is the best arrangement. microgrid System works for two methods of activity Grid associated and Grid isolated mode.[5]. Despite of lot of advantages of micro grid, dynamic behavior of micro grid results in failure of protection system. Therefore to design protection of micro grid is key issue [8].There is lot of difference in magnitude and direction of short circuit current in grid connected as well as grid separated mode which may lead to discerning operation of micro grid .Main grid contribute large amount of current in system [7].

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There are other reasons in system which changes fault current for example radial and mesh loop configuration and inverter based DGs and synchronous DGs leads to different contribution on current. Conventional over current relay with fixed internal setting fails in protection of micro grid.

Protection system of micro grid should be reliable with high speed of operation. Protection system with used of numerical relay having coordination among relay and with central unit should be essential.to design such system is challenging task. Various protection systems which update operating condition is studied previously one strategy to obtain short circuit current is curve fitting. In which reverse operating time is acquired on a diagram for some failures. Direct and nonlinear qualities are tried for relay coordination with various working graphs [8]but the exactness of this strategy is not accurate. With the assistance of graph hypothesis technique [9] relay which is known as a breakpoint, relay are distinguished [10]-[12] exact choice of breakpoint through this strategy prompts to answer for relay coordination still choosing breakpoint is troublesome. By using Lagrange's gradient multiplier problem is formulated for relay coordination is called analytical method applicable for radial system. [13]-[15] but lot of iterations are carried out to reach solution which is tedious job for large no of bus system. Non-Linear enhancement procedures [16][17] in which issue is defined utilizing nonlinear programming .both TDS and PSM are chosen accurately minima trap can be acquired in this technique. Crossbreed streamlining strategy which is mix of Analytical and advancement optimization equipped for taking care of relay coordination issue for enormous interconnected network however worked with fixed topology[18]-[21].fuzzy and ANN-based enhancement strategies used to shape issue for relay coordination is predefined for different issues along these lines if new issue acquired with system, coordination fails[22]. The updated activity of relay would be more effective with DWT differential Algorithm [23].

This paper convinces, exact working of digital numerical relays. New advanced technique is used with designing numerical relay by using discrete wavelet transform. The advanced relay settings result in reliable and accurate operation of relay in the micro grid system during both grid connected and grid isolated mode of operation. Numerical relay coordination is carried out with discrete wavelet differential Algorithm technique.

II. PROBLEM FORMULATION AND CONSTRAINT

A. Optimization Problem

Improvement issue in Relay coordination can be planned as nonlinear programming determination whose principal goal is to progress complete relay working time. Summation of primary, as well as backup relay operating time must be optimized. At the point when failure is in neighboring zone Overcurrent relay which operates primary relay in its zone, the same relay is functioned as the secondary relay. In this way, synchronization should be maintained between both

$$F_R = Min \sum_{k=1}^{n} \sum_{P=1}^{2} A_i TMS_i \quad (1)$$

Where F_R is operating time which is objective function designed for relay

K is faulty bus locator, n is total count of relay used in system

p varies from 1 to 2.whwre 1 indicates primary relay and 2 indicates backup relay

$$T_1 = \frac{A}{\{(\frac{I_{sc}}{I_p})^{B}-1\}} \quad (2)$$

Where A and B are constant which varies as per relay characteristic changes, here overcurrent relay used hence value of A and B are set 0.14 and 0.02 .

I_{sc}: short circuit current and Ip is relay pick up current.

TDS (Time dial span) of relay

TDS and pick up current (I_P) of relay are two parameter from which operating time of relay is optimized. Pick up current is calculated from set minimum value of short circuit current above which relay starts to operate.

B. Constraint

to maintain synchronization between relays there should be limitation ought to be applied on target function. Initially, the primary pair of relay trip faulty bus if it fails then only backup protection activates[24]. Between two relay working time, one constant gap should be maintained called as CTD (coordination time duration)

$$B_{ackup} - P_{rimary} \geq CTD \quad (3)$$

$$TDS_{Imin} \leq TDS \leq TDS_{Imax} \quad (4)$$

$$I_{pimin} \leq I_{pi} \leq I_{pimax} \quad (5)$$

II. OPTIMIZATION STRATEGY FOR SELECTION OF RELAYS

When fault occur on system, current is passed to system through CT (current transformer).Discretization on fault signal is carried out with DWT up to 4 level of decomposition. All unwanted data from signal is removed all parameters are calculated as per requirement. Total operating time for primary and backup relay is estimated. Then trip signal is passed to primary relay, if it fails Differential algorithm activates to select best pair of backup relay with following algorithm [8].

Implementation of Differential Algorithm takes place in following steps.

Step 1.Start

Step 2.Define Objective function for Operating time of relay.

Step 3 Define various parameters and constant also set stopping criteria for each value.

Step 4 Generate initial populations by setting iteration count 1. Estimate random target set of vector M-size with respect to the variables which has to be optimized. Target vector set: Xi,P; i=1,2,3,…,M

Step 5. For generated chromosomes from each iteration check validity of objective function. Best pair of chromosomes is selected for reproduction which satisfied objective function.

Step 6 Reproduction selection of matching pair, chromosome with better fitness is selected for mating and greater chance to survive and reproduce. For each new solution to be produced, a pair of "parent" solutions is selected for breeding from the pool selected previously.

Step 7 .Mutation: It is performed in each iteration to prevent algorithm from local minimum trap, this process will continue till it reaches to termination criteria. For a given set of vector Xi,P , generate 3 random distinct vectors (Xr1,P, Xr2,P,Xr3,P and Xr4,P Generate mutant vector for target vector.

$$V_{iP} = X_{best,P} + f_1(X_{r1i,P} - X_{r2i,P}) + f_2(X_{r3i,P} - X_{r4i,P}) \quad (6)$$

Step 6.Crossover: crossover is process which is which is used to create new chromosomes called as offspring. This new offspring are again used in next population [17].

Step 7.Selection:

Step 8.Through reproduction, crossover, mutation obtain the value of X_{best} and stop the iterations. If stopping criteria is not satisfied increase count of iteration by 1 and switch to step 3.continue same process till criteria satisfied.

Following flow chart shows implementation of proposed DWT-Differential techniques.

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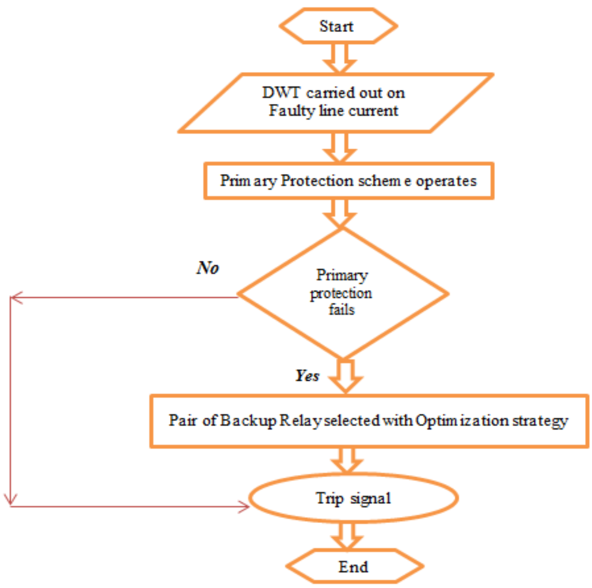

Fig 1:-Flowchart for Proposed Protection System

III. SYSTEM DESCRIPTION

DWT-Differential algorithm is tested in MATLAB by converting IEEE 9bus system to the crossbreed microgrid by connecting different DG sources such as two solar connected to bus 4 and bus 8.wind connected bus 5 and diesel connected to bus 6.

As shown in fig [6]When sustainable sources are not connected to power system then protection is done with the help of single overcurrent relay as flow of current is unidirectional.so traditional protection works for system. When sustainable sources connected to grid, flow of current are bidirectional hence there is need to design smart protection. All gadgets used like DG, Inverter are sensitive by nature so protection of bus should be effective in all way [9]. DWT-DA is tested on system by using 21 relays and 9 buses. Faults are created on each bus F1 to F8 short circuit current is note down and fault analysis is carried out. Following is data used to form Simulation model in MATLAB [15].

Table 1 Microgrid Parameter

Two feeder	115 Kv, X/R ratio=6,Short circuit MVA=500
Line Impedance	Z= 0.1529+j0.1406 Ω/km
Two feeders are	500m Long
Line Transformer Ratings	20 MVA,115KV/12.47KV
Solar wind and diesel DG ratings	480V,20MVA, xd'=0.11
Transformer connected to all DGs	20 MVA,115Kv/12.47KV
Load Capacity	2MVA,0.9 PF

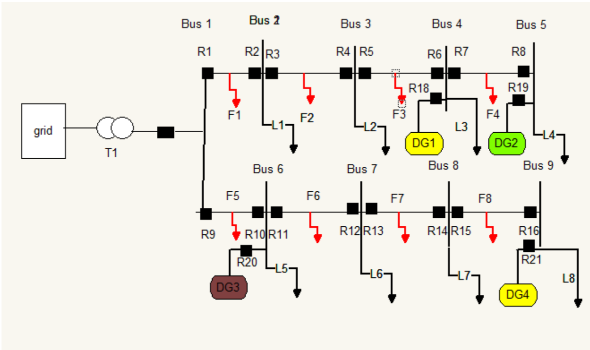

Fig 2:-Standard IEEE 9 bus with sustainable DG source

Table II Primary and backup relay pairs for grid-connected and islanded mode of operation

Faults	Modes	Primary Relay	Backup Relay	Faults	Modes	Primary Relay	Backup Relay
F1	Grid connected Mode	R1, R2	R10, R17, R4	F5	Grid connected Mode	R9, R10	R2, R17, R12, R20
	Islanded Mode	R1, R2	R10, R4		Islanded Mode	R9, R10	R2, R12, R20
F2	Grid connected Mode	R3, R4	R1, R6	F6	Grid connected Mode	R11, R12	R9, R20, R14
	Islanded Mode	R3, R4	R1, R6		Islanded Mode	R11, R12	R9, R20, R14
F3	Grid connected Mode	R5, R6	R3, R8, R18	F7	Grid connected Mode	R13, R14	R11, R16
	Islanded Mode	R5, R6	R3, R8, R18		Islanded Mode	R13, R14	R11, R16
F4	Grid connected Mode	R7, R8	R5, R18, R19	F8	Grid connected Mode	R15, R16	R13, R21
	Islanded Mode	R7, R8,	R5, R18, R19		Islanded Mode	R15, R16	R13, R21

IV. Working of Proposed System

Single Line to ground fault is created on system. Short circuit current I_{abc} is decomposed with 4 decomposition level daubechis Wavelet is used for it. Single line to ground Fault is created at bus 1 by choosing fault resistance 1ohm.Current is measured at relay 1 and decomposition of signal is carried out as shown in fig[3].In this way different faults are created on different locations and fault analysis is carried out.

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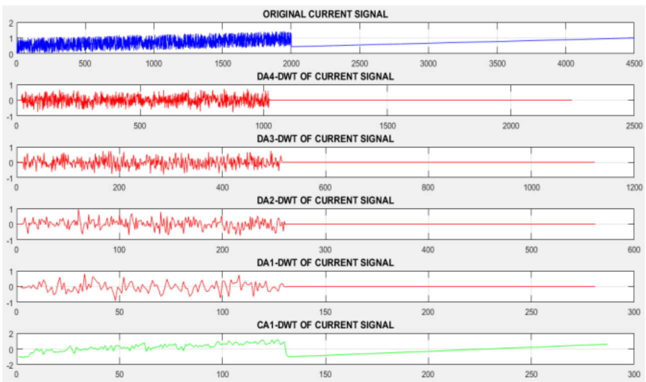

Fig 3:-feature extraction with DWT

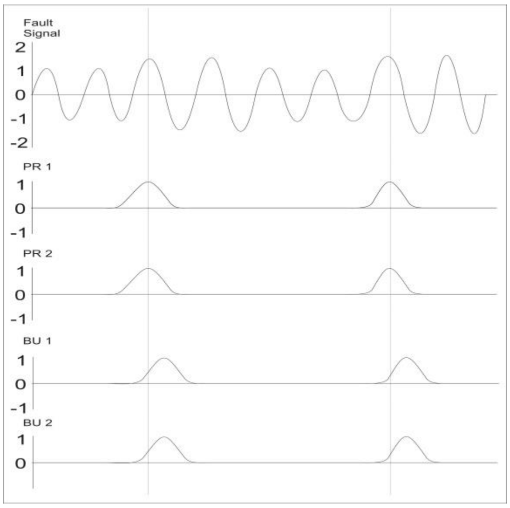

Fig 4:-Operation of primary and backup relay

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Table III Primary and Backup relay fault current for grid-connected and Islanded mode of operation

Fault	Short Circuit current in grid connected mode ($I_{f\text{-}G}$)						Short Circuit current in Islanded mode($I_{F\text{-}i}$)					
	Primary Relay		Backup relay				Primary Relay		Backup relay			
	PR_1	PR_2	BU_1		BU_2		PR_1	PR_2	BU_1		BU_2	
F1	R1 2.40×10^{4}	R2 2.45×10^{4}	R10 3.07×10^{4}	R17 3.58×10^{4}	R4 2.66×10^{4}		R1 1.91×10^{3}	R2 1.83×10^{3}	R10 1.89×10^{3}		R17 1.95×10^{3}	
F2	R3 2.56×10^{4}	R4 2.65×10^{4}	R1 2.41×10^{4}		R6 2.80×10^{4}		R3 1.90×10^{3}	R4 1.95×10^{3}	R1 1.91×10^{3}		R6 1.96×10^{3}	
F3	R5 2.74×10^{4}	R6 2.80×10^{4}	R3 2.53×10^{4}		R8 2.91×10^{4}	R18 3.65×10^{4}	R5 1.80×10^{3}	R6 1.96×10^{3}	R3 1.90×10^{3}		R8 1.94×10^{3}	R18 1.88×10^{3}
F4	R7 2.82×10^{4}	R8 2.95×10^{4}	R5 2.73×10^{4}	R18 3.64×10^{4}	R19 3.71×10^{4}		R7 1.85×10^{3}	R8 1.94×10^{3}	R5 1.80×10^{3}	R18 1.88×10^{3}	R19 1.85×10^{3}	
F5	R9 3.04×10^{4}	R10 3.07×10^{4}	R2 2.45×10^{4}	R17 3.58×10^{4}	R12 3.26×10^{4}	R20 3.82×10^{4}	R9 1.71×10^{3}	R10 1.87×10^{3}	R2 1.78×10^{3}	R17 1.58×10^{3}	R12 1.85×10^{3}	R20 1.90×10^{3}
F6	R11 3.19×10^{4}	R12 3.21×10^{4}	R9 3.02×10^{4}	R20 3.81×10^{4}	R14 3.35×10^{4}		R11 1.92×10^{3}	R12 1.84×10^{3}	R9 1.97×10^{3}	R20 1.67×10^{3}	R14 1.97×10^{3}	
F7	R13 3.30×10^{4}	R14 3.36×10^{4}	R11 3.12×10^{4}		R16 3.53×10^{4}		R13 1.86×10^{3}	R14 1.97×10^{3}	R11 1.92×10^{3}		R16 1.80×10^{3}	
F8	R15 3.46×10^{4}	R16 3.54×10^{4}	R13 3.32×10^{4}		R21 3.86×10^{4}		R15 1.88×10^{3}	R16 1.80×10^{3}	R13 1.86×10^{3}		R21 1.79×10^{3}	

V.COMPARATIVE ANALYSIS OF DISCOVERED SYSTEM

In order to assess performance of suggested method, comparative analysis is carried out with [26]. Reference method uses direct short circuit current signal (Isc) to calculate PSM and Top which contain high pass and loss pass content noise signal. This leads to increases in operating time of relay [24]. In Proposed Method instead of using fault current value (Isc) directly, feature extraction in signal is carried out with the help of DWT. It also omits the problem of window magnitude for time–frequency analysis. Value of PSM ultimately operating time of Relay is optimized then for further

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process optimized value of operating time of relay (Top) is pass through genetic Algorithm to select best pair of backup relay , if primary protection fails. The elaborated comparisons of results obtained using discovered method with ref [26] is shown in fig-5.

Average value of CTD 1 is 0.070487 and CTD 2 is 0.27349. It very well may be Noticed that all the CTD esteems are equivalent to or more prominent than 0.2 sec and all the Backup Relays are working before the primary relay. It implies that the relay settings are working precisely.

Table IV CTD values for Grid connected mode in primary and backup Protection

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}	0.003
F5	t_{2-9}0.00811	t_{17-9} 0.1128	t_{20-10}	2.0
F6	t_{9-11}0.0077	t_{20-11}0.108	t_{14-12}	0.0014
F7	t_{11-13} 0.00252		t_{16-14}	0.0072
F8	t_{13-15} 0.00156		t_{21-16}	0.004

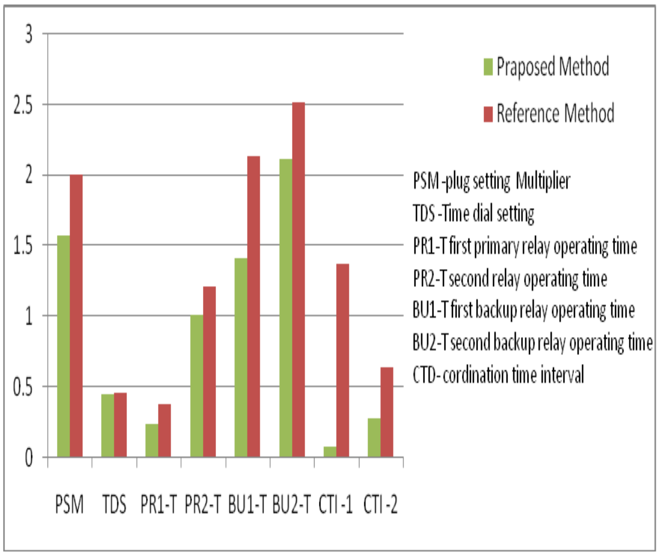

Fig 5:-comparison chart of proposed and reference method

VII. CONCLUSION

This paper proposed a DWT based differential Algorithm Access for the discovery of failure and choice of a relay pair of primary protection. In the event, if primary protection flops back up protection actuate with less working time. To check the execution of proposed strategy CTD comparison is proceed. The investigation and result exhibited in this paper plainly demonstrate that expulsion of noisy sign from short circuit current with DWT before sending to relay reduces the working time of relay consequently Effective relay coordination. It has been discovered that the DWT based element extraction can successfully expel the excess accessible in time-space information and henceforth adequately ready to diminish the working Time. The proposed method additionally has the potential and ability to execute for on-line genuine applications with greater reliability and security. Various kinds of faults can be tried with the same methodology.

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