ISSN (Online) 2395-2717

International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol 3, Issue 3, March 2017

Optimal Coordination of Dual Setting Directional Overcurrent Relays for Microgrid Protection

[1] Srinivas STP [2] K. Shanti Swarup
[1] [2] Departmenl of Electrical Engineering
IIT Madras

Abstract: — **Utilization of Renewable Energy Resources (RES) at the consumer neighbourhood resulted in self reliable power system operation.Distributed Generation (DG) supported distribution systems can be operated intact with the main grid or can be operated independently. Such a system can be termed as a microgrid. The feasibility of microgrid operation make its protection more complex. One of the profound challenges faced by the power engineers in designing a working microgrid system is relay coordination. Directional overcurrent relays (DOCRs) are economical and feasible protective means in subtransmission and meshed distribution system.However, in the microgrid scenario, the relay coordination problem becomes a complex issue due to varied system operation viz. grid connected and islanded modes. This paper suggests a solution to relay coordination problem in microgrids by using dual setting overcurrent relays. Unlike conventional DOCRs which rely on two settings TMS and PS only in forward direction, dual setting DOCRs operate in accordance to four relay setting of TMS and PS both in forward and reverse directions, thus provide more flexible relay settings. This work presents such a problem which is formulated as a nonlinear constrained optimization problem and solved using hybrid GANLP approach.**

I. INTRODUCTION

Increasing concerns of global warming due to extensive burning of fossil fuels led to utilization of renewable energy generated at the load end using Distributed Generation (DG). This resulted in autonomous operation of distribution system which accommodates both loads and generation side-by-side with or without relying on the main power system. These self-reliable distribution systems are called microgrids. Microgrid operation not only has the advantages like autonomous operation, efficient usage of low voltage renewable power generation, but also makes the power system protection more complex[1]. Because, existance of DGs in distribution side vary the magnitude and direction of short circuit currents. One of the major protection problems faced by the power engineers in planning a reliable power system is relay coordination. Because, proper relay coordination will prevent most of the faults on the power line.

When DGs are connected in distribution system look similar to interconnected transmission system. For such systems, directional overcurrent relays will ensure efficient protection and proper coordination. Extensive research has been done on protection coordination problem in the past few decades. Trial and error method and topological methods are used in initial days for protection coordination. After the advent, numerical optimization techniques were widely used and chosen as primal choice by the research engineers to find the optimal relay settings by minimizing the overall operating time. Linear Programming techniques [2]-[5] like Simplex, dual Simplex etc., and nonlinear programming techniques like MINLP [6] have been applied to find the optimal relay settings. Also, in recent past natural inspired optimization algorithms like Evo-lutionary Programming (EP), Genetic Algorithms (GA) [7],[8] Differential Evolution [9], [10], Particle Swarm Optimization (PSO) etc., have also been used in solving the optimal relay co- ordination problem.[11],[12] have reported a hybrid GA-NLP optimization techniques which utilizes the advantages of both GA and NLP techniques to find the global optimum. In [12] GA is used to find the initial values of Time Multiplier Setting (TMS) and Plug Setting (PS) of the DOCRs and the initial value is used in NLP method to achieve the global optimum thus improving the convergence. In microgrids, different DGs contribute to different fault current magnitudes. Conventional Synchronous Generators (CSGs) contribute more fault current than Inverted-based DGs (IBDGs) [13]. To mitigate the

ISSN (Online) 2395-2717

International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol 3, Issue 3, March 2017

impact of high fault currents due to CSGs, fault current limiters (FCLs) are connected in series thus achieving optimal relay coordination for both modes of microgrid operation[14]. In [15] a new protection scheme is proposed by using dual setting overcurrent relays for microgrid protection and the relay coordination problem is solved with new set of backup relays using NLP method. Though results show good reduction in overall relay operation time with dual setting DOCRs when compared with conventional DOCRs, the initial value to NLP method should be extensively varied in order to achieve the global optimum and convergence is time expensive. This paper utilizes the hybrid GA-NLP method discussed in [11],[12] to solve the relay coordination problem for the microgrid protection using dual setting DOCRs in which the initial value for NLP is obtained by running limited generations of GA, thus achieving the global minimum effectively.

II. DUAL SETTING DIRECTIONAL OVERCURRENT RELAYS

Directional Overcurrent Relays (DOCRs) are widely used in primary protection for sub-transmission and distribution system and in secondary protection for transmission system.

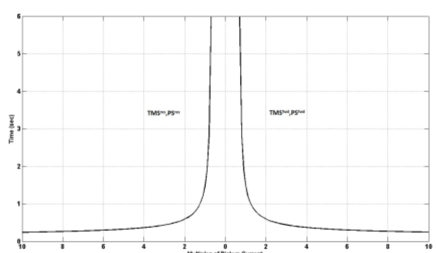

Fig. 1: Relay Characteristics of dual setting DOCR

For mesh connected systems, DOCR is an attractive option as the fault currents are of bidirectional nature. A DOCR has two settings viz. Time Multiplier Setting (TMS) and Plug Setting (PS) which determine its characteristics. These settings are found by optimally minimizing the overall operating time of the relay while satisfying the coordination constraints. On the other hand, a dual setting DOCR is guided by four settings called forward TMS, forward PS, reverse TMS and reverse PS. Fig. 1 shows the characteristics of the dual setting DOCR. When a particular relay is operating as primary relay its operation is guided by forward TMS and forward PS whereas when operating as backup relay it trips according to reverse TMS and reverse PS settings. Thus dual setting DOCRs provides more flexible operational capability when compared with conventional DOCRs by operating in different regions for primary and backup protections rather than a single zone.

III. OPTIMAL RELAY COORDINATION PROBLEM FORMULATION USING DUAL SETTING DOCRS

The optimal relay coordination problem is formulated to find the optimal values of TMS and PS of dual setting DOCRs both in forward and reverse direction with an objective of minimizing the overall time of operation. From the time- current characteristics of a dual setting DOCR, the operating time of DOCR in forward and reverse directions is given as follows:

$$t_{ij}^{fwd} = \frac{a(TMS_{ij}^{fwd})}{\left(\frac{I_{Fij}^{fwd}}{PS_i^{fwd}}\right)^b - 1} \quad (1)$$

$$t_{kj}^{rvs} = \frac{a(TMS_{kj}^{rvs})}{\left(\frac{I_{Fkj}^{rvs}}{PS_k^{rvs}}\right)^b - 1} \quad (2)$$

where, i is the relay number, j is the fault location identifier, a and b are constants based on the type of DOCR selected. Here a and b are taken to be 0.14 and 0.02 respectively. In (1) TMSfwd ij and PSfwd i are the TMS and PS settings of ith relay for a fault jth location and in (2) TMSrvs kj and PSrvs k are the TMS and PS settings for the kth backup relay for a fault at jth location. The backup relays operatein the reverse region of their time-current characteristics.Ifwd Fij andIrvs Fkj are the fault currents sensed by ith primary and kth backup relays respectively. The objective function for the optimization problem is defined as follows:

$$min \ T = \sum_{M=1}^{2} \sum_{i=1}^{N} (t_{ij}^{fwd} + \sum_{k=1}^{K} t_{kj}^{rvs}) \quad \forall \ (i,k) \ \in \ \Omega \ (3)$$

where is the set of all primary and backup relay pairs, N is the total number of relays, K is the number of backup relays for an ith primary relay, k is the backup relay identifier and M holds the number for mode of microgrid operation. Since microgrid can be operated in grid connected and islanded modes M can take values 1 and 2. The values for tfwd ij and trvs kj can be obtained from equations (1) and (2). Each dual setting DOCR is operated with four settings i.e. TMSfwd ij ,TMSrvs kj

International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol 3, Issue 3, March 2017

,PSfwd I and PSrvs k . So, the objective function is solved for 4N variables for N number of relays.This objective function is minimized by satisfying certain number of constraints which are given below.

A. Coordination Constraints

For sucessful coordination of DOCRs, the backup relay is allowed to operate only in instances where primary relay fails to operate. So, there should be a minimum time intervel for which the backup relay holds to allow the primary relay to operate. This time gap is called Coordination Time Interval (CTI). The CTI usually varies between 0.2 to 0.5. In the present work 0.3 is taken for CTI. The coordination constraint is given below,

$$t_{kj}^{rvs} - t_{ij}^{fwd} \geq CTI \quad \forall\ i, k, j \qquad (4)$$

B. Bounds on operating time of the relay

The performance of the relay in terms of speed should neither be too fast nor be too slow. Hence a constraint is imposed on the relay on its operational speed which is mathematically formulated as,

$$t_i^{min} \leq t_{ij} \leq t_i^{max} \qquad (5)$$

where tmin i and tmax i are the minimum and maximum operating times of ith relay and tij is the actual operating time of ith relay for jth fault location.

C. Bounds on TMS and PS

The value of TMS and PS of the relay directly affect its operating time which puts bounds on their values, given by,

$$TMS_{ij}^{fwd} \geq TMS_{ij}^{min}, \quad TMS_{kj}^{rvs} \leq TMS_{kj}^{max} \quad (6)$$

$$PS_i^{fwd} \geq PS_i^{min}, \quad PS_k^{rvs} \leq PS_k^{max} \qquad (7)$$

With the above stated constraints, the relay coordination problem converts into a highly constrained nonlinear optimization problem which is solved by using hybrid GA-NLP method.

IV. SYSTEM UNDER STUDY AND SIMULATION SETUP

The optimal relay coordination problem using dual setting DOCRs is studied on modified distribution portion of IEEE 30 bus system as shown in Fig. 2 which is part of American Electric Power System[16]. The distribution part of the system comprises of 14 buses and 16 feeders and is supplied with three 132/33 KV, 50 MVA transformers. Conventional Synchronous Generators(C S) of 10 MVA capacity, unity power factor are used as DGs which are connected to the system via 480/33 KV transformers at each bus. There are totally 29 dual setting DOCRs connected in the system.Short cirtcuit and loadflow studies are carried out on the system and midline bolted three phase faults are considered for the relay coordination. The relay coordination process is performed in two modes of microgrid operation, i.e., grid connected and islanded modes and optimal values of TMS and PS for both forward and reverse directions are found for each relay in each mode. For islanded operation the 33/132 KV transformers (connected at 2,8 and 12) are disconnected and it is assumed that all DGs will supply the total demand in the system during islanding.

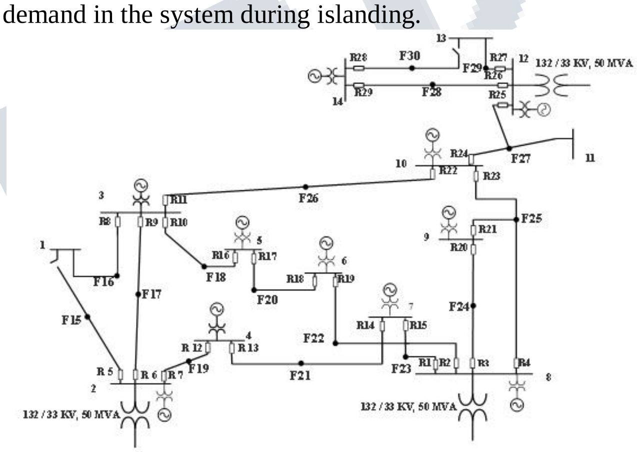

Fig. 2: Modified distribution system portion of IEEE 30 bus system

V. GA-NLP METHOD

The relay coordination problem in present work is solved by using hybrid Genetic Algorithm-Nonlinear Programming (GANLP) Method. Genetic Algorithm is nature inspired search method which is, philosophilcally, based on Darwin’s theory of ”Survival of the Fittest”. GA is widely used to solve complex problems in the field of optimization. Like any other optimization algorithm, the GA starts with some initial solution and like other optimization algorithms it terminates with a stopping criterion. But, in between, the GA runs through a different path to find the optimum. The GA works through the process of selection, cross over, mutation and replacement to achieve the optimum solution.These are discussed below.

A. Selection

When the GA starts, a random set of initial solutions are generated. In binary GA, each initial solution is encoded into binary format, called gene and all such genes are arranged in a string called chromosome. 'n' such chromosomes are generated in the inital process, called population. Among the generated population not all solutions are good in the sense of giving optimum fitness (optimum objective function value). So, among the available population good pupils are selected and bad pupils are discarded. This process is called selection.

B. Cross over

The chosen pupils of the initial population by selection process are made to participate into cross over. Cross over is the process of recombining the parts of two or more parental chromosomes to create new, possible better solutions called offspring.

C. Mutation

While cross over is made on two or more parental chromosomes, mutation is applied locally by modifying the solution. In binary GA, mutation is achieved by randomly choosing a location on the offspring chromosomes with a mutation probability pm and flipping the bit at that particular location.

D. Replacement

The offspring generated by selection, cross over and mutation replace the parental chromosomes. Again, there are many methods available in replacement like elitist replacement, steady state replacement etc. The flow chart for GA is shown in Fig 4. The relay coordination problem with objective function given in (3) and constraints (4) to (6), is said to be NLPP. In the present work, this NLPP is solved by 'fmincon' function available in the optimization toolbox of MATLAB. The initial solution to the NLPP is obtained by running certain number of iterations of GA and for GA the constraints (4) and (5) are handled by using penalty method. The constraints (6) and (7) are incorporated as upperbound and lower bound of the variables, which are given as input to NLPP and also incorporated while generating initial solution in GA. Fig 3. shows the flow chart of GA-NLP method.

TABLE I: OPTIMAL TMS AND PS SETTINGS USING Conventional DOCRS

Relay	TMS(s)	PS(p.u)	Relay	TMS(s)	PS(p.u)
1	0.4278	0.1938	16	0.431	0.4092
2	0.4294	0.2443	17	0.1220	0.1582
3	0.202	0.5777	18	0.4529	0.4892
4	0.3180	0.2313	19	0.4592	0.2304
5	0.1376	0.1524	20	0.4169	0.5768
6	0.3086	0.4989	21	0.4890	0.1417
7	0.3055	0.5435	22	0.4075	0.2204
8	0.1031	0.2716	23	0.3588	0.2764
9	0.3369	0.4970	24	0.3557	0.4119
10	0.1941	0.4233	25	0.3165	0.5828
11	0.3808	0.2268	26	0.4890	0.0747
12	0.4592	0.4719	27	0.4012	0.1064
13	0.1925	0.1922	28	0.2318	0.0532
14	0.1204	0.1914	29	0.2035	0.0746
15	0.4733	0.2360			

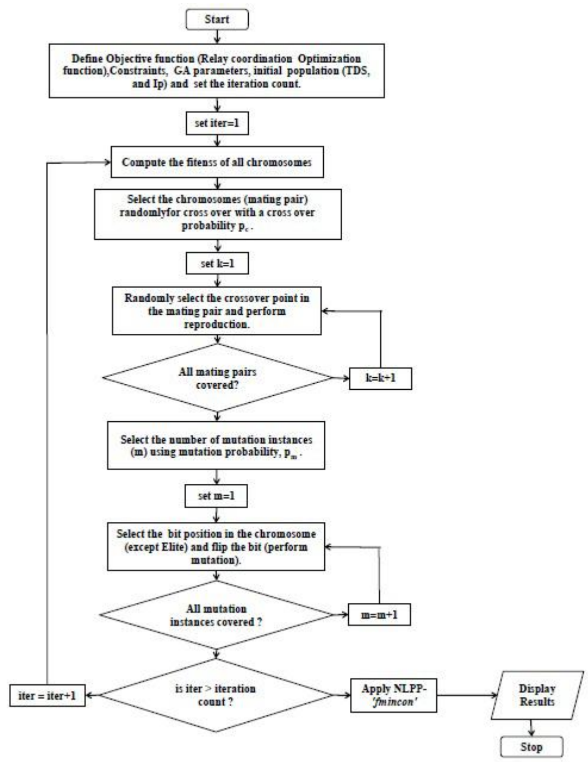

Fig. 3: Flow chart for GA-NLP implementation

VI. RESULTS AND ANALYSIS

The IEEE30 system is tested with both conventional and dual setting DOCRs. In Conventional scheme, for fault F15, R5 is the primary relay and R5 is backed up by R9 and R12 relays whereas, in dual setting scheme, for fault F15, R6 and R7 are back up relays for R5. Similarly the primarybackup relay pairs are set for other fault locations. The system is tested for both Islanded and Grid Connected modes with synchronous

DGs connected in order to achieve optimal relay coordination using one group of settings, i.e, TMS and PS settings for each relay, for both modes. Thus, the objective function is formulated with 2N variables, N being number of relays and subjected to the constraints (4)-(7). Table I shows the optimal operating times for normal DOCRs for various faults in Grid Connected mode and Table II shows the operating times of the relays in Islanded mode. In two modes, the optimal coordination could not be achieved with satisfying all the constraints. In Table I For a fault F18 the operating times of R16 and R18 are 0.621s and 0.510s respectively. This means that R18 cannot be coordinated with R16 in clearing the fault at F18. Similarly, there are many such miscoordinations recorded for faults F18, F19,F22, F24 and F25 as shown in Table II. Similarly in Table II, for Islanded mode the optimal coordination was not achieved with satisfying all the constraints. Miscoordination events are recorded for faults like F19,F20,F22,F23,F24,F25 and F27. The total relay operating times for Grid Connected mode is 78.61 sec and that for Islanded mode is 87.29 sec. The relay operating times in grid.

TABLE II: RELAY OPERATING TIMES USING CONVENTIONAL DOCRS-GRID CONNECTED MODE

Fault Location	Relay Operating times in sec.,p= primary,b= backup p	b1	b2	b3	b4
F15	R5 0.6587	R9 1.3679	R12 1.4385	-	-
F16	R8 0.3959	R6 1.0707	R16 0.9914	R22 1.0178	-
F17	R6 0.6656 R9 0.5256	R12 1.2688 R16 0.8834	- R22 0.9318	- -	- -
F18	R10 0.5449 R16 **0.6214**	R6 0.8918 R18 **0.5107**	R22 1.0163 -	- -	- -
F19	R7 **0.8798** R12 **0.8460**	R9 **0.8104** R14 **0.3552**	- -	- -	- -
F20	R17 0.3265 R18 0.4495	R10 0.6856 R2 0.7569	- -	- -	- -
F21	R13 0.5793 R14 0.3198	R7 1.1021 R1 0.6496	- -	- -	- -
F22	R2 0.5998 R19 **0.7568**	R15 1.0956 R17 **0.3695**	R20 2.0039 -	R21 1.8103 -	R23 1.0354 -
F23	R1 0.5492 R15 **0.6910**	R19 1.1669 R13 **0.6519**	R20 1.5620 -	R21 1.4405 -	R23 0.8955 -
F24	R3 0.2001 R20 **0.8252**	R15 0.9497 R23 **0.8031**	R19 1.1428 -	R21 0.8464 -	R23 0.8031 -
F25	R4 0.6067 R21 **0.8252** R23 0.75216	R15 1.0023 R25 **0.8031** R11 1.14133	R19 1.2312 - -	R20 1.0027 - -	- - -
F26	R11 0.7676 R22 0.7063	R6 1.689 R4 1.1847	R16 1.2509 R21 1.1385	- R25 1.2058	- -
F27	R24 0.6860 R25 0.6464	R4 1.3015 R29 0.9788	R11 1.2406 -	R21 1.2473 -	- -
F28	R26 0.5403 R29 0.5409	R24 1.0549 -	- -	- -	- -
F29	R27 0.3996	R24 0.9956	R29 2.9261	-	-
F30	R28 0.2423	R26 0.7396	-	-	-

connected mode are less than those of islanded mode because of less fault current levels in islanded mode when compared with the former. The respective TMS and PS values are shown in Table III. Table IV and Table V shows the optimal relay operating times for Grid Connected and Islanded modes while dula setting DOCRs are used in the system. Successful relay coordination is obtained with all satisfied constraints with dual setting DOCRs. The miscoordinations recorded in conventional scheme as shown in Table II and III for various faults have been satisfied in case of dual settting scheme

TABLE III: RELAY OPERATING TIMES USING CONVENTIONAL DOCRS-ISLANDED MODE

Fault Location	Relay Operating times in sec.,p= primary,b= backup p	b1	b2	b3	b4
F15	R5 0.2261	R9 1.5174	R12 1.5123	-	-
F16	R8 0.2708	R6 1.3214	R16 1.3789	R22 1.2072	-
F17	R6 0.6736 R9 0.7371	R12 1.3545 R16 1.247	- R22 1.0990	- -	- -
F18	R10 0.4174 R16 0.8906	R6 0.9290 R18 1.4463	R22 1.2213 -	- -	- -
F19	R7 0.6912 R12 **0.9787**	R9 1.0465 R14 **0.2911**	- -	- -	- -
F20	R17 0.2118 R18 **1.1191**	R10 0.5434 R2 **0.9256**	- -	- -	- -
F21	R13 0.3049 R14 0.2569	R7 0.8890 R1 0.7909	- -	- -	- -
F22	R2 0.7517 R19 **0.8304**	R15 1.1181 R17 **0.25205**	R20 1.6999 -	R21 1.5539 -	R23 1.0642 -
F23	R1 0.5492 R15 **0.6910**	R19 1.1669 R13 **0.6519**	R20 1.5620 -	R21 1.4405 -	R23 0.8955 -
F24	R3 0.6827 R20 **0.87104**	R15 1.1239 R23 **0.8434**	R19 1.4176 -	R21 1.3316 -	R23 0.9275 -
F25	R4 0.6914 R21 **0.7412** R23 0.7898	R15 1.0355 R25 **0.5567** R11 1.2306	R19 1.1587 - -	R20 1.0954 - -	- - -
F26	R11 0.7406 R22 0.7978	R6 1.1368 R4 1.4414	R16 1.7643 R21 1.1697	- R25 2.1989	- -
F27	R24 0.9063 R25 **1.0955**	R4 1.4280 R29 **0.9788**	R11 1.3089 -	R21 1.2499 -	- -
F28	R26 0.8202 R29 0.3355	R24 1.3227 -	- -	- -	- -
F29	R27 0.75561	R24 1.2646	R29 1.1426	-	-
F30	R28 0.3487	R26 1.1753	-	-	-

as given in Table V and VI. Table IV shows the optimal

IFERP
connecting engineers... developing research

ISSN (Online) 2395-2717

International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol 3, Issue 3, March 2017

TMSfwd,TMSrvs,PSfwd and PSrvs settings of the dual settting DOCRs. The overall operating times in Grid Connected mode and Islanded mode are 31.56 sec and 35.34 sec. It can be observed that the overall operating times are reduced by 59.8% and 59.5% and overall reduction of 59.6% is achieved. Since dual setting DOCRs can operate with different settings in forward and reverse directions, their settings can be optimally set more flexibly as compared with the conventional DOCRs and reduced operating times are achieved.

TABLE IV: OPTIMAL TMS AND PS SETTINGS USING DUAL SETTING DOCRS

Relay	Forward		Reverse		Relay	Forward		Reverse	
	TMS (s)	PS (p.u)	TMS (s)	PS (p.u)		TMS (s)	PS (p.u)	TMS (s)	PS (p.u)
1	0.117	0.2469	0.2868	0.1836	16	0.1165	0.4055	0.2112	0.4055
2	0.1	0.2093	0.2319	0.2447	17	0.1540	0.1190	0.2957	0.119
3	0.1015	0.4704	0.2478	0.4704	18	0.154	0.119	0.2537	0.119
4	0.125	0.2190	0.1497	0.2899	19	0.101	0.2447	0.2767	0.2093
5	0.1301	0.1519	0.3965	0.1523	20	0.1	0.4717	0.2116	0.4704
6	0.1	0.4758	0.1673	0.4758	21	0.1	0.2134	0.2757	0.1346
7	0.1	0.4684	0.1738	0.4684	22	0.108	0.2174	0.1711	0.2174
8	0.1207	0.235	0.1427	0.2543	23	0.1157	0.1694	0.2293	0.1694
9	0.1	0.4758	0.1841	0.4758	24	0.1	0.2715	0.1061	0.4681
10	0.1	0.4055	0.1798	0.4055	25	0.1	0.3251	0.5	0.3251
11	0.112	0.2174	0.1987	0.2268	26	0.1298	0.0744	0.2192	0.0744
12	0.1	0.4684	0.2026	0.4684	27	0.1191	0.1051	0.4482	0.1087
13	0.1309	0.1909	0.2564	0.1909	28	0.1669	0.0293	0.4012	0.03
14	0.1309	0.1909	0.2577	0.1909	29	0.112	0.0747	0.2544	0.0744
15	0.1412	0.1836	0.3139	0.1836					

VII. CONCLUSION

This work presented optimal relay coordination for microgrid systems with both grid connected and islanded modes using dual setting DOCRs. The incapability of conventional DOCRs in optimally coordinating for highly meshed systems is shown and the problem is overcome using dual setting DOCRs. The coordination procedure is tested on modified distribution part of IEEE30 bus system with synchronous DGs connected at each bus. Having different relay characteristics in forward and reverse operations, dual setting DOCRs have successfully coordinated each other achieving no constraint violations and overall operating times have reduced significantly in latter case.

REFERENCES

[1] R.H. Lasseter , “Microgrids“, Power Eng. Soc. winter meeting, IEEE, 2002,Vol.1, pp.305-308.

[2] P. P. Bedekar, Bhide, S.R., Kale, V.S., , “Optimum time coordination of overcurrent relays in distribution system using Big-M (penalty) method“, WSEAS Transactions on Power Systems, vol. 4, pp. 341-350, 2009.

[3] P. P. Bedekar, Bhide, S.R., Kale, V.S., , “Optimum coordination of overcurrent relays in distribution system using dual simplex method“,2009 2nd International Conference on Emerging Trends in Engineering and Technology, ICETET 2009, pp. 555-559.

[4] P. P. Bedekar, Bhide, S.R., Kale, V.S., , “Determining optimum TMS and PS of overcurrent relays using linear programming technique“,ECTICON 2011-8th Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI) Association of Thailand Conference, 2011, pp. 700-703.

[5] P. P. Bedekar, Bhide, S.R., Kale, V.S., , “Optimum time coordination of overcurrent relays using two phase simplex method“,World Academy of Science, Engineering and Technology, vol. 52, pp. 1110-1114, 2009.

[6] J. Gholinezhad, Mazlumi, K., Farhang, P. , “Overcurrent relay coordination using MINLP technique“,2011 19th Iranian Conference on Electrical Engineering, ICEE 2011.

[7] D. K. Singh, Gupta, S. , “Optimal coordination of directional overcurrent relays: A genetic algorithm approach,“,2012 IEEE Students’ Conference on Electrical, Electronics and Computer Science: Innovation for Humanity, SCEECS 2012.

[8] P. P. Bedekar, Bhide, S.R., Kale, V.S., , “Optimum coordination of overcurrent relays in distribution system using genetic algorithm,“, International Conference on Power Systems, ICPS ’09 2009.

[9] R. Thangaraj, Pant, M., Deep, K. “Optimal coordination of over-current relays using modified differential evolution algorithms,“,Engineering Applications of Artificial Intelligence, vol. 23, pp. 820-829, 2010.

[10] V. Rashtchi, Gholinezhad, J., Farhang, P. , “Optimal coordination of overcurrent relays using Honey Bee Algorithm,“,in 2010 International Congress on Ultra Modern Telecommunications and Control Systems and Workshops, ICUMT 2010, pp. 401-405.

IFERP
connecting engineers... developing research

ISSN (Online) 2395-2717

International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol 3, Issue 3, March 2017

[11] A. S. Noghabi, Sadeh, J., Mashhadi, H.R. , "Considering different network topologies in optimal overcurrent relay coordination using a hybrid GA,"IEEE Transactions on Power Delivery, vol. 24, pp. 1857-1863, 2009.

[12] P. P. Bedekar, Bhide, S.R. , "Optimum coordination of directional overcurrent relays using the hybrid GA-NLP approach,"IEEE Transactions on Power Delivery, vol. 26, pp. 109-119, 2011.

[13] P. Barker, R. De Mello , "Determining the impact on distributed generation on power systems.I. Radial distributed systems."IEEE Power. Eng. Soc. Summer Meeting,,pp. 1645-1656, 2000.

[14] Waleed K.A.Najy, H. H. Zeineldin and Wei Lee Woon, "Optimal protection coordination for microgrids with grid connected and islanded capability,"IEEE Transactions on Industrial Electronics, vol.60, no.4, April 2013., vol.60, no.4, April 2013.

[15] H.H.Zeineldin, H.M.Sharaf, D.K.Ibrahim and E.E. Abou El Zahab, "Optimal Protection Coordination for Meshed Distribution Systems with DG using Dual Setting Directional Overcurrent Relays,"IEEE Transaction on Smart Grid,vol.6, no.1, pp. 115-123, January 2015.

[16] Univ. Washington, Power Systems Test Case Archive, Seattle, WA. Mar.2006 [Online]. Available: http://www.ee.washington.edu/research/

[17] MATLAB Optimization Toolbox. Natick, MA.

TABLE V: RELAY OPERATING TIMES USING DUAL SETTING DOCRS-GRID CONNECTED MODE

Fault Location	Relay Operating times in sec.,p= primary,b= backup				
	p	b1	b2	b3	b4
F15	R5 0.1969	R6 0.8351	R7 0.5459	-	-
F16	R8 0.2596	R9 0.5772	R10 0.5596	R11 0.5596	-
F17	R6 0.1882 R9 0.1720	R7 0.4882 R10 0.5027	- R11 0.5118	- -	- -
F18	R10 0.1879 R16 0.2311	R9 0.4879 R17 0.5311	R11 0.5587 -	- -	- -
F19	R7 0.2100 R12 0.1787	R6 0.5300 R13 0.4787	- -	- -	- -
F20	R17 0.2317 R18 0.2269	R16 0.5318 R19 0.5269	- -	- -	- -
F21	R13 0.2224 R14 0.2224	R12 0.5224 R15 0.5224	- -	- -	- -
F22	R2 0.1699 R19 0.1699	R1 0.5877 R18 0.4699	R3 1.0280 -	R4 0.5909 -	- -
F23	R1 0.1788 R15 0.2101	R2 0.5113 R14 0.5300	R3 0.8177 -	R4 0.4788 -	- -
F24	R3 0.1824 R20 0.1801	R1 0.5106 R21 0.4801	R2 0.4993 -	- -	- -
F25	R4 0.2384 R21 0.1637 R23 0.2137	R1 0.5384 R20 0.4637 R12 0.5137	R2 0.5814 - R24 0.5137	R3 0.5384 - -	- - -
F26	R11 0.2049 R22 0.1999	R9 0.5763 R24 0.5454	R10 0.6926 R23 0.5	- -	- -
F27	R24 0.2000 R25 0.2000	R22 0.5586 R26 0.5000	R23 0.5317 -	- -	- -
F28	R26 0.2000 R29 0.1726	R25 0.5095 -	- -	- -	- -
F29	R27 0.1874	R25 0.4874	R26 1.4910	-	-
F30	R28 0.2365	R29 0.5365	-	-	-

IFERP
connecting engineers... developing research

ISSN (Online) 2395-2717

International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol 3, Issue 3, March 2017

TABLE VI: RELAY OPERATING TIMES USING DUAL SETTING DOCRS-ISLANDED MODE

Fault Location	Relay Operating times in sec.,p= primary,b= backup p	b1	b2	b3	b4
F15	R5 0.2063	R6 0.7443	R7 0.5797	-	-
F16	R8 0.2801	R9 0.782	R10 0.5801	R11 0.5801	-
F17	R6 0.2194 R9 0.2194	R7 0.5194 R10 0.5256	- R11 0.5276	- -	- -
F18	R10 0.2088 R16 0.2432	R9 0.5542 R17 0.5487	R11 0.5870 -	- -	- -
F19	R7 0.2181 R12 0.2181	R6 0.5181 R13 0.5181	- -	- -	- -
F20	R17 0.2453 R18 0.2416	R16 0.5634 R19 0.5634	- -	- -	- -
F21	R13 0.2334 R14 0.2334	R12 0.5609 R15 0.5624	- -	- -	- -
F22	R2 0.1670 R19 0.1758	R1 0.6077 R18 0.4758	R3 0.9200 -	R4 0.5892 -	- -
F23	R1 0.1952 R15 0.2187	R2 0.5403 R14 0.5187	R3 0.7810 -	R4 0.4955 -	- -
F24	R3 0.2036 R20 0.2008	R1 0.5455 R21 0.5021	R2 0.5402 -	- -	- -
F25	R4 0.2664 R21 0.1723 R23 0.2174	R1 0.5664 R20 0.5261 R12 0.5360	R2 0.5664 - R24 0.5174	R3 0.6162 - -	- - -
F26	R11 0.2111 R22 0.2050	R9 0.6752 R24 0.6294	R10 0.7410 R23 0.5218	- -	- -
F27	R24 0.2190 R25 0.2615	R22 0.5694 R26 0.5615	R23 0.5422 -	- -	- -
F28	R26 0.2154 R29 0.1860	R25 0.6626 -	- -	- -	- -
F29	R27 0.2036	R25 1.5934	R26 1.2373	-	-
F30	R28 0.2499	R29 0.6049	-	-	-