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Designing a Protection Scheme in Micro-Grid Systems with DG Using Central Protection Unite and Multiple Setting Group Protection Relays

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Abstract

Distributed generators now is widely used in electrical power networks, in some cases it works seasonally, and some types works at special weather conditions like photo voltaic systems and wind energy, and due to this continuous changes in generation condition, the fault current level in network will be affected, this changes in fault current level will affect in the coordination between protection relays and to keep the coordination at right way, an adaptive protection system is required that can adaptive its setting according to generation changes, the fault current level in each case is evaluated using ETAP software, and the required relay setting in each case is also evaluated using Grey Wolf Optimizer (GWO) algorithm, and to select suitable setting which required in each condition, to select the active setting group of protection relay according to generation capacity, central protection unite can be used, and to improve protection stability and minimizing relays tripping time, a proposed method for selecting suitable backup relay is used, which leads to decrease relays tripping time and increase system stability, output settings for relays in all cases achieved our constrains.

Keywords

Directional Overcurrent Relay, Protection Coordination, Distributed Generators, Central Protection Unite, Multiple Setting Group Protection Relay

1. Introduction

Due to the increase of using DG in power networks and the diversity in renewable energy resources, new optimal protection relay settings need to be considered in order to keep power system stability [1].

Some types of DG can be used according to loading conditions, it can be used at summer only or at rush hours, also some types can work at daylight like PV systems; therefore, protection system should be adaptive to generation condition and should be flexible to system status.

When a micro-grid is connected to power network, the configuration is changed to a complicated multi-source power system, fault currents and fault levels need to be recalculated and power ratings of protection equipment's should be rearranged accordingly, the protection of microgrid should be in such a way that a safe and secure protection is provided in both grid-connected and stand-alone operation modes [2] [3].

Modern multifunction digital relays have a number of features, which make them an ideal choice for interconnection protection of dispersed generators. The most important of these features are user-selectable functionality, self-diagnostics, communications capabilities and Oscillo graphic monitoring [4].

A multiple setting group protection relay has the ability to change setting locally with selector or remotely through communication system, as it has the ability to move between up to eight different setting groups [5].

Central protection units communicate with every network component such as breaker status and relay setting and each new connection/disconnection is reported to it. Therefore, Central control unites have the ability to extract the current state of the network, list the connected entities and choose a proper relay setting [6].

The optimum settings of DOCRs need to be determined for all groups. Here, the major task is to obtain values of TMS of DOCRs suitable for proper protection coordination under all the topologies considered in each group. This can be done by considering all the primary-backup relay pairs of all the topologies of a group so that the obtained optimum values of TMS can coordinate properly in these topologies [7].

2. Microgrid Central Protection Unite

Microgrid Central Protection Unit (MCPU) communicates with every single relay and distributed generator in the microgrid. The communication with relays is necessary to update the operating currents of the relays and to detect the direction of fault currents and thus isolate the fault properly. DGs, on the other hand, are monitored to follow their status and include/disregard their fault contribution if they are ON/OFF, respectively [3].

MCPU is used in some studies to be responsible of calculation of tripping currents, time delays (optional) and updating of relay operating point [8] and [2], On the other side, in another study, the programmable scheme logic in modern multifunctional protective relays is used, it's an extremely powerful tool that allows the user to adapt the relay logic to very different applications or to change system conditions [9], while in our study all tripping currents and time delay at different operating cases will be stored in relay at different setting group, MCPU will choose optimal setting group needed according to generation capacity.

Our proposed MCPU shown in Figure 1 doesn't need to be updated with system current and voltage, just it will supervise if any change happens in circuit breakers status, if any change is noticed in system, MCPU will send signal to all DOCRs and select suitable setting group to be activated in such case.

With the wide use of optic fiber communication in distribution grid, it is practicable to achieve MCPU logic for microgrid [10].

One of the most important advantages in our proposed MCPU, all relays will be restored to default setting group, in case of communication fail between MCPU and relays or breakers and in case of any fault happed, relay will send trip signal to breaker.

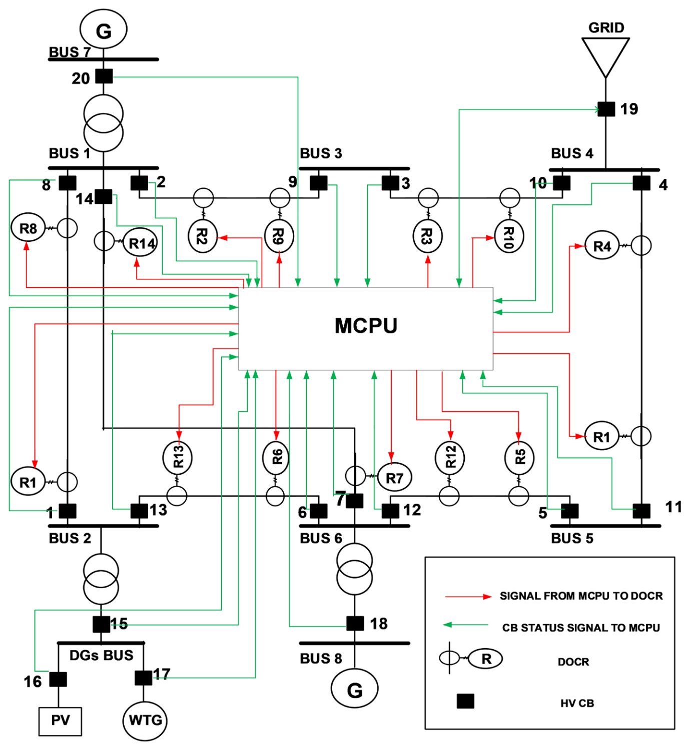

Figure 1. Micro grid central protection unite.

3. Protection Relay Coordination

In order to keep the system stable under any fault condition, protection relay should isolate faulted area in the instance of fault occur, if this relay fails to operate under any condition, nearest relay to faulted zone should operate as a backup relay.

Earlier studies in directional over current relay (DOCR) coordination was using protection relay fixed with single setting group [11].

For multiple setting protection relay, the function of relay to act as primary or backup depends on the direction of fault current, each multiple setting DOCR has many sets of independent relay settings we can use one for forward direction as a primary relay and another one in reverse direction of fault current as backup relay [12].

4. Proposed and Conventional Back-Up Relay Selection

The difference in coordination between the primary back-up relay pairs for proposed and conventional back up DOCR is shown as in Figure 2.

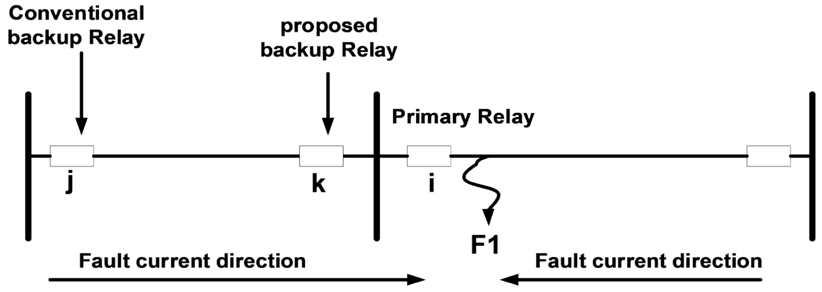

Figure 2. Primary and back-up relays of distribution system.

Figure 2 shows apart of IEEE 8-bus system, in case of occurrence of a fault at the point f1, the relay (i) acts as primary relay which should operate to isolate the fault, if this relay fails to operate and after a certain time, another relay should operate as a backup relay this backup relay will be as follow:

- In case of conventional single setting DOCR the relay (j) should operate after a time delay, this time delay called coordination time interval (CTI), therefore the tripping time of relay (j) should be more than of relay (i) with this value of CTI which leads to increase total tripping time of relays
- In case of proposed multiple setting DOCR the relay (k) will switch to setting group (2) and work as a backup relay and will operate after CTI and this will keep setting group (1) for the condition of occurring fault in the zone of relay (k), in this case relay J will be primary relay.

Therefore, the reverse side of each relay is deployed as the backup relay for the next front line where in our case according to fault direction relay (k) will select setting group for forward fault current relay will work according to setting group (1) and reverse direction fault current the relay will work according to setting group (2).

To avoid the operation of relay (j), a communication link is considered to send a block signal on behalf of relay (k) reverse [13].

5. DOCR Coordination Principles Using Single and Multiple Setting Protection Relay

The operating time of inverse definite minimum time relay IDMT is obtained according to IEEE standard C37.112-1996: [14]

$$t_i = TDS_i \times \left(\frac{28.2}{\left(\frac{I_{fi}}{I_{pi}} \right)^2 - 1} + 0.1217 \right) \tag{1}$$

where

t_i The operating time of relay (i) (tipping time)

I_F The fault current passing through relay (i)

I_P The pickup current of relay (i)

TDS_i Time multiplier setting of relay (i)

The value of the pickup current of a relay (i) should be less than the minimum value of the fault current at this point [15].

Furthermore, the time dial setting TDS_i of relay i is ranged from 0.1000 to 1.1000 [16].

CTI value ranges from 0.2 to 0.3 sec. In this paper 0.2 sec value is chosen [17].

In case of using conventional DOCR our object function will be:

$$object\ function\ (J) = \sum_{i=1}^{n} t_i \quad [18]$$

In this case we need to get the optimal values of pickup current and TDS values of each relay.

While in case of using proposed multiple setting DOCR, each relay will be installed with two different setting , first one will be used at forward fault and second setting group will be used in reverse direction faults and object function will be as equation:

$$object\ function\ (J) = \sum_{i=1}^{n} \left(t_{(i\ forward)} + t_{(i\ reverse)} \right)$$

In this case the parameters which need to be optimized for each relay will be duplicated, where two values of pickup current and TDS is needed to each relay.

6. Under Study System

To study the effect of using multiple setting DOCR in micro-grid systems IEEE 8-bus test system is used, and in order to clarify our study, two different types of distributed generator (DG) is connected at bus-2, first is photo voltaic (PV) system and second is wind turbine generator (WTG) as shown in **Figure 3**.

All data of our studied IEEE 8-bus test system which shown in **Figure 4** taken from [19], the data for proposed DGs available at [20].

To get the value of maximum short circuit current sensed at each relay on the system, system is simulated using Etap software as shown in **Figure 5**, for simplicity the values of pickup current of each relay is considered constant and taken from [14].

Grey Wolf Optimizer (GWO) [21] algorithm is developed using MATLAB software to achieve optimal TDS values.

7. Study Methodology

IEEE 8-bus system is simulated using Etap software, our study will be concentrated only under three different cases shown in **Table 1** and **Figure 3**.

Case-1 CB-15 is opened, which means no DGs is connected at bus-2.

Case-2 CB-15 is closed, CB-16 is closed and CB-17 is opened, in this case PV system connected at bus-2.

Case-3 CB-15 is closed, CB-16 is opened and CB-17 is closed, in this case WTG system connected at bus-2.

For the three different cases the maximum fault current sensed by each relay is calculated with ETAP and the results is shown in Table 2, moreover the conventional and proposed backup relays also considered in study as in Table 3.

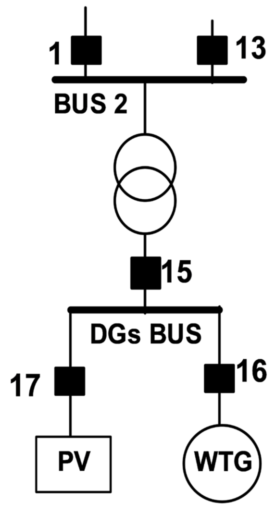

Figure 3. DGs connected at bus-2 of IEEE 8-bus test system.

Table 1. IEEE 8-bus system study cases.

CB	Case-1	Case-2	Case-3
CB-15	open	close	close
CB-16	open	close	open
CB-17	open	open	close
System	Without DGs	PV connected	WTG connected

Table 2. Maximum fault current for IEEE 8-bus system for different casees.

Primary Relay	Fault current (A)			Conventional Back-up relay	Proposed Back-up relay	Fault current(A)		
	Case-1	Case-2	Case-3			Case-1	Case-2	Case-3
1	3232	3508	4171	6	13	3232	3232	3232
8	6177	6244	6454	9	2	1160	1173	1215
8	6177	6244	6454	7	14	1903	1956	2124
2	6020	6201	6761	1	8	1003	1113	1522
9	2467	2511	2614	10	3	2467	2511	2614
2	6020	6201	6761	7	14	1903	1956	2124
3	3547	3653	3899	2	9	3547	3653	3899
10	3874	3951	4119	11	4	2335	2411	2579
6	6195	6254	6446	5	12	1193	1205	1243
6	6195	6254	6446	14	7	1887	1935	2089

Continued

13	2988	3264	3927	8	1	2988	2988	2988
14	5277	5418	5852	9	2	1160	1173	1215
7	5302	5448	5908	5	12	1193	1205	1243
14	5277	5418	5852	1	8	1003	1130	1522
7	5302	5448	5908	13	6	994	1129	1551
4	3772	3843	4001	3	10	2233	2303	2461
11	3703	3816	4085	12	5	3703	3816	4085
5	2385	2425	2521	4	11	2385	2425	2521
12	5990	6178	6754	13	6	994	1129	1551
12	5990	6178	6754	14	7	1887	1935	2089

Table 3. Conventional and proposed backup relays for IEEE 8-bus system.

Primary relay no.	Conventional Backup relay no.	Proposed Backup relay no.
1	6	13
2	1	8
2	7	14
3	2	9
4	3	10
5	4	11
6	5	12
6	14	7
7	5	12
7	13	6
8	9	2
8	7	14
9	10	3
10	11	4
11	12	5
12	13	6
12	14	7
13	8	1
14	9	2
14	1	8

8. Results and Discussion

GWO algorithm used to get optimal TDS value for each relay at different cases and the result TDS values in case of using conventional backup relays is shown in

Table 4, while in case of using proposed backup relay, every relay will be installed with two different TDS per case, which means every relay will be installed with 6 six different setting groups as in Table 5, while in conventional backup relay only three setting group needed per relay because same value of TDS will be used in case of primary and backup protection.

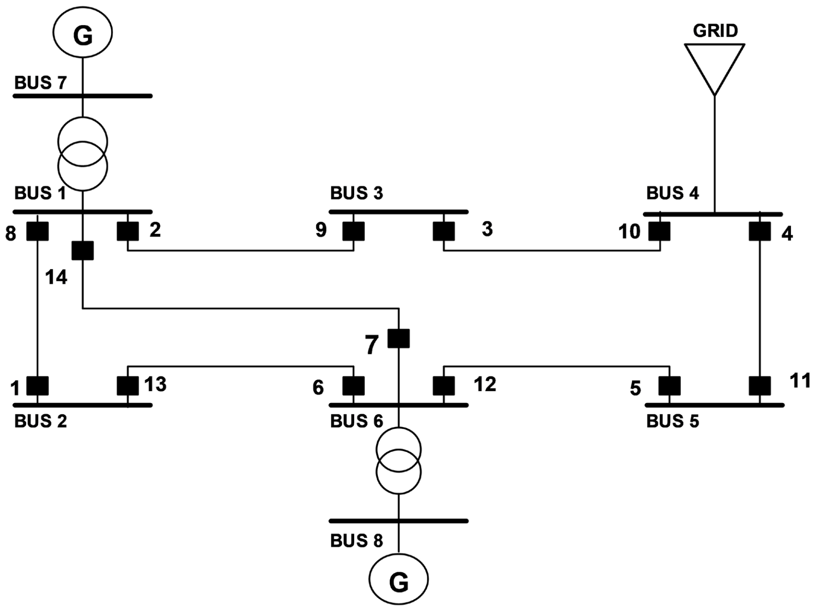

Figure 4. IEEE 8-bus test system.

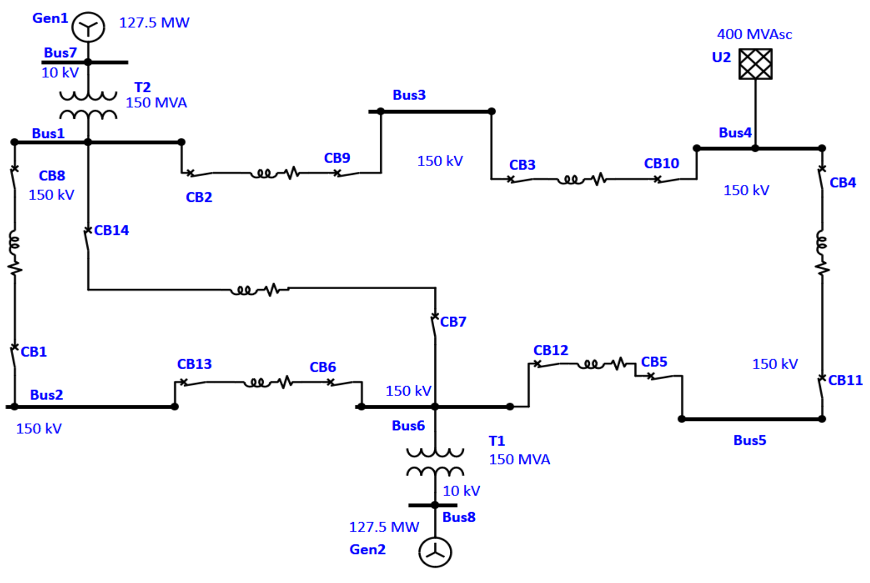

Figure 5. IEEE 8-bus test system simulation using ETAP.

Using the TDS values from Table 4 and Table 5, the value tripping time for primary and backup relays is calculated in case of conventional and proposed backup relays at the three different cases and shown in Table 6 and Table 7.

From Table 6, it can be noted that primary relays tripping time in case of using proposed backup relay is less than its values when using conventional backup relay, as in Table 6 trip time is reduced by 33, 35 and 37% for case-1, case-2 and case 3 respectively, which increases system performance in decreasing total tripping time.

Table 4. IEEE 8-bus test system tds values using gwo with conventional backup relays.

Relay no.	TDS value		
	Case-1	Case-2	Case-3
1	0.10001	0.10003	0.10002
2	0.21702	0.23003	0.2615
3	0.22237	0.23439	0.2626
4	0.10896	0.11113	0.11634
5	0.1	0.10001	0.1
6	0.38496	0.36599	0.33468
7	0.10451	0.11259	0.13145
8	0.35545	0.33329	0.29986
9	0.1	0.10001	0.1
10	0.29295	0.29778	0.30944
11	0.1776	0.18802	0.2122
12	0.55267	0.58186	0.64994
13	0.1	0.1	0.10001
14	0.10011	0.10003	0.10042
Relay setting group	Setting group (1)	Setting group (2)	Setting group (3)

Table 5. Tds of relays for IEEE 8-bus test using gwo with proposed back up relays.

Relay no.	Case-1		Case-2		Case-2	
	Primary	Backup	Primary	Backup	Primary	Backup
1	0.1001	0.2531	0.1002	0.23812	0.10038	0.21432
2	0.1009	0.1	0.1005	0.1	0.11239	0.1
3	0.1006	0.2929	0.1032	0.62354	0.10007	0.30954
4	0.1001	0.1	0.1	0.1	0.10001	0.10002
5	0.1	0.3272	0.1	0.33918	0.10004	0.36934
6	0.141	0.1	0.1076	0.1	0.10206	0.10002
7	0.1017	0.1001	0.1001	0.1	0.10004	0.1
8	0.1001	0.1	0.1203	0.1	0.15043	0.1
9	0.1	0.2838	0.1001	0.29716	0.10001	0.32195
10	0.1011	0.2144	0.1001	0.22422	0.10985	0.24681

Continued

11	0.1002	0.1988	0.1001	0.20206	0.10001	0.21029
12	0.1181	0.1	0.1028	0.1	0.10169	0.1
13	0.1001	0.278	0.1001	0.26386	0.10007	0.2412
14	0.1017	0.1001	0.1001	0.10001	0.10072	0.1
Relay setting group	Setting group (1)	Setting group (2)	Setting group (3)	Setting group (4)	Setting group (5)	Setting group (6)

9. Docr Setting Group Control Using Mcpu

Now, after getting the optimal TDS values for all relays, every relay will be programmed with six setting groups in case of using proposed backup relay method, or three different setting groups in case of using conventional backup relay method.

MCPU in Figure 1 is used to supervise the CBs condition as in table I, and upon this condition, MCPU will chose suitable setting group, and make it active through communication link with all relays, the proposed protection system with logical nodes and data sets can be provided by IEC 61850-7-420 [12].

Figure 6 shows flow chart of our study in case of using proposed backup relay method, MCPU will keep connected with system until detecting any change of CB15, CB16 and CB17, and upon this change it will change setting group according to Table 5.

Table 6. Primary relays tripping time for IEEE 8-bus system.

Relay NO.	Case-1		Case-2		Case-3	
	Conventional	**proposed**	**Conventional**	**proposed**	**Conventional**	**proposed**
1	0.1128	0.1128	0.0971	0.0973	0.0717	0.0720
2	0.1364	0.0634	0.1377	0.0601	0.1365	0.0586
3	0.1541	0.0697	0.1547	0.0812	0.1557	0.0593
4	0.1579	0.1450	0.1554	0.1399	0.1507	0.1296
5	0.2027	0.2027	0.1960	0.1960	0.1814	0.1815
6	0.1180	0.0432	0.1109	0.0326	0.0978	0.0298
7	0.0509	0.0495	0.0526	0.0468	0.0546	0.0415
8	0.1093	0.0307	0.1012	0.0365	0.0875	0.0439
9	0.1894	0.1894	0.1829	0.1829	0.1690	0.1690
10	0.1755	0.0605	0.1729	0.0581	0.1681	0.0596
11	0.1566	0.0883	0.1572	0.0837	0.1577	0.0743
12	0.1766	0.0377	0.1789	0.0316	0.1800	0.0281
13	0.1306	0.1307	0.1107	0.1108	0.0795	0.0796
14	0.0785	0.0798	0.0750	0.0750	0.0661	0.0663
Total trip time	1.9507	1.3041	1.8841	1.2199	1.7572	1.0938

Table 7. Backup relays tripping time for IEEE 8-bus system.

Conventional back-up	Proposed back-up	Case-1		Case-2		Case-3	
		TRIP TIME (SEC) Conventional back-up	TRIP TIME (SEC) Proposed back-up	TRIP TIME (SEC) Conventional back-up	TRIP TIME (SEC) Proposed back-up	TRIP TIME (SEC) Conventional back-up	TRIP TIME (SEC) Proposed back-up
1	8	1.583	0.944	1.167	0.725	0.531	0.353
2	9	0.354	0.270	0.354	0.268	0.355	0.259
3	10	0.358	0.345	0.355	0.340	0.350	0.329
4	11	0.402	0.402	0.396	0.396	0.381	0.381
5	12	0.966	0.613	0.941	0.598	0.868	0.556
6	13	0.313	0.313	0.297	0.297	0.272	0.272
7	14	0.338	0.617	0.343	0.578	0.337	0.478
8	1	0.332	0.330	0.311	0.311	0.280	0.280
9	2	1.042	2.569	1.011	2.464	0.921	2.170
10	3	0.389	0.389	0.382	0.801	0.369	0.369
11	4	0.375	0.387	0.372	0.361	0.368	0.312
12	5	0.356	0.288	0.357	0.283	0.357	0.274
13	6	1.628	0.967	1.122	0.700	0.508	0.339
14	7	0.630	0.329	0.593	0.312	0.498	0.265
Total Trip Time		9.066	8.763	7.961	8.439	6.402	6.642

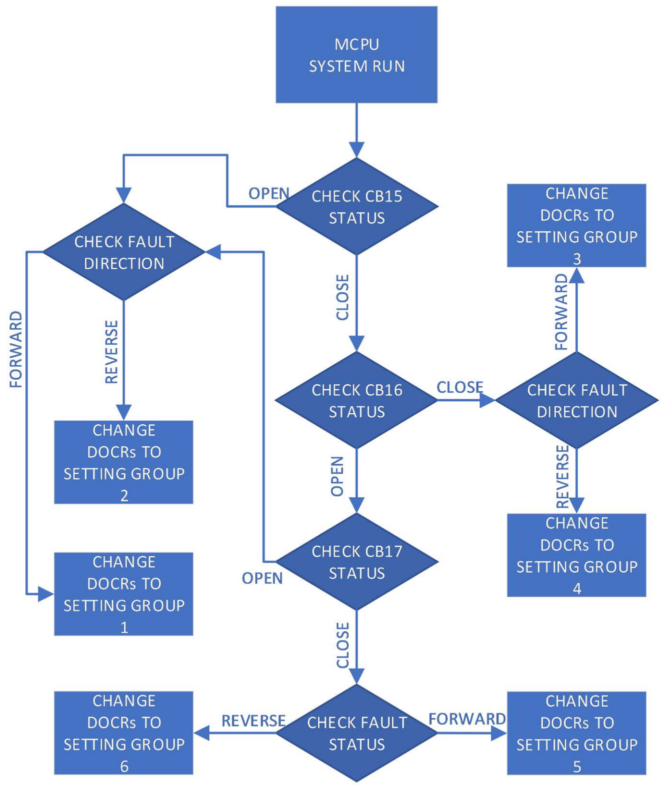

Figure 6. IEEE 8-bus test system protection control using MCPU.

10. Conclusions

This paper presented effect of using MCPU in microgrid, in case of connecting DGs, MCPU monitor system status and changes relay setting group according to generation capacity, while in case of taking fault current direction in our consideration, a proposed backup relay will be useful in decreasing relays tripping time.

ETAP software is used to evaluate fault current which sensed at each relay, while MATLAB software is used to implement GWO algorithm which is used to get optimal TDS value for each relay.

The value of CTI between primary and backup relay in each case is found to be more than 0.2 sec, which achieves selectivity in our proposed protection system.

It's found that MCPU is important in case of presence DGs in system, MCPU will keep relay coordination and protection stability at right way even if changing fault current due to DGs connecting in microgrid.

Our proposed MCPU was designed with simple rules which doesn't require a special system memory or data processing unite, sense it depends only on a simple logic in changing relay setting group according to DGs connection in microgrid.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Zeineldin, H.H., Sharaf, H.M., Ibrahim, D.K. and Abou El-Zahab, E.E.-D. (2014) Optimal Protection Coordination for Meshed Distribution Systems with DG Using Dual Setting Directional Over-Current Relays. *IEEE Transactions on Smart Grid*, **6**, 115-123. https://doi.org/10.1109/TSG.2014.2357813

[2] Mirsaeidi, S., Said, D.M., Mustafa, M.W., Habibuddin, M.H. and Ghaffari, K. (2016) Fault Location and Isolation in Micro-GRIDS Using a Digital Central Protection Unit. *Renewable and Sustainable Energy Reviews*, **56**, 1-17. https://doi.org/10.1016/j.rser.2015.10.162

[3] Ustun, T.S., Ozansoy, C. and Zayegh, A. (2013) Fault Current Coefficient and Time Delay Assignment for Microgrid Protection System with Central Protection Unit. *IEEE Transactions on Power Systems*, **28**, 598-606. https://doi.org/10.1109/TPWRS.2012.2214489

[4] Mozina, C.J. (2012) Impact of Smart Grid and Green Power Generation on Distribution Systems. 2012 *IEEE PES Innovative Smart Grid Technologies* (*ISGT*), Washington, DC, 16-20 January 2012, 1-13. https://doi.org/10.1109/ISGT.2012.6175625

[5] Tziouvaras, D.A. (1990) Novel Applications of a Digital Relay with Multiple Setting Group. *Western Protective Relay Conference*, Washington DC,23-25 October 1990, 1-18.

[6] Ustun, T.S., Ozansoy, C. and Zayegh, A. (2013) Differential Protection of Microgrids with Central Protection Unit Support. *IEEE* 2013 *Tencon-Spring*, Sydney, 17-19 April 2013, 15-19. https://doi.org/10.1109/TENCONSpring.2013.6584408

[7] Alam, M.N., Chakrabarti, S. and Pradhan, A.K. (2022) Protection of Networked Microgrids Using Relays with Multiple Setting Groups. *IEEE Transactions on Industrial Informatics*, **18**, 3713-3723. https://doi.org/10.1109/TII.2021.3120151

[8] Ustun, T.S., Ozansoy, C. and Zayegh, A. (2013) Modeling and Simulation of a

Microgrid Protection System with Central Protection Unit. *IEEE* 2013 *Tencon-Spring*, Sydney, 17-19 April 2013, 5-9. https://doi.org/10.1109/TENCONSpring.2013.6584406

[9] Piesciorovsky, E.C. and Schulz, N.N. (2017) Comparison of Programmable Logic and Setting Group Methods for Adaptive Overcurrent Protection in Microgrids. *Electric Power Systems Research*, **151**, 273-282. https://doi.org/10.1016/j.epsr.2017.05.035

[10] Xu, M., Meng, T., Zou, G., Zhang, J., Lin, X. and Yang, J. (2015) A Centrealized Protection and Control Scheme for Microgrid. 2015 *IEEE PES Asia-Pacific Power and Energy Engineering Conference* (*APPEEC*), Brisbane, 15-18 November 2015, 1-5. https://doi.org/10.1109/APPEEC.2015.7380867

[11] Adelnia, F., Moravej, Z. and Farzinfar, M. (2013) A New Formulation for Coordination of Directional Overcurrent Relays in Interconnected Networks. *International Transactions on Electrical Energy Systems*, **25**, 120-137. https://doi.org/10.1002/etep.1828

[12] Tiwari, R., Singh, R.K. and Choudhary, N.K. (2020) Optimal Coordination of Dual Setting Directional Over Current Relays in Microgrid with Different Standard Relay Characteristics. 2020 *IEEE* 9*th Power India International Conference* (*PIICON*), Sonepat, 28 February-1 March 2020, 1-6. https://doi.org/10.1109/PIICON49524.2020.9112883

[13] Yazdaninejadi, A., Nazarpour, D. and Golshannavaz, S. (2017) Dual-Setting Directional Over-Current Relays: An Optimal Coordination in Multiple Source Meshed Distribution Networks. *International Journal of Electrical Power & Energy Systems*, **86**, 163-176. https://doi.org/10.1016/j.ijepes.2016.10.004

[14] Liu, A. and Yang, M.-T. (2012) A New Hybrid Nelder-Mead Particle Swarm Optimization for Coordination Optimization of Directional Overcurrent Relays. *Mathematical Problems in Engineering*, 2012, Article ID: 456047. https://doi.org/10.1155/2012/456047

[15] Barker, P.P. and de Mello, R.W. (2000) Determining the Impact of Distributed Generation on Power Systems: Part 1-Radial Distribution Systems. 2000 *Power Engineering Society Summer Meeting* (*Cat. No*.00CH37134), Seattle, 16-20 July 2000, 1645-1656. https://doi.org/10.1109/PESS.2000.868775

[16] Stenane, N.M. and Folly, K.A. (2014) Application of Evolutionary Algorithm for Optimal Directional Overcurrent Relay Coordination. *Journal of Computer and Communications*, **2**, 103-111. https://doi.org/10.4236/jcc.2014.29014

[17] Godwal, S.D., Pandya, K.S., Vora, S.C., Mehta, C.R. and Rajput, V.R. (2023) Optimal Overcurrent Relay Coordination for Interconnected Power Systems: A Proper Approach and Improved Technique. *e-Prime-Advances in Electrical Engineering, Electronics and Energy*, **5**, Article 100248. https://doi.org/10.1016/j.prime.2023.100248

[18] Papaspiliotopoulos, V., Kurashvili, T. and Korres, G. (2014) Optimal Coordination of Directional Over Current Relays for Distribution Systems with Distributed Generation Based on a Hybrid PSO-LP Algorithm. *MedPower* 2014, Athens, 2-5 November 2014, 1-6. https://doi.org/10.1049/cp.2014.1697

[19] Zeineldin, H.H., El-Saadany, E.F. and Salama, M.M.A. (2006) Optimal Coordination of Overcurrent Relays Using a Modified Particle Swarm Optimization. *Electric Power Systems Research*, **76**, 988-995. https://doi.org/10.1016/j.epsr.2005.12.001

[20] Saleh, M.I., El-Saady, G., Yousef, A.M. and Ibrahim, E.-N.A. (2023) Adaptive Protection Relays Coordination in Power Networks with Connected Disturbed Generators. 2023 24*th International Middle East Power System Conference* (*MEPCON*), Mansoura, 19-21 December 2023, 1-6. https://doi.org/10.1109/MEPCON58725.2023.10462438

[21] Bouzary, H., Chen, F.F. and Shahin, M. (2019) Optimal Composition of Tasks in Cloud Manufacturing Platform: A Novel Hybrid GWO-GA Approach. *Procedia Manufacturing*, **34**, 961-968. https://doi.org/10.1016/j.promfg.2019.06.103