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Optimal Setting and Coordination of Overcurrent Relays for Improved Fault Detection and Clearance on the Rumuodomaya, Port Harcourt 11kV Distribution Network

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Abstract

In modern power system relays and circuit breakers need to be coordinated to minimize unnecessary outages, since protective relays are one of the equipment in the power system. Fault detection of any abnormal activity and protection of the area under its observation. Relays coordination is necessary to reduce unnecessary outages which must be done in a manner that the relay nearest to the point of fault operates faster, in the event of failure, before backup protection does. This paper presents optimal setting and coordination of overcurrent relays to improve fault detection and clearance on the Rumuodomaya 11KV Distribution Network in Rivers state. Calculations and simulation were realized in study. Electrical Transient Analysis Program (ETAP 20.0) was used to simulate both the setting and relay coordination studies, so as to improve on the fault detectionon coordination sequence and time of operation Genetic Algorithm (GA) toolbox embedded in MATLAB. When 3-phase fault was initiated at FGC feeder, tripping sequence violation occurred revealing a total time of operation between the primary relay and its backup as 109ms, 346ms, 494ms and 1055ms, with order of tripping from 33kV line breaker to 33kV control panel to T_1, 11kV incomer and to FGC feeder breaker respectively. Whereas, when the relay coordination were initiated the time of operation between primary relay and backup relays now increased as 144ms, 342ms, 454ms and 702ms, and it showed the right order of relay tripping coordination for FGC feeder breaker to 11kV incomer breaker to 33kV control panel breaker and to 33kV line breaker. Again, correct sequence of breaker tripping 1234 orders achieved in optimized case, the speed of operation was also improved respectively.

Keywords: Electrical Transient Analysis, Primary Relay, Algorithm, MATLAB, Backup Relay.

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INTRODUCTION

In modern times, electrical energy is a primary requirement for everyone in any nations that desires development in all ramifications[1]. It involves transporting generated electricity to the distribution network via the transmission systems. From the creation of electrical transmission, sub-transmission, and distribution networks, the protection system of these networks was a vital task to accomplish. The sub- transmission and distribution sections protection play important role in maintaining the quality and reliability of the power systems, which are often disturbed. Disturbances can be a form of short circuit, overload, lightning surge, bad weather etc., which may result in disruption of continuity of operation, damage to the electrical system, and injury or death of operators [2]. In order to avert or minimize the negative effects of the disturbances. The operator should ensure proper relay coordination between the primary and back up relays maintaining a specific time interval to allow their proper sequence of operation, discrimination and selectivity, thereby preventing unnecessary trips from being made by the healthy part of the network. This implies that electrical faults must be cleared as soon as possible to prevent power system equipment damage and human injury [3]. But due to various factors such as increasing load on a feeder and aged protection equipment, then, setting protection scheme can be less accurate. To ensure accurate setting and coordination of protection relays, an appropriate method of optimization have to be introduced to help protection engineers to design more reliable and efficient systems by setting up the operation time of the backup relay, so in case of mal-operation of the primary relay, the backup could isolate the fault immediately in accordance with the condition of equipment installed and the current load [4]. This reason arouses the interest for this research to carry out optimization of relay coordination on the test case power system using Genetic Algorithm (GA). This will assist in ensuring the protection of personnel and equipment by establishing suitable interrupting ratings of the protective device.

Related Works

Numerous researches have been done using different approaches or techniques to improve or optimize relay coordination on power system network with a view to minimize unnecessary outages. The researches propose the usage of different methods such as; analytical technique, heuristic technique and evolutionary technique for optimizing the time multiplier setting of the protective relays.

According to [6], they carried out a study on protection coordination of 33/11kV power distribution substation in Iraq, with the aim to coordinate the protection scheme. To obtain time multiplier setting (TMS) and time current characteristics (TCC), CYME 7.1 software package was used for simulation.

According to [7], they presented a paper on relay coordination analysis in SPDC Forcados distribution network for operation, planning and future expansion. Both load flow study and short circuit current analysis were performed for proper selectivity. Electrical Transient Analysis Program (ETAP) software was used for the simulation.

According to [8], they carried out a study on the development of an efficient optimizer; Sigmoid Acceleration Coefficient based Chaotic Search Class Topper Optimization (SACCTO), which is met heuristic for optimal overcurrent relay coordination in power distribution system. To validate the effectiveness of the proposed algorithm, three types of distribution networks are examined for optimal relay coordination problems.

According to [9], they proposed an optimal coordination of directional overcurrent relays using Hybrid Firefly-Genetic Algorithm. The proposed algorithm was tested on the IEEE 3-bus, 8-bus, 9-bus and 15-bus networks. The result obtained shows the effectiveness of proposed time of DOCRs compared with other optimization methods.

According to [10], they proposed a study on design and analysis of power distribution system for optimum overcurrent relay coordination using voltage component of fault current limiters. Genetic algorithm (GA) was used to achieve optimal setting of overcurrent relay parameters, the reported characteristics and proposed objective function were tested on a 9-bus distribution system.

MATERIALS AND METHODS

The research materials used are the distribution line parameters such as, bus data, route length of the line. Electrical Transient Analyzer (ETAP), MATLAB and Excel Microsoft packages weresome of the material used forsimulation and analysis. Other data used were obtained from Transmission Company of Nigeria, (TCN) & Port Harcourt Electricity Distribution Company (PHED).

Table 1 : Data Used for Calculation and Simulation

S/N	Parameter	Value Assigned
1	Route length of 33kV line	5.6km
2	Maximum load on 33kV line	14.20MW
3	T_1 15MVA impedance of injection substation	10.60%
4	T_2 15MVA impedance at injection substation	10.45%
5	Peak Load on FGC 11kV Feeder	2.45MW
6	Peak load on OBIWALI 11kV Feeder	4.05MW
7	Peak load on ELIGBOLO 11kV Feeder	6.21MW
8	Peak load on Rukpokwu 11kV Feeder	1.51MW
9	Conductor size for 11kV line	150mm.sq
10	Conductor size for 33kV line	240mm.sq
11	Conductor Type	AAC
12	Base MVA	100
13	Relay Types	O/C & EF relay
14	Conductor Resistivity at 20°C	$2.65 \times 10^{-8}\Omega m$
15	33kV line spacing	3ft = 914.4mm
16	Incomer CTRs, 33kV	400/1
17	Outgoing CTRs, 11kV	1000/1

Source: Transmission Company of Nigeria & Port Harcourt Electricity Distribution Company (2023)

Equations Used for Relay Setting Calculations

Fault current through CT = $\frac{Fault\ \ current}{CT\ Raio}$ (1)

Pick up current (I_p) = $\frac{1.2*full\ \ load\ \ Current}{CT\ Raio}$ (2)

PSM = $\frac{Fault\ \ current}{Pick\ \ up\ \ current}$ (3)

The formula used to calculate the operation time in each OCR TCC using IEEE very inverse curve is;

$$\text{TDM} = \frac{\mathbf{19.61}}{[(\boldsymbol{PSM^2})-\mathbf{1}+\mathbf{0.491}]} \quad (4)$$

$$\min Z = \sum_{i=1}^{24} \frac{0.14\,(x_i)}{\left(\frac{I_{Relay}}{x_{i+24}}\right)^{0.02}-1} \quad (5)$$

Where;

I_{Relay}: is the time of the fault current through the closest relay.

In the formula, all the constraints and boundaries obtained in GA formulation are incorporated.

RESULTS AND DISCUSSION

Figure 1 and Figure 2 show the order of tripping sequence of primary relay and backup relays when FGC feeder (Bus 4) was subjected to a 3-phase fault and simulated for relay coordination studies in both existing and optimized condition. It was realized in Figure.1 that the tripping sequence was not in order of Relay 1(109ms) to Relay 2(346ms) to Relay 4(494ms) to Relay 6(1065ms). It indicates that the relays responses is wrong and violated the right order of relay coordination which supposed to be from the point of fault (primary relay) to backup relays upstream. When the relay coordination was optimized, it is was observed that the tripping sequence is in the right order of Relay 6(144ms) to Relay 4(342ms) to Relay 2(454ms) to Relay 1(702ms), indicating relays responses was proper, that is from the point of fault(primary relay) to backup relays upstream.

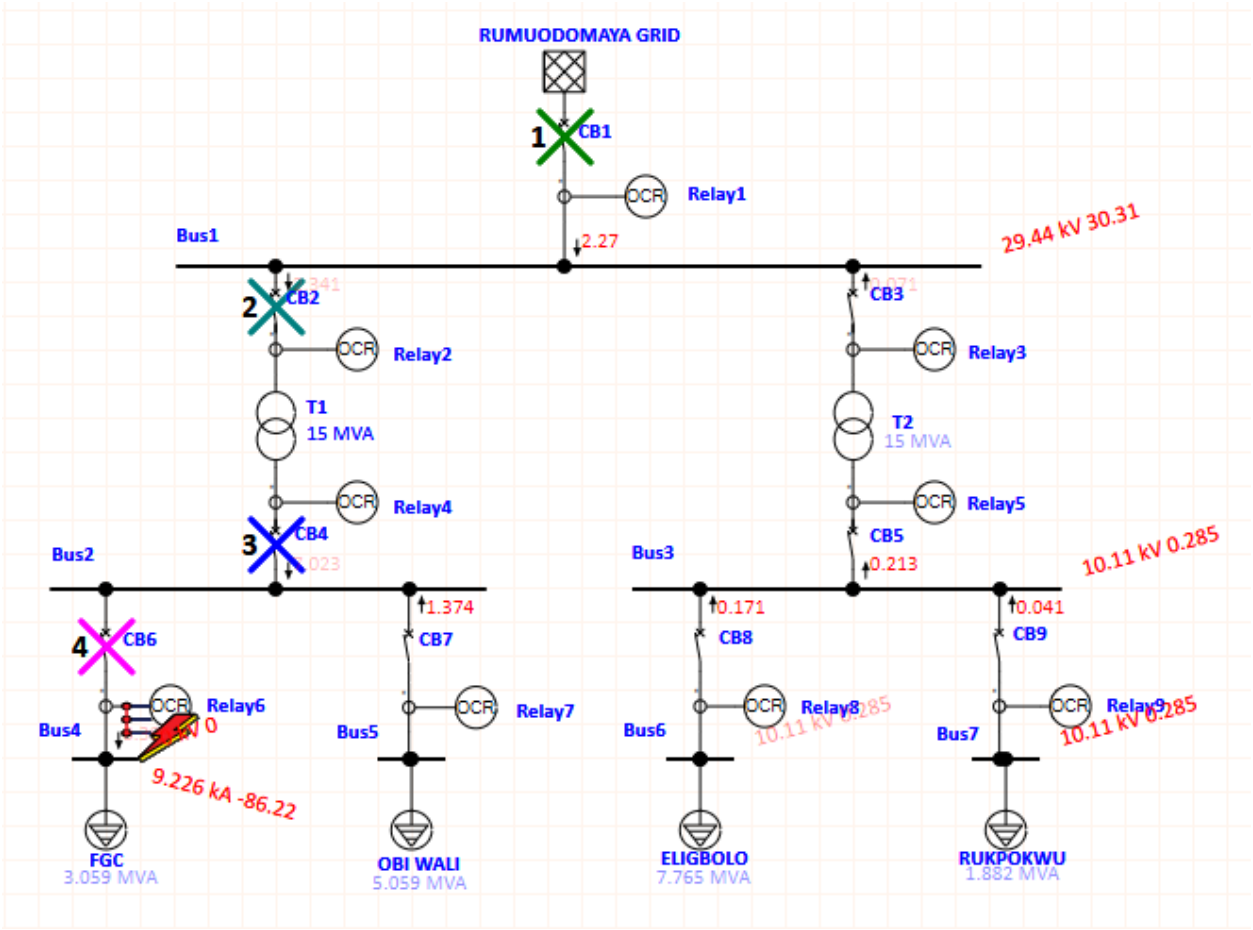


Figure 1: Simulation Diagram of Base Case for Fault on FGC Feeder

Figure 1 shows that the FGC feeder experienced a fault characterized by a high fault current of 9.226 kA and a phase angle of -86.22 degrees. In response to this fault, Circuit Breaker CB6, detected by Relay 6, would trip to isolate the FGC feeder from Bus 4. This isolation prevents the fault from affecting the entire distribution network, thereby maintaining system stability. The diagram provides essential data for understanding the fault's impact and the operation of protective devices in maintaining system integrity.

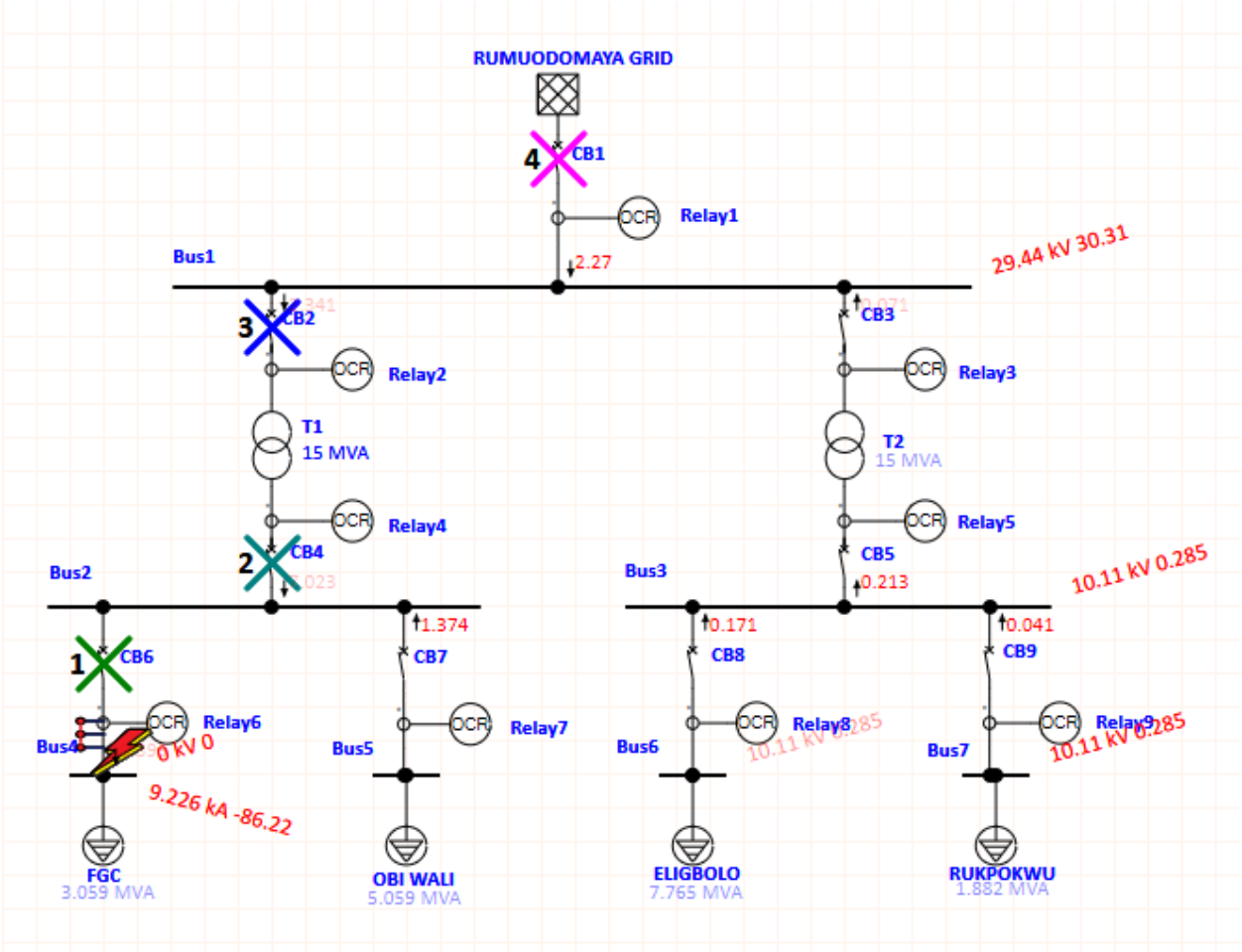


Figure 2: Simulation Diagram of Optimized Case for Fault on FGC Feeder

Figure 3 shows the comparison plot of relays and associated circuit breakers considering tripping order sequence / time versus zones in the system, when subjected to a 3- phase fault at FGC 11kV feeder for both the base case and optimized case.

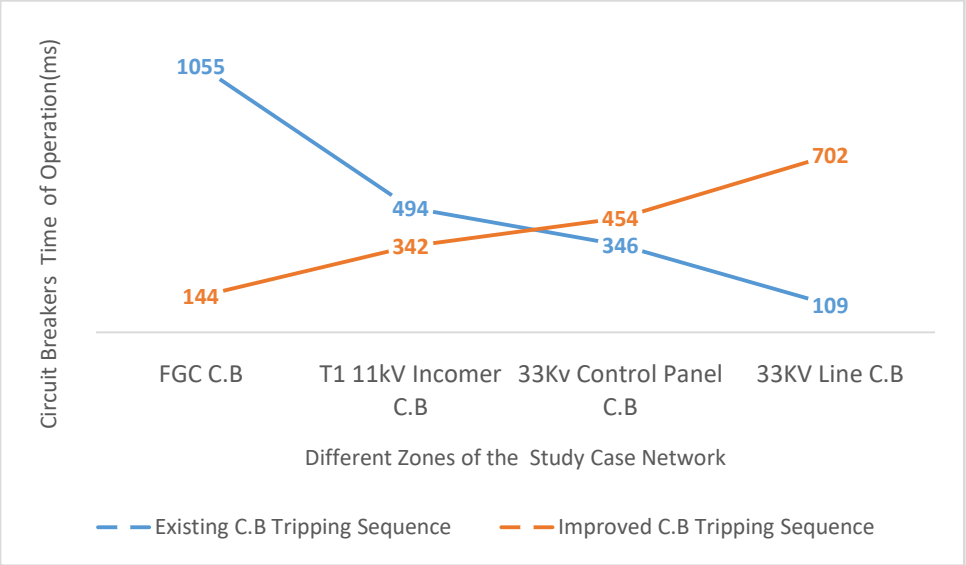


Figure 3: Plot of Sequence of Circuit Breakers Operation/ Time versus Different Zone for Fault on FGC Feeder for both Base and Optimized Cases

Figure 3 Indicates the existing case and a wrong tripping sequence of circuit breakers in the order of 4 3 2 1 at different protected zones of the network .It implies that FGC is feeder is subjected to fault, the 33kV line breaker trips first, hence, disconnecting both the faulty and healthy part of the network. But when the TDM of the relays was optimized using GA, shows the proper tripping order of the circuit breakers 1 2 3 4 was maintained. This implies that when FGC feeder is subjected to fault, the feeder breaker at the point of fault trips first and continues in the proper order upstream.

CONCLUSION

Relay coordination could help in improving power supply to the study area and increase revenue generation for the utility through customer satisfaction. In this study, the relays coordination of 11kV Rumuodomaya network was optimized using Genetic Algorithm implemented in MATLAB/ GA toolbox. Electrical Transient Analyzer Program (ETAP) was used for relay coordination simulation studies and the use of GA toolbox embedded in MATLAB, the relays TDM which was optimized using PSM as the constraint. The result obtained from the optimized case of the relay coordination indicates proper sequence of relays coordination and relays time of operation was improved upon significantly comparing with the base case.

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