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Coordination Analysis of Protection Relay Settings Utilizing Particle Swarm Optimization Method

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Abstract. Cempaka Substation becomes one of the existing electricity distribution systems in South Kalimantan. As a transmission line, a reliable protection system is required having s proper relay coordination, thus indicating thereby optimizing the electricity distribution. This study aims to navigate the value of the relay setting, optimization is required to find the optimal value for the relay setting. The optimization applied is Particle Swarm Optimization (PSO) to produce optimal values for relay settings. The calculation is conducted with the help of MATLAB software. The result of the calculation presents the value of the time dial setting (TDS) and the value of the pickup current (Ip). Furthermore, the value from the calculation results is entered into the simulation utilizing ETAP software in order to navigate the results of the protection relay setting when a disturbance occurs. The standards which are applied as references in this study include local standards or international standards such as SPLN, IEC 60947. Thus, from the research that was performed conducted, the distance between the primary relay and backup was 1.2 seconds fulfilling the standard of a reliable protection system of 0.3 seconds.

INTRODUCTION

Substation (GI) refers to one part of the electric power transmission system that acts as a transforming electric power from high voltage to low voltage or vice versa. The electrical system for the GI Cempaka substation receives electricity from the PLTU Asam-Asam, which has a capacity of 460 MW. In the distribution of electricity, it is pivotal to have a good and reliable protection system [1]. Therefore, it is pivotal to increase the reliability of the electrical system, a protection relay is required thus indicating to enable normal operation of the system. At the substation, there is a transformer, serving as an important component to increase or decrease the voltage coming from the generator. Therefore, transformer protection is deemed essential in maintaining the reliability of the electric power system.

The protection system plays a role in preventing damage to equipment from spreading, thus indicating that the electric power system can be maintained. In maintaining electrical energy to reach the customer, it is pivotal to have a protection system. One of the disturbances in the transmission system is usually due to overcurrent surges, thus indicating thatit can cause losses to the transmission system itself and losses to consumers.

The way the relay works is by ordering the Circuit Breaker (CB) to trip, thus indicating that the damage does not spread to other equipment [2]. In the relay coordination protection system, it is vital in maintaining the reliability of the system, when the setting value on the relay is improper, it generates the system disorganization and even worse, it could result in a blackout or blackout [3].

There are several previous studies related to relay settings. Research that uses the Differential Evolution (DE) [4] method which results in better relay setting values. The operating time of the relay is better than utilizing manual calculations on a radial system network. Another study uses the IEEE 8 bus distribution system [5] where this study uses conventional calculations without utilizing algorithms. In the same system, there are other studies utilizing Cuckoo Optimization, which is suitable for optimal relay coordination on an IEEE 8 bus network [6]. As for the research that uses the Modified Particle Swarm Optimization (MPSO) method [7], this research produces the best primary and secondary relay timing values. Another study applied the Fuzzy Inference System (FIS) method [8], this study resulted in a faster trip time than before. As for other studies utilizing the Adaptive Modified Firefly Algorithm method [9], this study resulted that the optimization method was able to minimize the relay setting time.

The Cempaka Substation becomes one of the existing electricity distribution systems in South Kalimantan. As a transmission line, a reliable protection system is required and has proper relay coordination, thus indicating that electricity distribution works optimally. This study aims to handle the value of the relay setting, optimization is required to find the optimal value for the relay setting. The optimization applied is Particle Swarm Optimization (PSO)

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Based on this condition, the researcher applies the Particle Swarm Optimization (PSO) method to optimize the operating time setting value of the primary relay and backup relay. Parameters that need to be optimized are the values of Time Dial Setting (TDS) and Pickup Current Setting (Ip). TDS regulates how long it takes the relay to disconnect when a fault occurs [10]. By utilizing PSO the value obtained is more optimal and faster than the evolutionary algorithm, where PSO uses a combination of local and global to find evolutionary information among individual particles [11]. It is hoped that utilizing PSO would maximize the value of the relay setting thus indicating the better reliability of the substation system.

METHODS

The parameters applied are the overcurrent value data, the short-circuit current value in each bus, and the short-circuit value in each relay. In the calculation of relay optimization utilizing the application of MATLAB 2017a software. Upon the completion of PSO optimization, the value will be entered into the power grid system with the application of ETAP 12.6.0 software.

RESEARCH BLOCK DIAGRAM

Figure 1 shows the research flowchart, it can be explained that the first step is to search for data on transformer 6, and also the relay applied at the Cempaka Substation. After getting the data and then doing a simulation utilizing ETAP 12.6.0 software. From these data, the conventional calculation process and calculations utilizing the PSO method were performed conducted with the help of Matlab 2017a software. After that, enter the calculated value utilizing the PSO method into the ETAP simulation, whether the relay moves according to the specified value, and whether the relay works better than before. If not, it is pivotal to recalculate if it meets the requirements, then an analysis of the SLD circuit is performed to discover the results before utilizing PSO and after utilizing PSO.

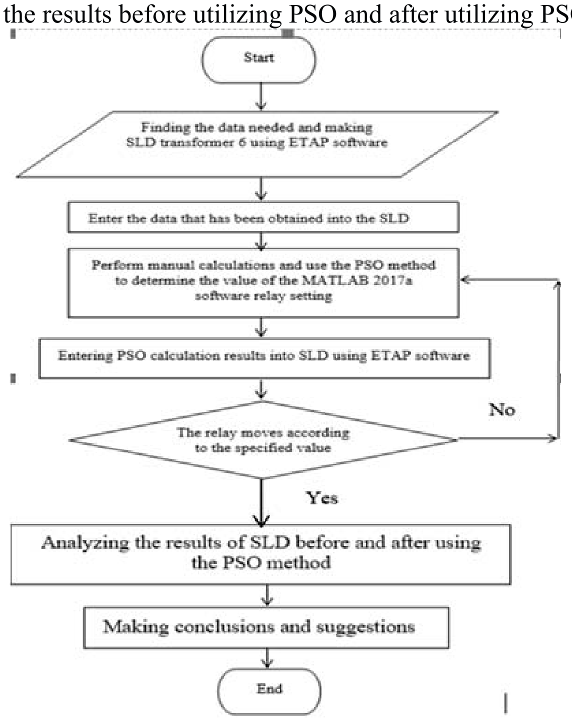


FIGURE 1. Research Flowchart of Relay Setting Analysis

DATA COLLECTION

Data collection is conducted by:

1. Observation is to collect data starting from transmission line capacity data, input data from the Cempaka 6 GI transformer generator system, and load data on transformer 6.
2. Literature Study, is conducted to search references in libraries, journals, previous theses, and internet site pages.
3. Analyzing data, is conducted to gather data from the research location and processing it, which is then performed through simulation of the system under normal conditions and when the system is experiencing disturbances.

PSO BLOCK DIAGRAM

The electrical power system on transformer 6 at the Cempaka GI is performed conducted by creating a single line diagram with the help of ETAP 12.6.0 software. The steps applied by PSO in getting a good relay operating time, the flow of the PSO program is illustrated in Figure 2.

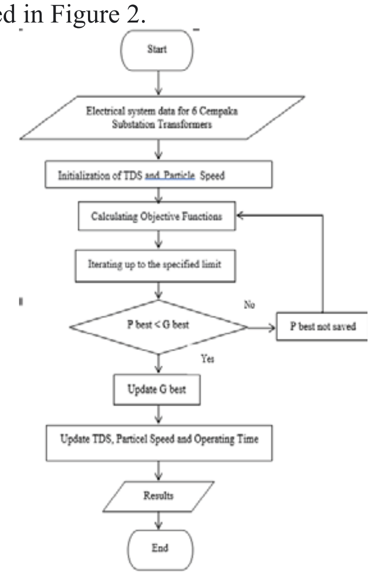


FIGURE 2. PSO Algorithm Flowchart

PSO SYSTEM DESIGN

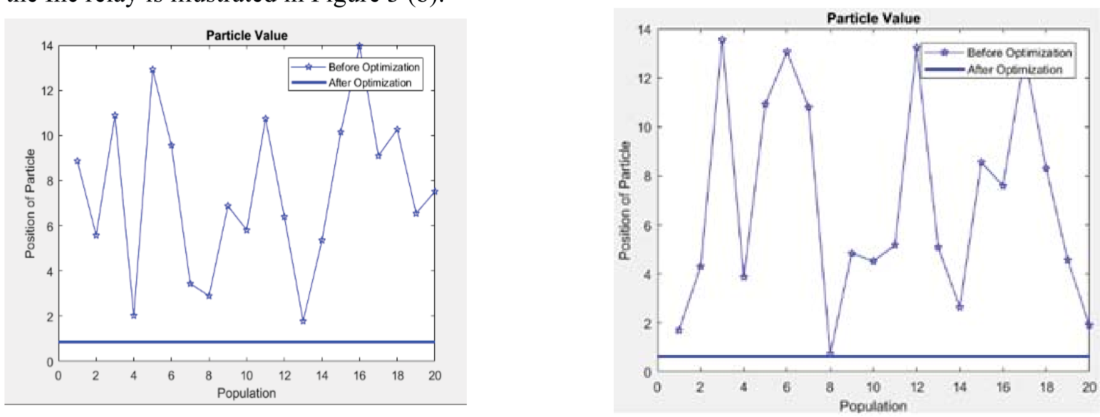
The PSO algorithm is applied to navigate a solution to the problem of setting the protection relay follows the explanation. In the first part, the step is conducted by entering data such as: FLA, short-circuit fault current of primary relay and backup relay, and CT ratio. The selected fault is a 3-phase fault. Furthermore, the initial position Xi (t) is replaced by the variable of TDS and the velocity Vi (t) of each particle. The step is progressed to perform the calculation of the objective function, further iterating on the decision section whether Pbest is less than Gbest, if so, it will update Gbest while updating the TDS value, particle velocity and operating time. Otherwise, the Pbest value is not saved and the iteration continues until achieving the iteration limit. Furthermore, after the iteration is fulfilled, the last value from Gbest, updates the TDS value. The result of this program displays the TDS and Iset values of the relay.

RESULTS AND DISCUSSION

The relay applied in the 6 GI Cempaka transformer is the Schneider brand with MICOM P141 type with serial number 36076169, with a CT ratio of 300/1. The Incoming relay uses the same brand and the same type but the serial number and CT ratio value are different, including the 36076169 series, and the CT ratio value is 2000/5.

In the research carried out, the values for the parameters of PSO are as follows: Number of Particle: 20, Number of Iterations: 100, w min: 0.4, w max: 0.9, c1: 1.5, c2: 2, Minimum TDS, 0.1, Maximum TDS is 14.

The application of the number of iterations of 100 is to perform calculations accurately, and the application of the number of particles of 20 can affect the accuracy performance. The application of the number of particles is taken from the general value applied in completing calculations with the PSO algorithm. For the value of inertia weight (w) has dynamic properties following the number of iterations. The value of the minimum TDS is various, following the minimum manual calculation process of the relay. After the parameters are entered into MATLAB, the results of the initialization of particle distribution before and after optimization can be seen, the HV relay is illustrated in Figure 3 (a) and the Inc relay is illustrated in Figure 3 (b).



(a) (b)

FIGURE 3. (a) HV Relay Particles **(b)** Inc. Relay Particles

From the convergent curve, it is illustrated that in the 0th iteration to the 35th iteration, the particle value has decreased but has not yet reached a stable point. The particles started to stabilize at the 36th iteration to the 100th iteration.

After getting the TDS and pick up values from the PSO algorithm, these values are entered into the electric power system simulation that has been made in the ETAP 12.6.0 software in order to navigate whether the setting values on the relay have met the protection system requirements

In Figure 4 the disturbance is given to bus 2, the first relay to work is the inc transformer 6 relays then the HV transformer 6 relay as a backup relay. From the results that the relay interference goes well. In this condition, it is illustrated in Figure 5 that the relay that works first is the relay closest to the disturbance. 3.4 Relay Termination Time Comparison.

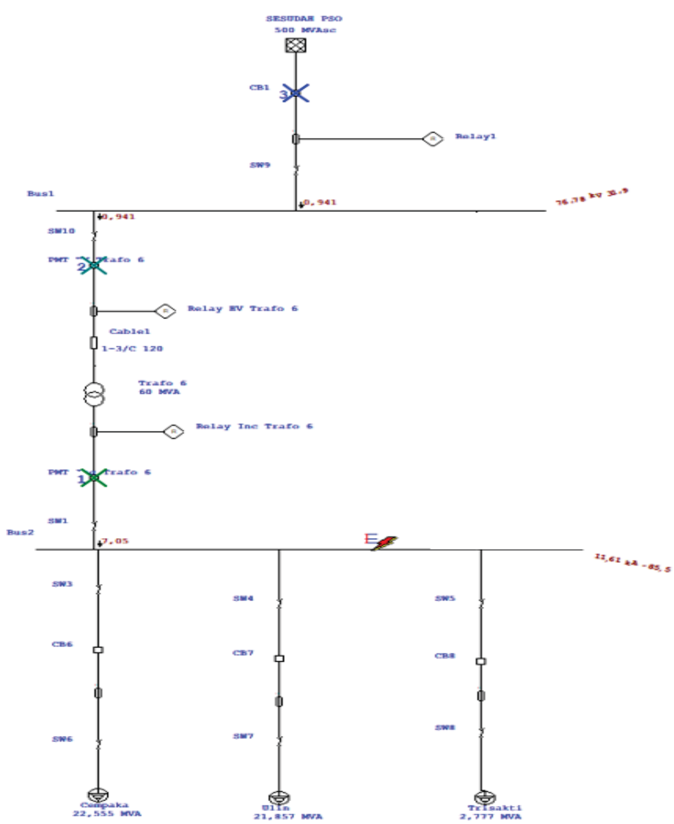


FIGURE 4. SLD Utilizing PSO

From Figure 5, it can be explained that the incoming transformer 6 relay tripped at 4.27 seconds and the current detected in the relay was 5,671 kA. While the backup relay that works is the HV transformer 6 relay trips at 4.47 times with a detected current of 0.756 kA. The trip time distance between the primary and secondary relays is 0.2. The requirement for a good protection system is 0.3 thus indicating there is no overlap between the main relay and the backup relay.

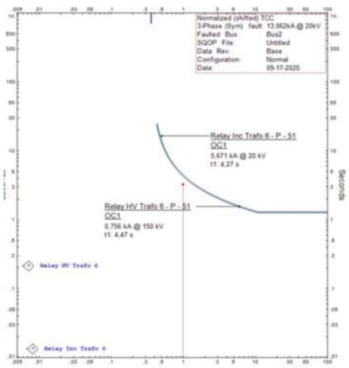


FIGURE 5. TCC Curve of Transformer 6 without PSO

Figure 6 presents the condition in which the disconnection time of the HV relay and the Inc relay. The fault is given to bus 2, then the Inc transformer 6 relay as the main safety detects a fault current of 7,054 kA and works at an operating time of 3.28 seconds. Meanwhile, the Hv Relay transformer 6 as a backup relay detects a fault current of 0.941 kA and works at an operating time of 4.48 seconds. From the TCC curve of the relay above, said the intersection has not been found, thus the relay has met the requirements of the protection system.

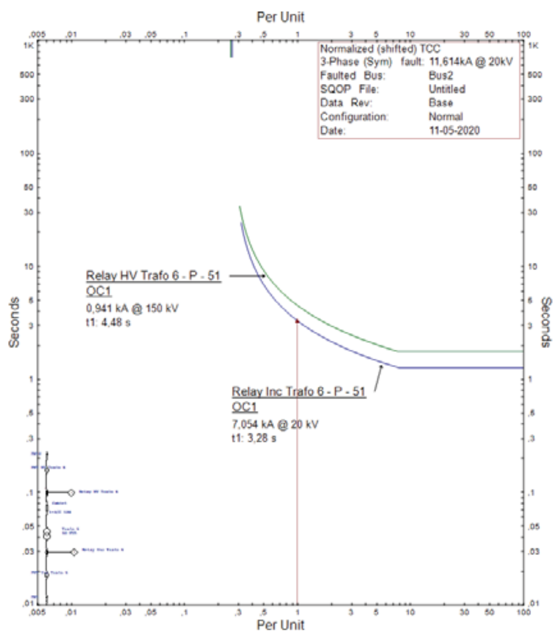


FIGURE 6. TCC Curve of Transformer 6 Utilizing PSO

CONCLUSIONS

From the test results, it is concluded that the optimization process of setting values utilizing the PSO algorithm on the Cempaka 6 GI transformer system network has been successfully performed. The full load current value and the short circuit current value are obtained from single line diagram analysis in ETAP software. The results of the operation of the primary and backup relays have met the requirements of the protection system with a distance of 1.2 seconds. The relay trip time after utilizing PSO is faster than before utilizing PSO. The application of PSO for the relay setting value could minimize the occurrence of overlap, enabling the electric power system.

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