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Improvement power losses using bank capacitors and tap changers with the shark smell algorithm

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Abstract

Regulating system voltage reduces the power losses in transmission line. The tap changer on the power transformer and capacitor bank are the most effective way to regulate the system voltage. However, a trial and error mechanism using the power flow method to determine the value of tap settings and bank capacitors in conventional method consume a lot of time and it is far from optimize value. This study provides an optimized value based on the shark smell algorithm for the tapping transformers and bank capacitors of the system. There are several combination carried out in this work i.e. optimizations only for tap setting of transformer, bank capacitor optimization, and optimization for both tap setting and bank capacitor values. The 150 kV electrical system of Central Java and Yogyakarta has been become the object of work. The active power losses with a conventional adjustment is 107.818 MW. As the initial value of bank capacitor is 25 MVar, no reduction of power losses is obtained as bank capacitor optimization is executed, because the original value of bank capacitors in the system has been optimum already. Better results are obtained when the optimization only for tap setting and the optimization for both tap setting and bank capacitor. This two combination make power losses become 67.3% from the initial losses. In other words, the use of Shark Smell algorithm in optimization provides 32.7% active power losses reduction. Based on the experimental value, the results show that the shark smell algorithm can provide better optimization for the 150 kV electrical system.

Keywords: Bank capacitors, tap changer, power losses, shark smell algorithm

1. Introduction

Modern electric power systems are represented by an interconnection system that is highly dependent on the control system to make optimal use of existing resources. The transmission network as an important sector of the electric power system plays an important role in sending electric power to customers[1]. The main problem faced by modern electric power systems is voltage drop or voltage instability after a power system disruption. Steady state instability is associated with power angle instability and slow synchronization loss between generators, load bus voltage drops under high load conditions and reactive power limits[2]. Generally, electrical substations which are far from the power plant center will experience a significant decrease in the level of voltage, so a reactive power compensation system is needed that can keep up with the change in voltage[3]. One way that can be done is by placing a capacitor bank and tap changer together on the transmission network. The use of both equipment is expected to be able to reduce power losses that occur in the electric power system.

The power losses produced by reactive components can be reduced by installing a capacitor bank in an optimal position[4]. The use of capacitor banks can improve the power factor and working voltage[5]. The use of capacitor banks can be combined with tap changers to control reactive power. Tap changers can help keep the voltage at the desired limit. The combination of the two devices can be optimal if installed with the most optimal setting value[6]. The challenge faced in combining the two devices is to

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find the appropriate setting value for an electric power system. If the system installed by the two devices is not so large it will be easier to try one by one the possible settings for the system. Problems arise if the two devices are installed in a large and complicated system it will be very difficult to try one by one the possible settings for the system. The optimal setting value will cause power losses can be reduced and both equipment does not work too often so that it can extend the life of both equipment. The use of optimization algorithms is needed to facilitate the search for optimal setting values for the two devices. One algorithm that can help calculate bank capacitor optimization is the Shark Smell Optimization (SSO) algorithm. The method based on shark behavior uses olfaction and its speed in approaching odor particles of prey blood [7]. The concentration of the odor is the main thing to guide the shark's movement to the prey [8]. The advantage of this algorithm is that it can minimize the appearance of local optimum solutions so that global optimum solutions can be achieved and not be trapped in local optimum solutions [9]. These advantages are the reason the author uses the SSO algorithm in this study. In this study, individuals represent the value of bank capacitors and the value of tap changers. Fish movement represents the iteration process in finding the best solution. Prey blood odor particles represent the value of electrical power losses. The higher the concentration of odor particles, the smaller the value of electrical power losses [10].

2. Method

The design of this optimization system starts by entering the SSO parameters and network data. This study uses The Central Java and Yogyakarta 150 kV network. The process of calculating power flow uses the Newton-Raphson method. The optimization process uses the shark smell algorithm. The advantage of this algorithm is that it can minimize the appearance of local optimum solutions so that global optimum solutions can be achieved and not be trapped in local optimum solutions. The computational process uses the MATLAB R2014 program with *.m scripts. The general design process flow chart can be shown in Fig. 1. In Fig. 1, this algorithm begins by determining the operating parameters of the SSO. These parameters include population size, maximum iteration, the stochastic gradient parameter (ηk), the inertia parameter (∝k), the speed limiting parameter (βk), and the time interval (tk).

After operating parameters are determined, the initial population and initial individual speed are generated. The individual in the SSO algorithm is described as a shark. Then do network data input. The network data to be analyzed is The Central Java and Yogyakarta 150 kV network.

Existing network data calculated power flow. Fitness in this study contains information in the form of active power losses. The next step is individual movement. This movement consists of forward and circular movements. Forward movement is used to approach the target of the prey from the results of smell.

$$Y = X + V \bullet \Delta t \tag{1}$$

Where,
Y = new position of forward movement
X = individual starting position
V = individual speed
Δt = time interval
Rotating movements are used to find the position of the prey more precisely after forward movement.

$$Z = Y + R \bullet Y \tag{2}$$

Where,

Z = new position of rotating movement
Y = new position of forward movement
R = random number generated

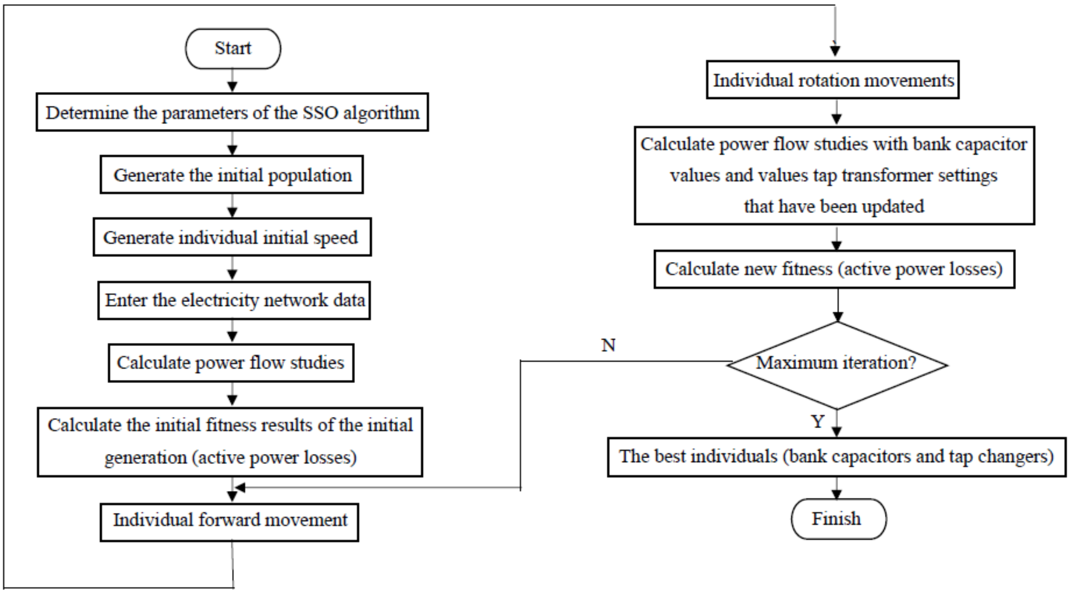

Fig. 1. Flow diagram of the system

The results of this individual movement process are entered into the initial data of the Central Java and Yogyakarta 150 kV network. Next with the new network data the power flow and new fitness values are calculated. The new fitness value contains new active power loss information.

3. Results and Discussion

Optimization testing in this study uses SSO which is done for 10 iterations. This test uses the population number (pop) parameter with a value of 300, the maximum iteration parameter (maxit) with a value of 10, the stochastic gradient parameter (ηk) with a value of 0.9, the inertia parameter (∝k) with a value of 0.05, the speed limiting parameter (βk) with a value of 4, and the time interval (tk) with a value of 1 for each test variation.

The Central Java and Yogyakarta 150 kV network has 125 buses with 44 transformers and 4 bank capacitors. Each transformer and bank capacitor has a different value. The total load on the Central Java and Yogyakarta 150 kV network is 3232.44 MW and 1268.27 MVar. The Central Java and Yogyakarta 150 kV network with initial conditions not yet optimized results in active power losses of 107.88180 MW.

The first test is testing using the initial settings of the Central Java and Yogyakarta 150 kV network. The next test is whether the transformer tap value is optimized without being combined with the bank capacitor optimization. The regulated bank capacitor is worth 25 MVar. This test uses the tap changer value according to the minimum setting value and the maximum setting value for each transformer. In this optimization test there are 44 transformers whose tapping modifier values will be optimized.

The next test is the optimization of the capacitor bank without combined with tap changer optimization. All tap changer are valued according to the initial setting values for each transformer. This test uses the same SSO parameters as the previous test. This test uses a minimum capacity limit value of bank capacitors of 8 MVar and a maximum limit value of capacity of bank capacitors of 25 MVar. The next test is tap changer optimization combined with bank capacitor optimization. This test uses the same SSO parameters as the previous test.

Comparison of the smallest active power losses of 150 kV system in the Central Java and Yogyakarta for conventional adjustment without SSO and other combination of SSO is provided Table 1.

Table 1. Comparison of active power losses before optimization and after optimization

Optimization Algorithm	Active Power Losses (MW)
No Optimization (Initial Settings)	107.8180
Tap Changer Optimization	72.4972
Bank Capacitor Optimization	107.8180
Optimization of Bank Capacitors and Tap Changer	72.5519

The results in Table 1 show that the SSO algorithm can provide better optimization results than conditions without optimization. The initial setting of the optimum capacitor bank also influences the results of optimization of tap changer and optimization of the combination of bank capacitors with tap changer. The optimization of the bank capacitor produces the same active power losses as the initial setting with conventional adjustment or without SSO because the optimal value of the bank capacitor is 25 MVar and it is the same with value of the bank capacitor of the initial setting. The optimization only for tap changer and the optimization for both tap changer and bank capacitor give significant results in power losses reduction. This two combination make power losses become 72.5519 MW or 67.3% from the initial losses. In other words, the use of Shark Smell algorithm in optimization provides 32.7% active power losses reduction.

The optimum condition of the capacitor bank helps the optimization process become faster and more directed towards the best fitness (the smallest active power losses). The test is continued by reducing all capacitor bank capacity values on tap changer optimization to 12.5 MVar and an active power loss of 76.4399 MW is obtained and a power loss reduction of 29.1% is obtained from the condition without optimization. A decrease in the value of the bank capacitor from its initial setting causes active power losses to increase on tap changer optimization.

Tests were also carried out by increasing all capacitor bank capacity values on tap changer optimization to 50 MVar and obtained active power losses of 67.8472 MW and a reduction in power losses of 37.1% from conditions without optimization. The increase in the value of the bank capacitor from its initial setting causes the active power losses to be reduced in tap changer optimization.

Fig. 2 shows that if the value of the bank capacitor is increased to 50 MVar, than the system voltage profile rises away from the nominal voltage at 150 kV. In the optimization condition of the capacitor bank without optimization of tap changer, the system voltage profile appears to fall away from the value of 150 kV. A combination of tap changer and bank capacitor optimization has made bus 74 as a remote bus which is far from power source and transformer, still has voltage value that is closest to the nominal voltage.

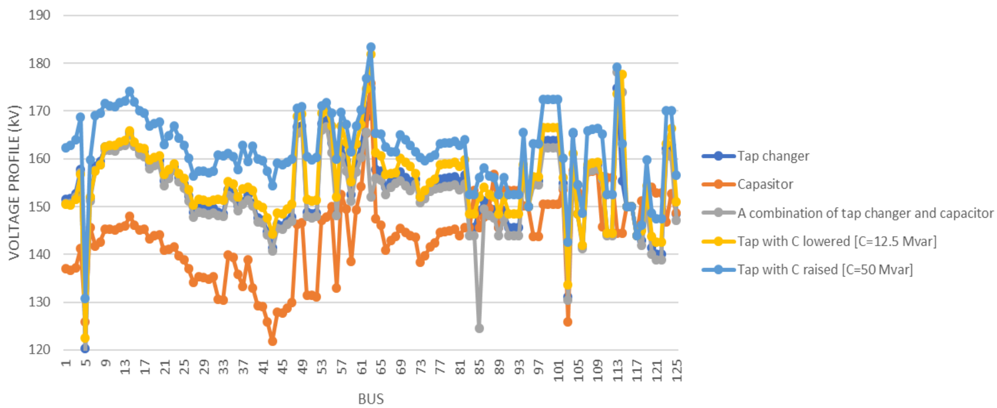

Fig. 2. Bus voltage profile for Central Java and DIY systems

Table 2. Comparison of active and reactive power generated

Optimization Method	Power generated in MW and MVar
Tap Changer Optimization	3304.927 + j1781.881
Bank Capacitor Optimization	3340.257 + j1974.138
Optimization of Bank Capacitors and Tap Changer	3304.992 + j1928.649
Optimization of Tap Changer with Value of the Bank Capacitor is lowered	3308.880 + j1888.696
Optimization of Tap Changer with Value of the Bank Capacitor is increased	3300.287 + j1694.126

Table 2 shows that the power generated at the optimization with combination of tap changer and bank capacitor is greater than the power generated at tap changer optimization. Based on the results of tested system, the high bank capacitors value and the value of the appropriate tap changer settings has played an important role in reducing active power losses. Optimization of active power losses in this study resulted in active power decrements to 35.3 MW.

Based on these results in the system being tested, the high value of bank capacitors and the value of the appropriate tap changer settings play an important role in reducing active power losses. Optimization of active power losses in this study resulted in a decrease in active power of 35.3208 MW or 35320.8 kW.

4. Conclusion

In the case study of 150kV Central Java and Yogyakarta electrical system, tap changer optimization provide the active power losses of 72.5 MW or give a power loss reduction of 32.7% from the losses occurred in the initial condition of system without optimization. Optimization of bank capacitors produces no reduction in power losses because the initial value of the capacitor bank has been at optimum setting. The combination of Bank Capacitors and Tap Changer Optimization gives the similar result with results , tap changer optimization i.e. a power loss reduction of 32.7%. High value of bank capacitor causes the voltage profile of system rises away from the nominal value. The capacitor bank optimization without tap changer optimization makes voltage profile of system fall away from the nominal value. A combination of tap setting and bank capacitor optimization has made voltage of remote bus which is far from power source and transformer, is closest to the nominal voltage.

Conflict of Interest

The authors declare no conflict of interest

Author Contributions

A developed the theory, wrote the paper, and performed the computations. B participated in drafted the manuscript paper and SSO algorithm design. C participated in drafted the manuscript paper and collect a network data of Central Java and Yogyakarta electrical system. All authors had approved the final version.

References

[1] Ahmadigorji M and Amjady N. A multiyear DG-incorporated framework for expansion planning of distribution networks using binary chaotic shark smell optimization algorithm. *Energy*, 2016; 102: 199–215.

[2] Robandi I. *Desain Sistem Tenaga Modern*. Yogyakarta: ANDI Publisher, 2006.

[3] Bangun AW. Penempatan SVC untuk memperbaiki profil tegangan pada jaringan transmisi PT. PLN lampung. Universitas Lampung, 2016.

[4] Gnanasekaran N, Chandramohan S, Kumar PS, and Mohamed IA. Optimal placement of capacitors in radial distribution system using shark smell optimization algorithm. *Ain Shams Eng. J.*, 2016; 7(2): 907–916.

[5] Alamajibuwono H, Sukmadi T, and Handoko S. Optimasi penempatan kapasitor menggunakan algoritma genetika pada sistem distribusi untuk memperbaiki faktor daya dan tegangan," *Tek. Elektro Univ. Diponegoro*, 2011.

[6] Wang LY *et al.*, A solution to lower tap changing or capacitors regulator times in reactive power control in distribution systems. In *Proc. IEEE Power Eng. Soc. Transm. Distrib. Conf.*, 2005; 2005: 1–5.

[7] Ehteram M, Karami H, S. F. M., El-Shafie A, and Amini Z. Optimizing dam and reservoirs operation based model utilizing

shark algorithm approach. *Knowledge-Based Syst.*, 2017; 122: 26–38.

[8] Abedinia O and Amjady N. Short-term wind power prediction based on hybrid neural network and chaotic shark smell optimization. *Int. J. Precis. Eng. Manuf. - Green Technol.*, 2015; 2(3): 245–254.

[9] Fouladi E and Mojallali H. Design of optimised backstepping controller for the synchronisation of chaotic Colpitts oscillator using shark smell algorithm, *Pramana - J. Phys.*, 2018; 90(1).

[10] Oveis A, Amjady N, and ALI G. A new metaheuristic algorithm based on shark smell optimization. *Complexity*, 2014; 21(5): 97–116.