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Artificial Bee Colony Algorithm for Optimal Power Flow on Transient Stability Java-Bali 500 KV

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Abstract. Power flow optimization is the growing issue today given the system that are not grow and develop that are not comparable with electricity power demand from consumer. Therefore, smart effort has to be done to overcome this increasingly electricity power demand. Power flow optimization is one of the effort that can be done to optimize the current system. The use of Ant Bee Colony algorithm is one of the method that capable to give optimal result without disturbed by mathematic problem that need much computation time. From simulation result at Java-Bali System 500 kv, the satisfied result has been achieved where this method can reduce system power losses from active power losses 297.607 mva and reactive power losses 2926.825 mvar become 71.292 mva and 530.241 mvar.

Keywords: Ant Bee Colony, Optimal Power Flow, Transient Stability

1. Introduction

Electricity power system can not be separated with the effort to optimize operation which mean that variable control has to be arranged to produce operation system that save and cheap. To gain this desired system operation process, Optimal Power Flow (OPF) which is method that use mathematic calculation to gain a cheap fuel cost result and still in previously prescribed limit. According to [1-5] Non Linear Programming and Linear Programming widely use to solve several problem in the optimal power flow.

Like another conventional method, this method is considered as classic method due to limitation in solving mathematic equation that represent dynamic system characteristic that is optimization problem in transient condition.

If we see the operation condition at field, operation system of electricity power all this time were operate at condition that far from its safety limit. System operate at maximum operation condition, because the increasingly rise electricity energy demand was not accompanied by the addition of new power plant for reasons of cost efficiency, thus the system always fully operational. This condition certainly make the operation system prone to collapse if there is a small interfere or changes in the system. Base on this condition, preventive action has to be done for planning and operating electricity power system, which is by performing system optimation that notice the system transient condition.

But, transient stability analysis can not be separated from the use mathematic equation with its non linear pattern that need time and accuracy to get the result. This is getting difficult because the differential equation is the equation that describe dynamic behavior from the system [1-5].

According to [6-8], several research that involve sensitivity in reschedule was used to gain solution in power plant cost and several research with discretization scheme which is change differential equation become algebra equation as inequality constrain produce low accuracy solution.

From several advanced research, according to [9,10], because of system that has been used was increasingly big and the variable was increasingly complex, thus calculation convergence will be a problem by itself. The using of method with transformation technic [11] can change infinitedimensional problem Transient Stability Control Optimal Power Flow (TSCOPF) become finite-dimensional programming problem. But, like another classic optimation method, this method have a weakness, that is this method experience convergence at optima local solution, thus transient stability limit will not include in constrain of optimization problem. Solution to solve those problems are using Artificial Intelligence Algoritma to solve transient stability calculation problem [1-3]. The using of AI become easy tool to solve Transient Stability Control Optimal Power Flow (TSCOPF) problem and can find optimal global or good solution without restricted by model that has been used. Several application that use AI like Genetic Algorithm (GA), Particle Swarm Otimization (PSO) dan Differential Evolution (DE) can give satisfied result in TSSOPF problem.

Research in this paper try to give a solution for developing Transient Stability Control Optimal Power Flow (TSCOPF) with optimization technic of heuristic modern that use Artificial Bee Colony Algorithm (ABC) as a algorithm that stimulated the behavior of honey bee for solving the problem of electricity power system optimization.

2. Methodology

2.1. Transient Stability Constrained Optimal Power Flow Formula

Transient Stability Control Optimal Power Flow (TSCOPF) problems basically are formulation from system fuel cost that expressed as quadratic function equation below :

$$f_i = a_i + b_i P_{Gi} + c_i P_{Gi}^2 \tag{1}$$

With a_i, b_i, dan c_i are the cost coefficient form each power plant unit.

By incorporating various constrain like fuel losses due to valve opening process at turbine, generator effect due to valve point effect, thus the objective function become non linear, non convex with several minima. So, the equation will become :

$$\begin{aligned} F = &\sum_{i=1}^{N}(a_i + b_i P_{Gi} + c_i P_{Gi}^2) + K_p (P_{G1} - P_{G1}^{\lim})^2 \\ &+ K_v \sum_{i=1}^{NL}(V_i - V_i^{\lim})^2 + K_q \sum_{i=1}^{N}(Q_{Gi} - Q_{Gi}^{\lim})^2 \\ &+ K_s \sum_{i=1}^{nl} abs(S_i - S_i^{\lim})^2 + K_l \sum_{j=1}^{NL}(L_j - L_j^{\lim})^2 \end{aligned} \tag{2}$$

With K_p, K_v, K_q, K_s, dan K_l are penalty factor, NL is the amount of load bus, nl is the amount of transmission and $x^{lim}$is margin limit. By incorporating valve point loading effect to power plant cost curve, thus the equation become [1]

$$f_i = a_i + b_i P_{Gi} + c_i P_{Gi}^2 + \left| d_i \sin(e_i (P_{Gi}^{\lim} - P_{Gi})) \right| \tag{3}$$

By incorporating objective function and the using constrain, thus the complete equation will be :

$$\begin{aligned} F = &\sum_{i=1}^{N} \begin{pmatrix} a_i + b_i P_{Gi} + c_i P_{Gi}^2 \\ + \left| d_i \sin(e_i (P_{Gi}^{\lim} - P_{Gi})) \right| \end{pmatrix} + K_p (P_{G1} - P_{G1}^{\lim})^2 + K_v \sum_{i=1}^{NL}(V_i - V_i^{\lim})^2 \\ &+ K_q \sum_{i=1}^{N}(Q_{Gi} - Q_{Gi}^{\lim})^2 + K_s \sum_{i=1}^{nl} abs(S_i - S_i^{\lim})^2 + K_l \sum_{j=1}^{NL}(L_j - L_j^{\lim})^2 \end{aligned} \tag{4}$$

With a_i, b_i, c_i dan e_i are cost coefficient from each power plant unit. While Kp, Kv, Kq, Ks dan Ki are penalty factor NL that show the amount of load bus, nl dan x^{lim}sequentially are the amount of transmission and margin limit. So the non linear equation of power flow become :

$$P_{Gi} - P_{Di} - V_i \sum_{j=1}^{N} V_j (G_{ij} \cos\alpha_{ij} + B_{ij} \sin\alpha_{ij}) = 0 \quad Q_{Gi} - Q_{Di} - V_i \sum_{j=1}^{N} V_j (G_{ij} \sin\alpha_{ij} - B_{ij} \cos\alpha_{ij}) = 0 \tag{5}$$

With N is the amount of bus total, P_{Gi} dan Q_{Gi} *are* active and reactive power of i^th^ power plant bus . P_{Di} danQ_{Di} are active power for i^th^ load bus, Vi are magnitude of voltage bus, α_{ij} is the voltage angle difference between i^th^ bus and j^th^ bus, B_{ij} is transfer.

2.2. Transient Stability

In transient condition, power system generator was described in equation :

$$M_i \frac{d^2\delta_i}{dt^2} = P_{mi} - P_{ei}$$

$$\dot{\delta}_i = \omega_i \quad (6)$$

With $\dot{\delta}_i$ and ω_i are rotor angle and velocity angle of i^th^ generator, P_{mi} and P_{ei} are mechanic power input and electricity power output from i^th^ generator and Mi is inertia moment from i^th^ generator.

Center of inertia (COI) from electricity power system can be represent by linear combination from every angle of generator rotor as follows :

$$\delta_{COI} = \frac{1}{M_T}\sum_{i=1}^{N_G} M_i\delta_i \quad (7)$$

With $M_T = \sum_{i=1}^{N_G} M_i$ is center of inertia. Rotor angle and velocity in COI frame are showed at equation (8) and (9).

$$\theta_i = \delta_i - \delta_{COI} \quad (8)$$

$$\dot{\theta}_i = \tilde{\omega}_i \quad (9)$$

Therefore, equations that connect with COI frame are denoted as :

$$M_i\dot{\tilde{\omega}}_i = P_{mi} - P_{ei} - \frac{M_i}{M_T}P_{COI} \equiv PAC_i \quad (10)$$

$$P_{COI} = \sum_{i=1}^{N_G}(P_{mi} - P_{ei}) \quad (11)$$

With PAC_1 is acceleration power from i^th^ generator.

Transient Energy Function (TEF) from model of electricity power system above was defined as follows

$$TEF = KE + PE \quad (12)$$

$$KE = \frac{1}{2}\sum_{i=1}^{N_G} M_i\tilde{\omega}_i^2 \quad (13)$$

$$PE = -\sum_{i=1}^{N_G}\int_{\theta_i^{SEP}}^{\theta_i} PAC_i^P \, d\theta_i \quad (14)$$

With KE is kinetic energy, PE is potential energy, θ_i^{SEP} is rotor angle from post-fault system from stable equilibrium point and PAC_i^P is power acceleration at post-fault system.

2.3. Artificial Bee Colony Algorithm (ABC)

Artificial Bee Colony is an algorithm that adopt the behavior of bees colony in search of food. When bees were searching for food, they divide their duty in three group, which is labor group, onlooker and scout. The food searching process was start from bees gathering in a hall called dance area, where they will make a decision to determine food sources that they has been known before. The decision maker are bees group called onlooker bees. Meanwhile labor bees are bees group that will visit that food sources. Bees that has to find food sources randomly called scout bees.

Based on [17] to solve the problem, control variable can be expressed as

$$u^T = \left[P_{g2},...P_{gN2},V_{g1},...V_{gN2} \right] \quad (15)$$

This equation without consider slack bus. To measure the quality ant bee colony algorithm, calculation of fitness Fi can be expressed as:

$$F_i = 1/(fi + K_v F_{vi} + K_q F_{qi} + K_{ps} F_{ps}) \quad (16)$$

Where the generating fuel cost f_i F_{vi} and F_{qi} are sum of the normalized of PQ bus voltage and reactif power from ouput generator i, respectively

3. Implementation

To see the affectivity of method that has been used, test was performed at Java Bali system 500 kV as shown as figure 1.This electricity system from Java Bali 500 kV is consist of 8 generator and 25 bus that has been interconnectly connected. Several power plant are water power plant and most of it are steam power plant. The specification can be seen at the table below

The generators are Suralaya, Muaratawar, Cirata, Saguling, Tanjungjati, Gresik, Paiton, and Grati. Among these eight plants, power plants Saguling Cirata are water powerplants, while others are steampower plants. In this study Suralaya power plant act as a slack generator.

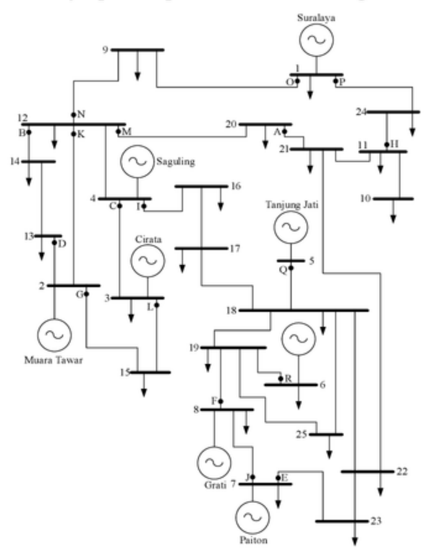

Figure 1. Java Bali 500 KV System

The load data obtained from PT PLN(Persero) . The kV base is 500 kV, MVA base is 1000 MVA, and the system frequency is 50 Hz. Generator data used are shown in Table 1

Table 1.Generator Data

Generator Number	Generator Name	Xd' (pu)	H	Generator Number	Generator Name	Xd' (pu)	H
1	Suralaya	0.297	5.19	5	Tanjung Jati	0.258	3.2
2	Muaratawar	0.297	1.82	6	Gresik	0.297	2.54
3	Cirata	0.274	2.86	7	Paiton	0.297	4.42
4	Saguling	0.302	1.64	8	Grati	0.297	3.5

Implementation that has been done to the system by using cycle as much as 50 to receive the best result. From trial result that has been performed, those cycles already give us the desired result. The amount of bees colony has been used are 50.

4. Result and Analysis

From simulation that has been performed, initial result was obtained that can bee seen at table 2. At table 2, looses at every bus can be seen. The total looses system are 297.607 mva for active power and 2926.825 mvar for reactive power.

Table 2. Initial Condition

NO BUS	VOLTAGE	LOSSES		NO BUS	VOLTAGE	LOSSES	
		P	Q			P	Q
10	0.980	0.003	0.033	15	1.000	5.075	49.663
11	0.970	0.510	5.705	16	0.963	0.818	27.875
12	0.948	0.053	11.623	17	0.970	0.228	2.193
13	0.911	1.928	4.987	18	0.960	0.080	0.772
14	0.907	2.086	5.975	19	0.875	0.342	24.145

Next steps is perform optimization load flow using method that has been proposed which is artificial bee colony algorithm. From simulation that has been performed, the result was obtained as follows :

Table 3.Final Condition

NO BUS	VOLTAGE	LOSSES		NO BUS	VOLTAGE	LOSSES	
		P	Q			P	Q
10	0.980	0.003	0.033	15	1.000	5.075	49.663
11	0.980	0.51	5.705	16	0.971	3.223	27.875
12	0.973	1.928	4.987	17	0.970	0.228	2.193
13	0.970	1.928	4.987	18	0.974	0.08	0.772
14	0.977	2.086	5.975	19	0.950	0.343	24.145

To further look the affectivity of method that has been used, calculation simulation was performed as much as 125 times to validate its reliability and accuracy. Figure 2 shown result for iteration as much as 125 times. Figure 2 shown the total of looses at the system. It can be seen that proposed method already give the same looses value at various iteration and this show that statistically method that has been used can show its reliability.

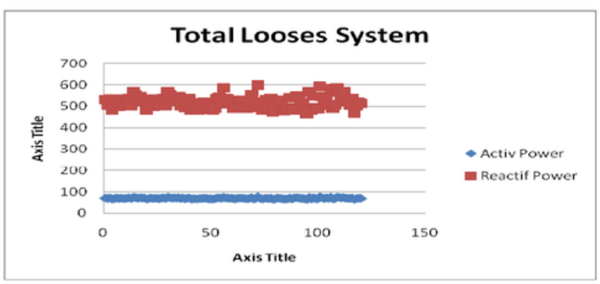

Figure 2. Total Looses System

5. Conclusion.

From proposed method, conclusion can be withdrawn that proposed method which is ant bee colony algorithm can give satisfied result for reduce looses especially for optimization of system power flow. Method that has been used show that statistically this method capable, reliable and proven to give accurate result.

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