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Optimum reactive power to improve power factor in industry using genetic algortihm

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ABSTRACT

Capacitor bank is a collection of power tools in the form of a capacitor that serves as a tool that can reduce or improve reactive power into the power grid. The load on the electricity network in general is an inductive load. If the average power factor (cos Θ) is less than 0.85, the State Electricity Company will provide the reactive power in KVAR fines usage charges on customers. An effort should be done to reduce the reactive power. An installation of bank capacitor is suitable to be implemented in an industry AC loads. It will reduce the reactive power and improve the power factor. In the case of 380 V, 50 Hz, 500 kW AC loads are improved the power factor from 0.7 to 0.93 using genetic algorithm, thus the AC loads current and reactive power will be decreased. It is suitable that the AC loads current is inversely proportional to the power factor, and the reactive power is proportional to the AC loads current.

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1. INTRODUCTION

The output electric power of the power transformer distributed to consumers is the active power and reactive power. The active power is the actual power used to conduct business (real power). The reactive power is the amount of power required for the formation of magnetic fields. For examples of power tools that influence is the reactive power of transformers, electric motors, welding machines and incandescent lamps. If the usage amount of reactive power (VAR) is greater will affect the active power and power factor (cos Θ) will be low. Indonesian National Electricity Company will charge to the customer if the power factor (cos Θ) goes down below 0.85. Low-voltage power factor incur losses, so the current active power required to do business with the same kilo watt (kW) will be greater. In anticipation of the power loss of Indonesian National Electricity Company suggested to install bank capacitor panel. There are three types of power are well known, especially to the load impedance (Z). The first one is apparent power, S in volt ampere (VA), the second one is active power, P in watt (W) and the last one is reactive power, Q in volt ampere reactive (VAR) [1].

While the apparent power expressed in units of volt ampere (abbreviated, VA), stated capacity of electrical equipment, as indicated on the generator and transformer equipment. In an installation, particularly in the plant or industry there are also specific loads such as electric motors, which require other forms of power, the reactive power (VAR) to create a magnetic field or in other words reactive power is the power that is used as an energy generation flux of magnetic causing magnetization and power is restored to the system because of the effect of electromagnetic induction itself, so that the power is in fact a load (demand) in a power system [2].

Electric power system engineers typically assume a capacitor as a positive reactive power generator, rather than as a burden that requires a negative reactive power. This concept is very plausible, because a capacitor that attract negative reactive power and installed in parallel with an inductive load will reduce the reactive power that should be in supply entirely by inductive load system. In other words, the capacitor dole reactive power required by inductive loads. This is equivalent to consider a capacitor as a device that provides exceptional current (lagging) rather than as a tool that precedes the current draw (leading). Thus, a variable capacitor is mounted parallel to an inductive load can be arranged so that the flow that precedes the capacitor becomes equal to the fixed component of the inductive load current on the left 90˚ to voltage. Thus, the total current in phase with the voltage. Inductive circuits still require reactive power is positive, but the reactive power value is zero. This is why his board power system engineers prefer to think of the capacitor as reactive power supply to the inductive load [3].

A combination of fuzzy multi objective and genetic algorithm (GA) based approach is proposed for optimal shunt capacitor placement to improve the substation power factor near unity, reduce the real power loss, and reduce the burden on the substation and to improve the voltage profile of the distribution network. In order to obtain best nodes for capacitor placement, a sensitivity index based on real power loss reduction and voltage profile improvement is considered by [4]. The other application of genetic algorithm is as stated by [5] that it is applied in optimum peak power of photovoltaic (PV) module. It is based on the formulation of voltage and current of PV module. The compensation and forcasting of reactive power should be studied in the power system as stated by [6, 7, 8, 9], it reviewed the reactive power compensation in microgrid system with renewable energy as electrical power in the distributed generation (DG) system and also it managed the reactive power in the factory or industrial power plant.

A suitable capacitor allocation and reallocation of power system is very important to power flow and also stability of the power system. A reactive power cost allocation has been studied by [10] that applying a power tracing principle. It applied a cost function of reactive power to produce required values as consideration of fix cost of reactive power. A reactive power reallocation on power system was studied by [11], it compared the power flow of system with and without the application of Distributed Static Compensator (DSTATCOM). A real and reactive power controller to reduce the price of reactive power has been studied by [12]. It applied opimumed reactive power method using the algorithm of Cuckoo Search in the Matlab software.

This paper presents an installation a bank capacitor in 380 V, 50 Hz, 500 kW industry AC loads. In this case, the power factor will be improved from 0.7 to 0.95 using genetic algorithm. An objective function is created to be implemented in the genetic algorithm application.

2. METHODOLOGY

2.1. Model of Bank Capacitor Installation in Industry

An installation of bank capacitor is shown in Figure 1. It is installed in the bus of 380 V to improve the power factor of 500 kW AC loads. In this case the power factor will be improved from 0.7 to be 0.93. The value of current flows through the AC load and also the reactive power are calculated by using (1) and (2) respectively [13, 14].

$$P = \sqrt{3}.V.I.\cos\theta \tag{1}$$

$$Q = \sqrt{3}.V.I.\sin\theta \tag{2}$$

where: P = active power (watt)
Q = reactive power (VAR)
V= line voltage (volt)
I = line current (ampere)
$Cos\ \Theta$ = power factor

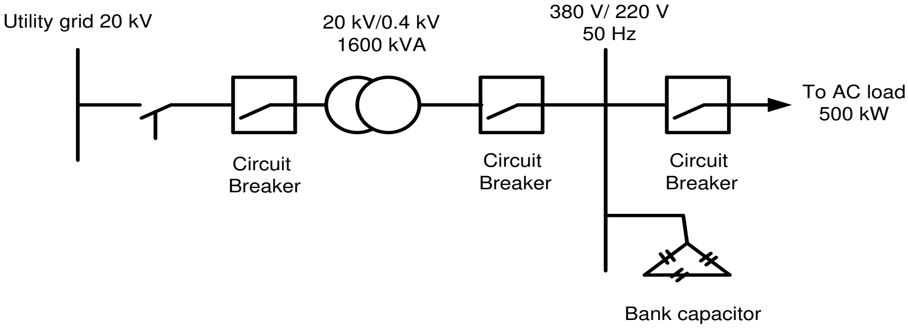

Figure 1. Installation of bank capacitor [14]

2.2. Genetic Algorithm

As shown in (1) is applied as objective function to calculate the line current that flows through the AC loads. The objective function is the current as function of the power or val is function of sol in the genetic algorithm application. The current or val is as dependent variable and power or sol is as independent variable. The independent variable of power or sol is limited between 0 to 500 kW. It means that the genetic algorithm calculates the current for power between 0 to 500 kW and it will show the value of current for the power of 500 kW and also for the specific generation number. The number of generation and population are 10, respectively. The code program implemented in the genetic algorithm is as shown in Figure 2.

```
function [sol,val] = Gabel1Eval(sol,options)
global inpxOpts inpmOpts inpselectOps inpbounds ;
%=======================================================
%V and costheta are needed if find the current
V=380;                        % line voltage in volt
costheta=0.7;                 % power factor
 %-====================================================
inpxOpts = [1 3;4 3;4 0];  %Crossover
inpmOpts = [2 0 0;2 0 0];  %Mutation coeficient
%inptermOps=10;              %Number of generation
%inpjumpop=10;               %Number of population
if nargin==2
% Calculation and ploting of  current
val=sol(1)/(sqrt(3)*V*costheta);
end;
inpbounds = [0 500];         % limitation of maximum power
                             % (min kW=0 anf max. kW=500 )
```

Figure 2. Code program implemented in the genetic algorithm to calculate the line current of AC load

As shown in (2) is applied as objective function to calculate the reactive power of AC loads. The objective function is the reactive power as function of the current or val is function of sol in the genetic algorithm application. The reactive power or val is as dependent variable and the current or sol is as independent variable. The independent variable of current or sol is limited between 0 to 1.0852 kA. It means that the genetic algorithm calculates the reactive power for the current between 0 to 1.0852 kA and it will show the value of reactive power for the current of 1.0852 kA and also for the specific generation number. The number of generation and population are 10, respectively. The code program implemented in the genetic algorithm is as shown in Figure 3.

```
function [sol,val] = Gabel1Eval(sol,options)
global inpxOpts inpmOpts inpselectOps inpbounds ;
%==================================================
% V and sintheta are needed if find reactive power
V= 380;                    % Line voltage (volt)
sintheta=0.714;
 %-================
inpxOpts = [1 3;4 3;4 0]; % Crossover coefficent
inpmOpts = [2 0 0;2 0 0]; % Mutation coefficient
%inptermOps=10;            % Number of generation
%inpjumpop=10;             % Number of population
inpselesctOps = [0.04];    % Selection coefficient
if nargin==2
% Calculation and ploting of reactive power
val=sol(1)*sqrt(3)*V*sintheta;
end;
inpbounds = [0 1.0852];    % limitation of current
                           %(min I=0 and max. I= 1.0852 kA)
```

Figure 3. Code program implemented in the genetic algorithm to calculate the reactive power of AC load

3. RESULTS AND DISCUSSION

3.1. Current Flows Through the AC Loads

The graph of current verses number of generation is shown in Figure 4. The figure shows the capability of genetic algorithm in the calculation of AC load current. Following Figure 2 that the calling function is Gabel1(10, 10). Gabel1 is function name and ten in the bracket is number of generation and population.

Based on Figure 4, it shows that for the power factor of 0.7, the current of 1.0852 kA can be achieved for only the generation number of 2. It indicates that the generation number is needed to achieve the current steady value of 1.0852 kA by the genetic algorithm is 2 for the limitation of active power, P (0< P > 500 kW). The AC loads current is still 1.0852 kA after the generation number of 2.

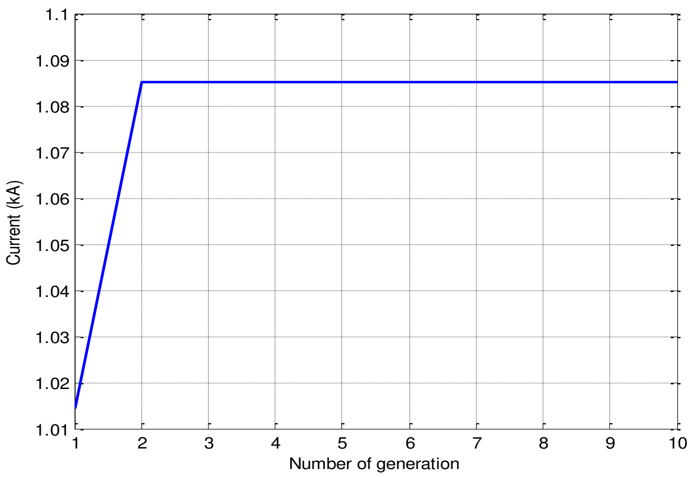

Figure 4. Graph of current versus number of generation

In this case, the power factor is improved from 0.7 to 0.93. Thus, ten steps of the power factor change from 0.7 to 0.93 are simulated in the genetic algorithm application. The graph of current verses power factor is shown in Figure 5. Figure 5 shows that the AC loads current will be decreased when the power factor is increased. It is following the using (1) that for the constant active power of 500 kW, the AC loads current is inversely proportional to the power factor.

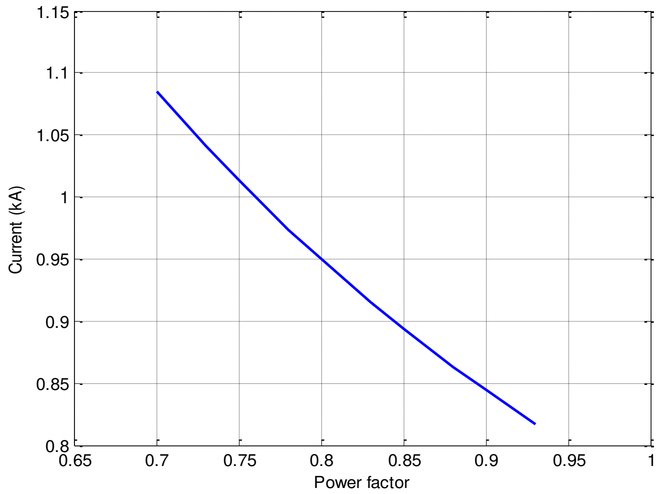

Figure 5. Graph of current versus power factor

3.2. Reactive Power of AC Loads

The graph of reactive power verses number of generation is shown in Figure 6. The figure shows the capability of genetic algorithm in the calculation of AC load reactive power. Following Figure 2 that the calling function is Gabel1(10, 10). Gabel1 is function name and ten in the bracket is number of generation and population.

Based on Figure 6, it shows that for the power factor of 0.7, the reactive power of 510 kVAR can be achieved for only the generation number of 2. It indicates that the generation number is needed to achieve the AC load reactive power steady value of 510 kVAR by the genetic algorithm is 2 for the limitation of AC loads current, I (0< I > 1.0852 kA). The AC loads reactive power is still 510 kVAR after the generation number of 2.

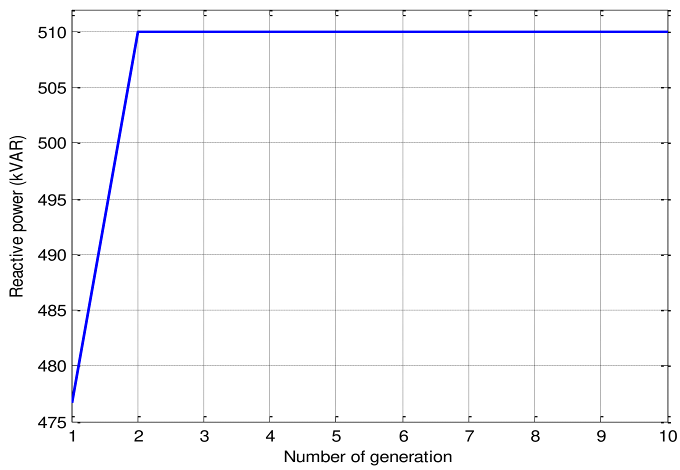

Figure 6. Graph of reactive power versus number of generation

In this case, the power factor is improved from 0.7 to 0.93. Thus, ten steps of the power factor change from 0.7 to 0.93 are simulated in the genetic algorithm application. The graph of AC loads reactive power verses power factor is shown in Figure 7.

Figure 7 shows that the AC loads reactive power will be decreased when the power factor is increased. It is following the (2) that the AC loads reactive power is proportional to the AC loads current. If the AC loads current decreases, thus the AC loads reactive power will be decreased also.

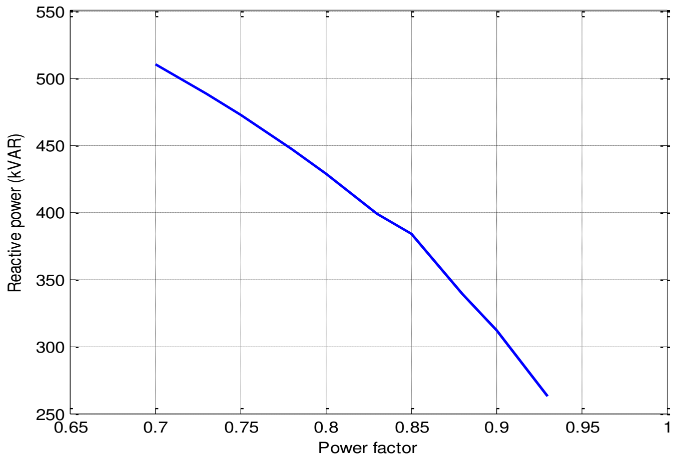

Figure 7. Graph of reactive power versus power factor

3.3. Three-Dimensional of Reactive Power as Function of Both Power Factor and Current

In this simulation of genetic algorithm application, every step of the power factor change from 0.7 to 0.93 are recorded for AC loads current and reactive power. It is due to the number of step of the power factor change is ten, thus it is formed a matrix with dimension 10x10. Then, it is created in three-dimensional graph of reactive power as function of both power factor and current using Matlab command.

The three-dimensional graph of reactive power as function of both power factor and current is shown in Figure 8. The AC loads current and reactive power will be decreased or the increasing of power factor. It is suitable that the AC loads current is inversely proportional to the power factor, and the reactive power is proportional to the AC loads current [15, 16].

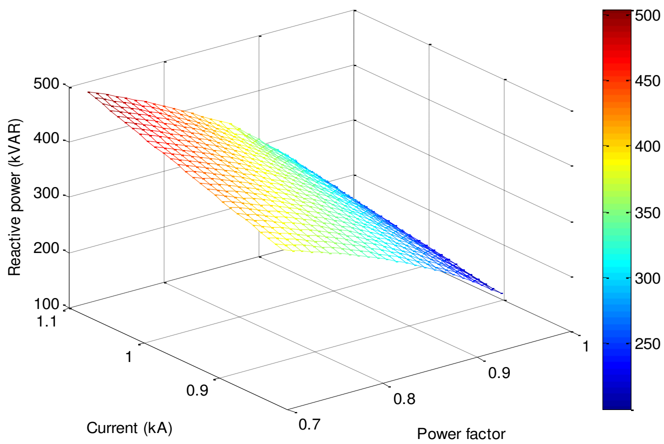

Figure 8. Three-dimensional of reactive power as function of both power factor and current

4. CONCLUSION

Based on the simulation of optimum reactive power for improving power factor in industry using genetic algorithm, some conclusions can be stated below. An objective function should be declared in the genetic algorithm application. A relationship of AC loads active and reactive power to the line voltage, AC loads current and power factor is created as objective function in the genetic algorithm application.

For a constant AC loads active power and an increasing of power factor, thus the AC loads current and reactive power will be decreased. It is suitable that the AC loads current is inversely proportional to the power factor, and the reactive power is proportional to the AC loads current.

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