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ANALYSIS OF REACTIVE POWER ON DIFFERENT BUSES OF A 57-BUS POWER SYSTEM

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ABSTRACT

With the help of Load flow study all the power flow parameters can be find out of power system network .However so many methods are available to solve the load flow problems but accuracy and speed are the main problems in all techniques. By using the PSO we can improve the accuracy and speed then another method. By using PSO techniques we find the optimal location in the system at which we can set the reactive power compensating device .The paper conclude analysis of a load flow system of 57-bus network and find out the optimal location at which voltage deviation is minimum and use the thyrister ckt and facts devices for compensate the reactive power as per requirements. . The power flow study provides the system status in the steady-state and it is fundamental to the power system operation, planning and control. PSO is applied in a new computational model for the system power flow obtainment. This model searches for a better convergence, as well as a wider application in comparison with traditional methods as the Newton-Raphson method.

KEYWORDS: load flow analysis, Particle swarm optimization, STATCOM, NR METHOD.

INTRODUCTION

Power Systems Operation Centers are managed remotelyand automatically. Such centers perform automatic generationcontrol, state estimation and topological analysis [10]. Most ofthe functions performed depend on the execution of several power flow studies, which determine the Power Systemoperation point while in steady-state [11]. The Load Flow problem consists in three calculations: buses voltages, total power in the system generation buses and power flow in the system lines. This problem is modeled through a set of non-linear equations, which is usually solved by numeric computational methods [12].Generally the Newton-Raphson method is applied in the load flow calculation due to its greater convergence. Though, the complexity of such calculations and the Jacobian matrix inversion, added to the dependence on initial estimated values which are required for accurate convergence, have revamped the accomplishment of researches and efforts, as well as developed alternative methods in order to solve load flow equations. These new methods are aimed at simplifying implementation method&optimizing computational solution time. Non-classical logics and artificial intelligence techniques have been applied to such methods.The computational intelligence algorithms have drawn researcher's attention to the area of artificial intelligence as they have became more interested in focusing into the application of these algorithms in Electrical Engineering themes. Among these techniques, Particle Swarm Optimization (PSO) is highlighted, and which is based on the behavior of bird's flocks in search for food [19]. PSO algorithms are used in functions optimization and are currently applied in several themes related to electrical power systems, such as: Optimal Power Flow, Power System Restoration [20] and Control of Voltage and Reactive Power [21]. PSO algorithms can provide nearly ideal convergence properties associated to simple implementation and reduced computational time [14]. Ref. [17] proposes a PSO algorithm to the Optimal Power Flow problem through the minimization of the generation cost function. Ref. [16] approaches the PSO to the load flow calculation in shipboard systems. Ref. [15] proposes a chaotic PSO algorithm with local search to the load flow calculation, exceeding some limitations found in the traditional numeric methods. This paper proposes the application of a PSO algorithm to the load flow computation in electric power systems. Such algorithm is based on the minimization of the active and reactive power mismatches in the system buses. The involved variables are continuous and must remain within the specified boundaries of the tested system.

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FLAXIBLE AC TRANSMISSION

Flexible transmission system is akin to high voltage dc and related thyristors developed designed to overcome the limitations of the present mechanically controlled ac power transmission system. Use of high speed power electronics controllers, gives 5 opportunities for increased efficiency.

- Greater control of power so that it flows in the prescribed transmission routes.
- Secure loading (but not overloading) of transmission lines to levels nearer their required limits.
- Greater ability to transfer power between controlled areas, so that the generator reserve margin- typically 18 % may be reduced to 15 % or less.
- Prevention of cascading outages by limiting the effects of faults and equipment failure.
- Damping of power system oscillations, which could damage equipment and or limit usable transmission capacity

STATCOM

The STATCOM (Static synchronous Compensator) is a shunt connected reactive compensation equipment which is capable of generating and absorbing reactive power that its output can be varied so as to maintain control of specific parameters of electric power system. STATCOM is normally consisting of voltage source inverter with dc-link capacitor. It is normally interfaced to a system through a transformer. The transformer serves the purpose of stepping up the STATCOM voltage and also its leakage reactance helps prevent short circuit of the dc-link capacitor. Hence when using multilevel STATCOM where by the STATCOM voltage could be built from a number of dc-link to that of the system voltage, interface reactor is required to serve as the transformer leakage reactance. Basically STATCOM can be modeled as a synchronous generator that absorbs/injects reactive power but does not generate any real power rather absorbed real power to cater for its internal and interface losses. Z STATCOM represents the impedance of the STATCOM. The imaginary part represents the transformer leakage reactance/interface reactor and the real part forms the ohmic losses of the STATCOM.

Assuming multilevel Inverter STATCOM, in this model, the ohmic resistance is excluded from the admittance matrix. This is due to the fact that, various switching techniques can be employed. Main switching techniques are PWM and fundamental frequency switching (FFS) where the switching losses are different. The real power losses of the STATCOM are computed before the load flow depending on the reactive power specified at the STATCOM bus. The bus introduced four parameters, the same number as the system buses.

The bus the STATCOM is connected to remains a load bus and so is the STATCOM bus. In the lagging power factor, the sign of the STATCOM reactive power is the same as that of the load but opposite in leading power factor .

LOAD FLOW REVIEW

In the power system analysis there are many methods to solve the load flow problems i.e. Gauss Seidal Method , Newton raphson method , Decoupled Method ,Fast decoupled method etc.

GUASS SEIDAL METHOD

The Gauss-Seidel iteration is an important method to solve the load Flow problems even today.The Gauss-Seidel iteration was the starting point for the successive over-relaxation methods which dominated much of the literature on iterative methods for a big part of the second half of this century. The methods were initiated in the 19th century, originally by Gauss in the mid 1820s and then later by Seidel in 1874. This method as it was developed in the 19th century was a relaxation technique. In this methods we have given the real and reactive power of pv bus

The general description of the Gauss-Seidel method is as follows:

1. It is a iterative method Before solving the bus voltage, we should assign the initial value $V(0)$ to unknown values;
2. Solve a new value to each bus voltage from the real and reactive Power specified;
3. A new set of values for the voltage at each bus is used to calculate another bus voltage at the next iteration;
4. The process is repeated until voltage differences at each bus are less than the tolerance value.

Formulas for manually determine the value of bus voltage, δ and reactive power**.**

For determine the value of bus voltage e.g. we taking Bus no. 2 for determine the bus voltage ,following formula implemented –

$$V_2 = \frac{1}{Y_{22}}\left[\frac{(P_2 - jQ_2)}{V_2^*} - (Y_{11})(V_1) - (Y_{23})(V_3) - (Y_{2n})(Vn)\right]$$

The iteration will continue till the value of consecutive two iteration are same**.** For determine the value of next bus i.e. Bus No.3 the value of V2 is considered the latest value of last iteration.

For finding the value of angle **δ** the value of bus voltage convert in polar form and the value of angle is δ of the respective bus.

For determine the value of reactive power of PV buses the formula is…i.e. we are taking bus no. 2 for determine the value of reactive power.

$$Q_2 = -[V_2]spec.[Y_{21}(V_1)SIN(\delta_1+Y_{12}-\delta_2)] + [Y_{22}\ (V_{21})\ SIN(\delta_2+Y_{22}-\delta_2)] + \ldots \ldots\ [Y_{2n}\ (V_2)\ SIN(\delta n+Y_{22}-\delta_2)]$$

Newton Raphson Method

Newton Raphson method is one of another useful method for study the load flow problem.

The Newton-Raphson method is an iterative technique for solving systems of simultaneous equations in the general form:

$f_1(\varkappa_1,\ldots\ldots\varkappa_n,\ldots\ldots\varkappa_r) = K_1$
$f_j(\varkappa_1,\ldots\ldots\varkappa_n,\ldots\ldots\varkappa_r) = K_n$
$f_n(\varkappa_1,\ldots\ldots\varkappa_n,\ldots\ldots\varkappa_r) = K_r$

where $f_1,\ldots f_n\ldots f_r$ are differentiable functions of the variables $\varkappa_1,\ldots\varkappa_n,\ldots\varkappa_r$
and K_1, ...K_n..K_r are constants.

Applied to the load flow problem, the variables are the nodal voltage magnitudes and phase angles, the functions are the relationships between power, reactive power and node voltages, while the constants are the specified values of power and reactive power at the generator and load nodes.

In this method only 5 iterations are needed to generate results which are stable to three decimal places, even though the initial estimates of all three unknowns are far from the correct value.

When making comparisons with other methods of solution, it is important to realize that each iterative cycle of the Newton Raphson method involves considerable computational effort, notably to invert the Jacobian.

Artificial Neural Network Based (ANNB) load Flow

This method is based on a three-layered neural network. The inputs of the neural network are active and reactive power of loads and PQ DG units, voltage magnitude of PV DG units and their active power injected. The outputs of the third layer are the magnitude and angle of PQ nodes voltages, reactive power and voltage angle of PV DG units and power loss of the distribution network. For example, a modified NR load flow is run for several times to give various input-output patterns. Then the neural network is trained by back propagation method. As a result, the trained neural network can model the nonlinear load flow system and obtain the results of load flow for other different inputs. The advantage of ANNB load flow is its less computation time cost for online problems. On the other hand, ANNB method is more flexible.

Experimental tests show that capability of ANNB load flow allows it to produce a correct output even when it is given an input vector that is partially incomplete or partially incorrect .

It is suitable for online modern distribution network management as a challenge in smart grid. However, if the injected power by DG units changes in a wide range, ANNB is not useful. So it may not be helpful in renewable DG integrated networks.

Moreover, selecting of initial patterns to train the neural network is a challenge in this method. Using chaotic neurons controlled by heuristic methods in ANN can improve the disadvantages of ANNB load flow.

Particle Swarm Optimaization Applied to the Power Flow Computation

Particle Swarm Optimization Swarm Intelligence is a kind of Artificial Intelligence based on the behavior of the animals living in groups and having some ability to interact with one other and with the environment in which they are inserted [10]. PSO is a Swarm Intelligence algorithm employed to functions optimization, developed through the simulation of simplified social models as bird flocks flying randomly in search for food [10]. PSO uses a set of particles in which each one of them is a candidate to the solution of the treated problem. Such particles are distributed in an *n*-dimensional space, and each particle has a position and a velocity in each time instant. The best individual position of a particle is defined as *local best*, and the best position of all the particles is defined as *global best*. The PSO particles have knowledge about their performances and about their neighbors' performances. The interaction between the particles and the environment they are inserted is made by the *rule function*, which is related to the problem modeling [10]. The basis of the PSO algorithm consists in, instant time, analyzing the displacement of each particle in search for the best position and updating its velocity and position using specific equations. The iterative process proceeds until all the particles converge to the obtained global best, which is the adopted solution to the treated problem.

B. Definition of the Proposed Algorithm The proposed PSO algorithm is applied to the computational achievement of the load flow solution, based on the minimization of the power mismatches in the system buses [9]. The particles' positions are defined as the voltage modules and angles of the buses. Applying the PSO algorithm, instead of calculating these voltages through the SFLE, initial estimated values are adopted and updated at each process' iteration with the PSO equations, in order to obtain the lowest possible power mismatches. The particles positions can assume continuing values within the limits specified in the input data. The rule function parameters that will be minimized in the PSO algorithm are defined as *grades*. The grades are defined as the arithmetic mean of the buses apparent power. Each particle has a *local grade*, value obtained by its local best. The *global grade* is the grade related to the best global of all the particles. The *current grade* is the grade obtained by a particle at a given iteration.

The first step of the algorithm is to generate the initial values to the particles positions, velocities, local best parameters and global best parameters. The angles receive a random initial value within the specified boundary. Before the initialization of the module value of each particle, the bus type needs to be verified and related in the equation. In the case of a PQ bus, the voltage module receives a random value within the specified boundary; for a PV bus, the voltage module receives the related value specified in the input data. The initial velocities are null. The local best parameters receive the particles positions values and the global best parameter receives the first particle value, arbitrarily. The grades are initialized with high values in order to be minimized later. Having that accomplished, the iterations are initialized. The following process is accomplished to each particle of the swarm. Firstly the buses voltages receive the particles positions. The reactive power of the PV buses is calculated using equation (1), then the active and reactive power of the slack bus are also calculated using this equation. Finally the power flow in the system lines is calculated in accordance to the equation (2).

$S_{ij} = P_{ij} + jQ_{ij} = V_i(V_i^* \quad V_j^*)Y_{ij}^* + V_i V_i^* Y_{sh,i}$ (2)

Where:

Sij = complex apparent power between the buses i and j; Pij = active power between the buses i and j; Qij = reactive power between the buses i and j; Vi = bus i voltage; Vj = bus j voltage; Yij = admittance between the buses i and j; Ysh,i = *shunt* admittance of the bus i. Thus, once all the power of the buses and of the lines is known, the active and reactive power mismatches of each bus are calculated. They are calculated as the sum of the injected power in the approached bus. The apparent power mismatches arithmetic mean is obtained, and this is the value that is desired to be minimized. The local best is replaced by the current particle position in case of the particle current grade is considered better than the local grade. Thus, after all the particles pass through the described process, a similar criterion is used to the global best updating. Next each particle is verified in the following criteria: whether the local grade or global grade is best, the best global is replaced by the approached best local. The velocities as well as the particles positions are updated according to the equations (3), (4) and (5); which are, respectively: velocities equation, positions equation and inertia weight equation. Such equations are based on the classical PSO equations and have had modifications and coefficients adjusted empirically for an improved efficiency in resolving problems. [9,10,11].

(1).(((1) (1))]

(1) 1,4. . ( ) 2,6.(1).[.((1) (1))

+ +

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r g t x t
v t wv t w r l t x t (3)
$x(t+1) = x(t) + v(t+1)$ (4)
$w = 1 \quad t/ni$ (5)

Where: *i* = particle index; *t* = iterations counter; *ni* = total number of iterations; *v(t)* = particle *i* velocity at iteration *t*; *x(t)* = particle *i* position at iteration *t*; *r* = random value, random number between 0 and 1, generated by the program; *l(t)* = particle *I* local best fount at iteration *t*; *g(t)* = global best found at iteration *t*; *w* = velocity equation's inertia weight. In the end of the iterations, it is obtained the final global best, which is adopted as the load flow solution. The proposed methodology is summarized at the Fig. 1 pseudocode. A remark about the proposed methodology is made below. Each particle has an initial estimative for the state variables, and these estimated values are random within the specified limits. Moreover, the PSO equations involve also random values, so several final values can be achieved for the same initial estimative. Therefore, the proposed algorithm start with different initial estimated values and can achieve different final results acceptable to the power flow solution (it depends on the program simulation). It does not occur in the numeric traditional methods, which start with the same initial estimative values and achieve the same final results.
Fig. 1. Proposed Algorithm Pseudo-code.

IV. NUMERICAL RESULTS
The practical results associated to the proposed PSO algorithm are obtained in this section. It is used, for this purpose, the IEEE 6-bus test system [13], Fig. 2. The proposed methodology aims to the power flow solution based on the minimization of the power mismatches in the system buses. Tables I and II present the power flow results for the tested system, obtained through a traditional program applying the Newton-Raphson method. The results of two different and arbitrary simulations of the proposed computational program applying PSO are presented. They are called simulation 1 and simulation 2. Tables III and IV present the results related to the simulation 1 and Tables V e VI are related to the simulation 2. Each accomplished simulation has a different solution for the power flow due to the PSO algorithm nature, as mentioned in the previous section. However, once the values are within the permitted limits, all the presented solutions are valid. The odd-numbered tables present the results related to the system buses. These tables' three last columns show, respectively, the active power mismatches, the reactive power mismatches and the apparent power mismatches. These values must be taken into account, as the power flow calculation through the proposed PSO algorithm applies the minimization of the apparent power mismatches in the system buses. The comparison of the mismatches results obtained in the load flow using the Newton-Raphson method and the PSO proposed algorithm comes to the conclusion that PSO presents, in general, better mismatches results for the system buses, except for the bus 6. This is due to the power mismatches values obtained through PSO were, in general, lower values than those of the obtained using the traditional Newton-Raphson method. The even-numbered tables present the results related to the system lines. These tables show the power flow in the system lines obtained for the voltage solutions found in each approached simulation

Bus System
For our research work we have taken IEEE 57 bus sytem :-
Line data of IEEE 57 bus system is given in table -1. We use these data to calculate the YBUS of IEEE 57 test bus system which is further use in Newton-Raphson load flow analysis of IEEE 57 bus system. As we see from the standard IEEE 57 bus data the bus system has
a) 1 slack bus
b) 4 generator or PV buses
c) 52 load or PQ buses
By using the load data and bus data we calculate the voltage at each bus by Newton Raphson load flow method.

BUS NO.	VOLTAGE
1	1.0400
2	1.0500
3	1.0450
4	1.0459
5	1.0444

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6	1.0400
7	1.0532
8	1.0463
9	1.0400
10	1.0598
11	1.0555
12	1.0570
13	1.0559
14	1.0571
15	1.0564
16	1.0545
17	1.0491
18	1.0793
19	1.1002
20	1.1109
21	1.1671
22	1.1689
23	1.1697
24	1.1780
25	1.2149
26	1.1270
27	1.1143
28	1.1077
29	1.1012
30	1.2256
31	1.2349
32	1.2213
33	1.2318
34	1.1774
35	1.1744
36	1.1707
37	1.1697
38	1.1677
39	1.1693
40	1.1689
41	1.1481
42	1.1709
43	1.1153
44	1.1555
45	1.1274
46	1.1734
47	1.1716
48	1.1706
49	1.1730
50	1.1626
51	1.1447
52	1.1181
53	1.1251
54	1.1211
55	1.1143
56	1.1806
57	1.1873

Table 1.1

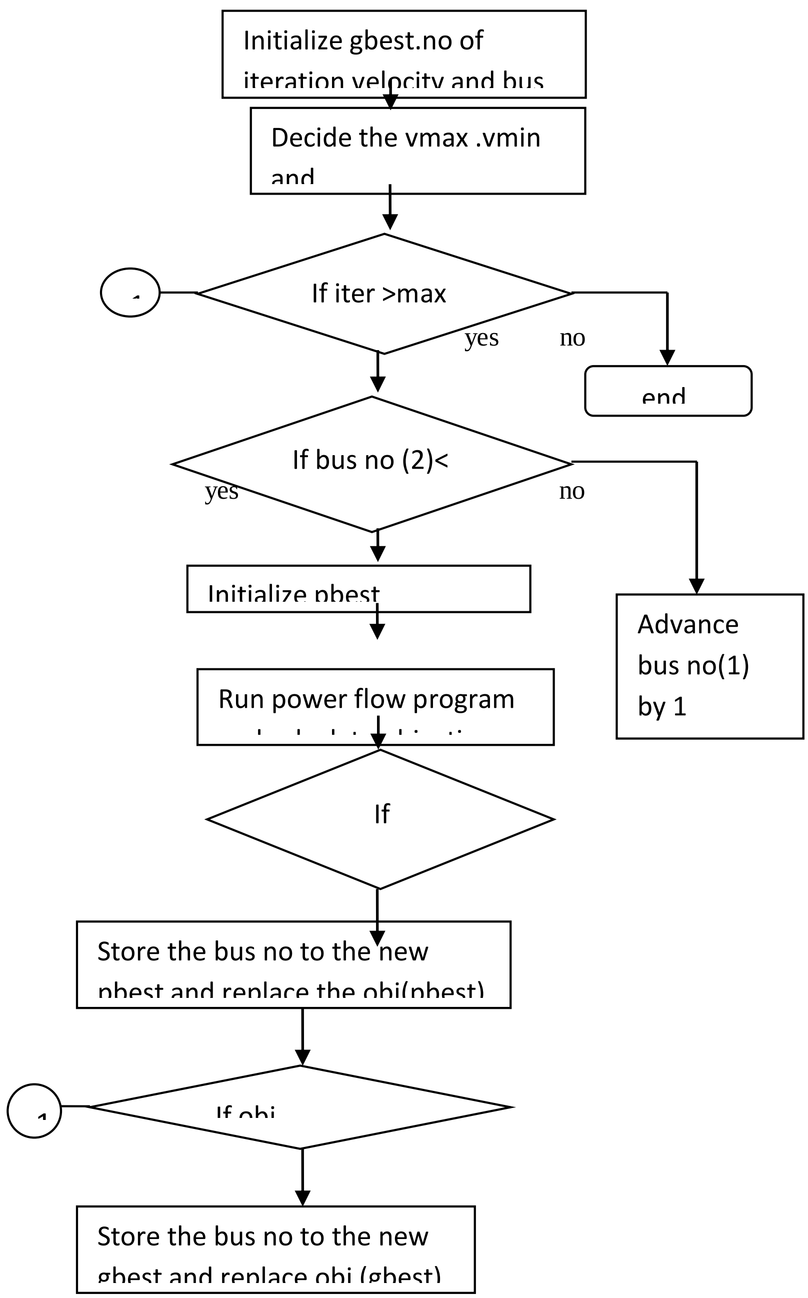
OBJECTIVE FUNCTION

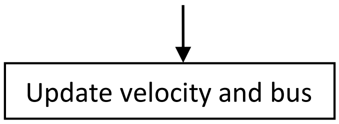
Objective function (J) is a RMS value of voltage deviation. It is given by

$$V_d = \sqrt{\sum_{i=1}^{N} (V_i - 1)^2}$$

Our main objective is to minimize the objective function because less objective function means less voltage deviation and good stability. Without using STATCOM the objective function of the IEEE 57 bus is **1.0975**.

Algorithm of PSO





PSO Parameter

We take the following PSO parameter by applying hit and trail method.

Inertia weight: we can take inertia weight in three manner

a) Constant inertia weight- the inertia weight can be taken constant throughout the process but it seems somewhat unconvincing because as the particle reach near the final solution the impact of pbest and gbest should be increase to avoid to trap in local minima.

b) Linearly decreasing inertia weight –we can tan take inertia weight as linearly decreasing but it has also problem to trap in local minima.

c) Randomly decrease inertia weight- in our thesis we take inertia weight as randomly decreasing inertia weight as it has not any problem to trap in local minima.

So for our study we take inertia weight as a function which decrease randomly from .9 to .1.

It is given by following

$$W_i = 0.9-0.8* \frac{iter -1}{max\ iter-1}$$

No. of of particle: we have taken 5 particle with the random initial STACOM position.

Acceleration constant: there are two accelerations constant we use.

a) Individual acceleration constant- this acceleration constant is used for show the impact of individual particle best position gain by particle it self on the next value of velocity of that particle. It is denoted by c1. For our study we take c1=2.6

b) Social acceleration constant- the social acceleration constant is used to show the effect of best position gained by any particle(gbest) on the next value of velocity of that particle. It is denoted by c2. For our study we take c2=1.4.

5.4.4 No of iteration: 10 iterations is sufficient while we deal with single STATCOM and when we use 2 STATCOM we need minimum 30 iterations.

RESULT

A. By using STATCOM:

a) Without Using PSO- without using PSO we have to calculate the objective function while apply the STATCOM on every bus one by one and then we can choose the optimal bus location with the minimum objective function. while we use only single STATCOM it is very easy to find the optimal location .because we have to check only 57 bus.

As we see that when we connected the STATCOM without using the PSO the min value of objective function is 0.9553 .we get the minimum value of objective function which is 0.9553 which is very less in comparison of other previous objective function without using STATCOM then 1.0957

b) By using PSO

When we use the particle swarm optimization techniques the min. objective value is 0.9020 and the optimal location is bus no. 15.And the no of iteration is also reduced to only 10.

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