JOURNAL OF CRITICAL REVIEWS

ISSN- 2394-5125 VOL 7, ISSUE 02, 2020

EXPERIMENTAL STUDY OF POWER SYSTEM MODELLING

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Received : 25.11.2019 Revised : 27.12.2019 Accepted : 30.01.2020

ABSTRACT

This paper predominantly manages the demonstrating of the force framework. The dynamic demonstrating of the 3-machine, 9-transport power framework is depicted in this paper. This displaying helps in the transient security investigation of the force framework. This model is utilized to investigate the transient dependability utilizing the proposed savvy calculations, for example, Non-Dominated Ranked Genetic Algorithm (NRGA), Artificial Bee Colony (ABC) and Enhanced Searching with Sensibility Replace Artificial Bee Colony (ESSRABC) strategies.

Keywords: power system, NRGA, ABC and ESSRABC.

1. INTRODUCTION

The multi-machine power framework adjustment idea has been actualized utilizing MATLAB simulink condition. The adjustment calculations, for example, NRGA, ABC and ESSRABC separately are executed in the simulink condition utilizing MATLAB work blocks. These calculations gather the boundaries of the multi machine framework, and afterward it will discover the eigenvalues and damping proportion to tune the PSS boundaries.

This paper likewise examines about the force framework stabilizer structure, its target capacity and tuning of the force framework stabilizer.

2. POWER SYSTEM MODELING

Little sign soundness investigation requires dynamic displaying of significant force framework parts, for example, the simultaneous generator, excitation framework, AC organization, and so forth., according to Venkateswara Reddy et al (2012). For the most part, coordinated generator acts complicatedly, in this way, accomplishing a definite model is really incomprehensible for such generators; be that as it may, demonstrating of the simultaneous generator is basic for investigation of the force system. The complex nonlinear model identified with a N-machine interconnected force framework, can be portrayed by a lot of differential-mathematical conditions by collecting the models for every generator, load and different gadgets, for example, controls in the framework, and interfacing them fittingly through the organization arithmetical conditions as depicted by Shayeghi et al (2008). The simultaneous generator with an excitation framework is assessed and the issue is to look for ideal arrangement of PSS boundaries.

1.State-Space Representation

A power system can be modeled by a set of nonlinear differential equations as (representing the power system operating at various conditions):

X = f(X, U) ………………………………………………………….(1)

where,

X is the nonlinear differential condition

X is the vector of the state factors, X =

δ speak to the rotor edge in elec. rad.

ω speak to the rotor speed in elec. rad./sec.

Eq speak to the inside transient voltage in p.u.

Efd is the E identical excitation voltage in p.u.

U speaks to the PSS yield signals

A force framework can be displayed by a lot of nonlinear differential conditions. In this work, the accompanying third request model of the ith machine is utilized. The accompanying model is generally viewed as adequately exact to examine electromechanical elements.

$\dot{\delta}_i = \omega_b(\omega_i - 1)$ …………………………………...(2)

$$\dot{\omega}_i = (P_{mi} - P_{ei} - D_i(\omega_i - 1))/M_i \quad \text{……………….(3)}$$

$$\dot{E}'_{qi} = (E_{fdi} - (x_{di} - x'_{di})i_{di} - E'_{qi})/T'_{doi} \quad \text{……………(4)}$$

$$T_{ei} = E'_{qi}i_{qi} + (x_{qi} - x'_{di})i_{di}i_{qi} \quad \text{…………………..(5)}$$

where,
M speaks to the machine dormancy consistent in MJ-s/elec. rad.
D speaks to the damping coefficient
Pm speaks to mechanical information power
Pe speaks to electrical yield power
id and level of intelligence are stator flows in d-hub and q-hub circuits individually
xd and xq are d-pivot and q-hub simultaneous reactance's individually
xd is the d-pivot transient reactance T is the time consistent of excitation circuit
KA and TA speaks to controller increase and controller time consistent individually
Te is the electric force in N-M
To examine the little sign steadiness at one working point as given by the condition (1) should be linearized. Expect xo is the underlying satiate vector at the current working point and u0 is the comparing input vector.
Since the annoyance is viewed as little, the non-straight capacities f can be communicated regarding taylor's arrangement articulation. By utilizing just the principal request terms, the guess for the ith state variable xi prompts the accompanying conditions with r as the quantity of data sources

$$\dot{x}_i = \dot{x}_{io} + \Delta\dot{x}_i \quad \text{……………………………….(6)}$$

$$\dot{x}_i = f_i(x_0, u_0) + \frac{\partial f_i}{\partial x_1}\cdot\Delta x_1 + \cdots + \frac{\partial f_i}{\partial x_n}\cdot\Delta x_n + \frac{\partial f_i}{\partial u_1}\cdot\Delta u_1 + \cdots + \frac{\partial f_i}{\partial u_r}\cdot\Delta u_r \quad \text{…………(7)}$$

with $x_i = f_i\,(x_0, u_0)$, the derived linearized state vector x is

$$\Delta\dot{x}_i = \frac{\partial f_i}{\partial x_1}\cdot\Delta x_1 + \cdots + \frac{\partial f_i}{\partial x_n}\cdot\Delta x_n + \frac{\partial f_i}{\partial u_1}\cdot\Delta u_1 + \cdots + \frac{\partial f_i}{\partial u_r}\cdot\Delta u_r \quad \text{…………………(8)}$$

Similarly the linearization for the system outputs y

$$\Delta\dot{x}_i = \frac{\partial f_i}{\partial x_1}\cdot\Delta x_1 + \cdots + \frac{\partial f_i}{\partial x_n}\cdot\Delta x_n + \frac{\partial f_i}{\partial u_1}\cdot\Delta u_1 + \cdots + \frac{\partial f_i}{\partial u_r}\cdot\Delta u_r \quad \text{………………..(9)}$$

Then the linearized system can be written in the following form:

$$\Delta\dot{x} = A.\Delta x + B.\Delta u \quad \text{…………………………………(10)}$$

$$\Delta y = C.\Delta x + D.\Delta u \quad \text{……………………………………..(11)}$$

where,
A - State matrix (system matrix)
B - Control matrix
C - Output matrix
D - Feed forward matrix
From the stability view point, the state matrix A is most important. This matrix includes the derivations of the n nonlinear ordinary differential equations of the system with respect to the n state variables x:

$$A = \begin{bmatrix} \frac{\partial f_1}{\partial x_1} & \cdots & \frac{\partial f_1}{\partial x_n} \\ \vdots & \ddots & \vdots \\ \frac{\partial f_n}{\partial x_1} & \cdots & \frac{\partial f_n}{\partial x_n} \end{bmatrix} \quad \text{……………………(12)}$$

2. Eigenvalues and System Stability

The eigenvalues λ of the state matrix A can be computed by solving the characteristics equation of A with a vector Φ:

$$A.\Phi = \lambda.\Phi \quad \text{……………………………………………(13)}$$

$$(A\text{-}\lambda I).\ \Phi = 0 \quad \text{…………………………………………(14)}$$

$$\text{Determent } (A\text{-}\lambda I) = 0 \quad \text{……………………………………..(15)}$$

This lead to the complex eigenvalues of A in the for

$\lambda = \sigma \pm j\omega$ ………………………………………...(16)

The damping of the corresponding mode is defined by the real part and the imaginary portion represents the frequency (f) of the oscillation provided by the mode.

$f = (\omega/2\Pi)$ ………………………………………………(17)

The prediction of stability in this analysis is based on the Lyapunov equation. According to this approach, the roots of the characteristic equation have the oscillatory stability of a linear structure (15). The eigenvalues of A from equation (16) can be used for this prediction:

- The initial framework is asymptotically stable because the eigenvalues have negative real parts (< 0).
- When eigenvalues has a positive real part ($\sigma > 0$), the original system is unstable.
- When $\omega \neq 0$, the system has a oscillatory response.
- When $\omega = 0$, the system has a non oscillatory response.

3. EXCITATION SYSTEM

This analysis considers the IEEE Type-ST1 (1992) excitation mechanism seen in Figure 1. It can be defined as:

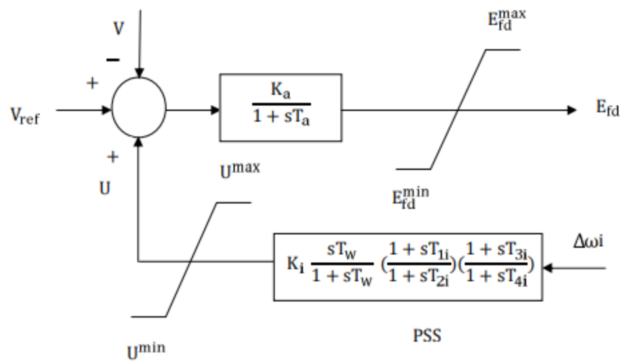

Figure .1 IEEE Type-ST1 Excitation System with PSS

$\dot{E}_{fdi} = (K_{Ai}(V_{refi} - V_i + U_i) - E_{fdi})/T_{Ai}$ ………………(18)

$V = (V_d^2 + V_q^2)^{1/2}$ ………………………………………(19)

$V_d = x_q i_q$ ……………………………………………(20)

$V_q = E'_q - x'_d i_d$ …………………………………(21)

where,

The terminal voltage and reference voltages are V and V.

V and V are the d-axis and q-axis terminal voltages, respectively.

Kai and T are the regulator gain and time constant respectively

E_{fd}^{max} and E_{fd}^{min} are the upper and lower limits of Efd

4. Power System Stabilizer Structure

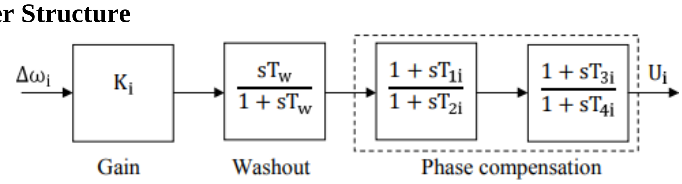

Figure .2 Structure of Power System Stabilizer

Haruni et al (2009) has described the conventional lead-lag PSS which is considered in this study as

$$U_i = K_i \frac{sT_w}{1+sT_w} \frac{(1+sT_{1i})}{(1+sT_{2i})} \frac{(1+sT_{3i})}{(1+sT_{4i})} \Delta\omega_i(s)$$ …………..(22)

where, Ui represents the PSS output signal

Ki is the stabilizer gain

T_w is the washout time constants represents the differential operator

$\Delta\omega i$ is the deviation in speed from the synchronous speed T1i - T4i are the time constants
The sum of damping added by the PSS is calculated by Benefit block (Ki). The benefit should preferably be set to a value equal to the highest damping level. It is, however, also hampered by other factors.
A high-pass filter acts as the washout block. Without it, the terminal voltage will be changed by frequent speed shifts. This enables the PSS to only respond to changes in tempo. The value of Tw is not important from the point of view of the washout feature and may be in the 0.5 to 20 second range. The primary concern is that it should be long enough to transfer stabilizing signals unchanged at the frequencies of interest, but not so long that under device islanding conditions it contributes to unwanted generator voltage excursions.
The phase compensation block offers the required phase-lead function to compensate for the phase lag between the input of the exciter and the electrical torque of the generator. A single first order block is seen in the diagram. In fact, to obtain the desired step reward, two or three first-order blocks can be used. The frequency spectrum of importance is usually 0.1 to 2.0 Hz, and across this whole frequency range, the step lead network may have compensation. Therefore, a solution is made and a trait suitable with various system conditions is chosen to be compensated for the process function differences with system conditions.
Deviations in rotor speed), (frequency (f), electrical power Pe, and accelerated power (Pa) are included in the input signals that have been defined as important. Because the key operation of the PSS is to regulate the oscillations of the rotor, the most commonly recommended in the literature was the rotor speed input signal.
However, frequency was found to be extremely proportional to the power of the transmitting mechanism, which is more proportional when the device is slower, which may counteract the regulation operation of the machine's electrical torque. The emergence of abrupt phase changes following fast transients and large signal noise caused by industrial loads are other limitations. On the other side, the frequency signal is more prone than the speed signal to inter-area oscillations and can have greater attenuation of the oscillation. A speed signal is used as an input signal in this dissertation work.
The Phase Adjustment Architecture Strategy consists of changing the stabilizer parameters via the generator excitation device to compensate for the phase lags and the power mechanism so that the torque varies with velocity changes in motion. This is the easiest technique, readily interpreted and executed. The pause in process depends on the operating point and the parameters of the device.
The algorithm for PSS parameter computation is as follows:
Phase 1: N from the mechanical loop, receive n
The mechanical loop's characteristic equation can be written as:

$$Ms^2+Ds+\omega_b K_1=0 \quad \text{.......................................(23)}$$

where, ω_b is the system frequency in rad./sec. and ω_n is the undamped natural frequency of the mechanical mode and is given below:
Step 2: Compute phase lag $\angle G_e$ between U and T_m of the loop to be compensated by PSS. G_e is the transfer function.

$$\omega_n=\sqrt{\left(\frac{K_1\omega_b}{M}\right)} \quad \text{...(24)}$$

Step 3: Design of phase lead lag compensator. The transfer function of phase lead compensator G_c is

$$G_c = \frac{(1+sT_{1i})}{(1+sT_{2i})}\frac{(1+sT_{3i})}{(1+sT_{4i})} \quad \text{.........................(25)}$$

For the full compensation ∟Ge + ∟Gc = 180o
T1i-T4i and Ki are the PSS parameters to be optimized. In consideration of two similar lead-lag cascade networks for PSS. T1i = T3i and T2i = T4i, thereby limiting the issue to Ki, T1i and T3i optimization only. The option was Tw = 10s. One lead lag block is used to compensate for step lag of around 50o, and lead lag blocks are picked accordingly. In order to completely adjust for step latency, the PSS parameters T1i and T2i are selected as follows:
Let, β is the phase lag compensated by one block, then

$$T_2 = (1/\omega_n\sqrt{a}) \quad \text{.......................................(26)}$$

Where, $a = \frac{1-\sin\beta}{1+\sin\beta}$ and $T_1 = aT_2$

The PSS parameters that are customizable are the PSS, K gain and the time constants, T-T. Phase lead mitigation for the phase lag that is added throughout the circuit between the exciter input and the electrical torque is given by the lead-lag block present throughout the device. Even if the denominator portion consisting of T and T provides a defined lag angle, the appropriate step lead may be extracted from the lead-lag block. Thus, the values of T and T are held steady at a rational value of 0.05 sec in order to reduce the numerical pressure in this analysis and the tuning of T and T is performed to obtain the net step lead needed by the method.

Step 4: The setting of the sum of damping applied depends on the gain at the frequency of the PSS transfer function. Ideally, a value equivalent to the highest damping should be set for the gain. The PSS benefit Ki desired is determined from

$$K_i = (2\varsigma_i\ \omega_n M) / (|G_c|\ |G_e|) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(27)$$

where, ς is the desired damping ratio

Performance Indices It is an attempt to follow a collection of requirements which, in terms of certain observable quantities, determine the overall output of the device. In terms of complex reaction to phase feedback and the steady state error of both stage and higher order inputs, a variety of output indicators have been adopted thus far. The Integral Square Error (ISE), given by:, is the most popular output index.

$$ISE=\int_0^\infty e^2(t)\,dt \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(28)$$

4. Test System

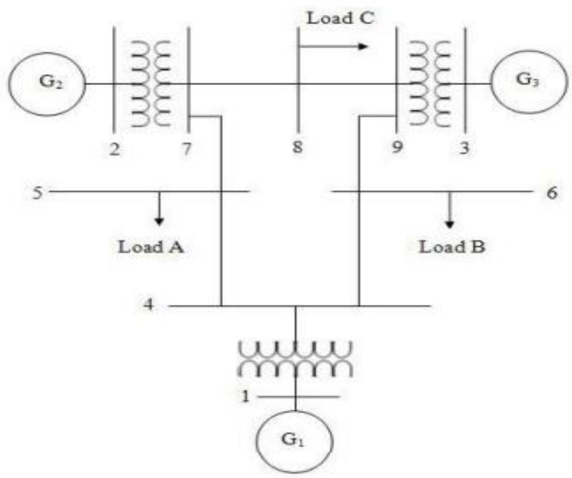

Figure.3 Single Line Diagram of WSCC 3-Machine, 9-Bus System

In Figure 3, the multi-machine power system model considered for this method is shown. The multi-machine device considered here is a 3-machine, 9-bus framework from the Western Networks Coordinating Council (WSCC). Consideration is provided to the G1, G2 and G3 machines present in the multi-machine structure.

Table.1 Generator Data

Generator	1	2	3
Rated MVA	247.5	192.0	128.0
kV	16.5	18.0	13.8
Power Factor	1.0	0.85	0.85
Type	Hydro	Steam	Steam
Speed	180 rpm/min	3600 rpm/min	3600 rpm/min
x_d	0.1460	0.8958	1.3125
x'_d	0.0608	0.1198	0.1813
x_q	0.0969	0.8645	1.2578
x'_q	0.0969	0.1969	0.25
x_l(leakage)	0.0336	0.0521	0.0742
T'_{do}	8.96	6.00	5.89
T'_{qo}	0	0.535	0.600
Stored energy at rated speed	2364 MW-s	640 MW-s	301 MW-s

5. OBJECTIVE FUNCTION AND PSS TUNING

During an unstable state, the decreasing rate of oscillation of the power system is calculated by the highest actual component of the power system's own value (damping factor) and the magnitude of each oscillation mode is calculated by its damping ratio. Thus, for the optimum environment of PSS parameters, the objective functions naturally include the damping ratio and damping component in the formulation. Consequently, for the optimum configuration of

A multi-objective function may be formulated as follows: PSS parameters,

J = - min (real (eigenvalues) / abs (eigenvalues))……………………………………. (29)

So, for a certain parameter range, the goal here is to optimize the minimum damping ratio. Maximizing the damping ratio would definitely aid in enhancing the overall damping of the device. In this case, the stabilizer parameter bounds are the problem constraints. It is then necessary to formulate the architecture dilemma as the following optimization method:

The following objective function J is, thus, used

$$J = \max(\min(\varsigma_i))\{i \in \text{set of number of eigenvalues}\} \qquad \text{……………………….(30)}$$

where, ς is the damping ratio associated with electromechanical modes

$$\varsigma_i = \frac{-\sigma_i}{\sqrt{\sigma_i^2+\omega_i^2}}$$ = is the damping ratio of the i^{th} eigenvalue……………………………………………….(31)

where, σi and ωi are the real part and the imaginary part (frequency) of the i^{th} eigenvalues respectively

In order to increase the device damping element, fixed time and maintain a degree of relative stability, this objective method is suggested to move these eigenvalues to the left of the S-plane. The goal of the stabilizer design method is to increase the device damping of the proper values of the badly damped electromechanical mode across the whole range of the defined loading conditions.

Closed loop eigenvalues are restricted to the left of a vertical line corresponding to the damping factor defined. To reduce the following objective function, the parameters of the PSS can be chosen:

$$J_1 = \sum_{\sigma_i \geq \sigma_0} (\sigma_0 - \sigma_i)^2 \qquad \text{…………………………………(32)}$$

There, the actual component of the eigenvalue of ith is and is a threshold selected. The meaning reflects the desirable damping degree of the device. By moving the dominant eigenvalues to the left of s = line in the s-plane, this degree can be accomplished. This guarantees a degree of financial peace as well. The requirement is placed on the J1 assessment to take into consideration only the unreliable or badly damped modes that belong specifically to electromechanical modes. Relative stability is measured by the value of. In a field in which, as seen in Figure .4, the closed-loop eigenvalues will be located.

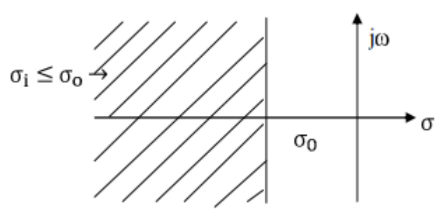

Figure 4 Region in the Left-Side of the S-plane (J_1)

To limit the maximum overshoot, the parameters of the PSS may be selected to minimize the following objective function:

$$J_2 = \sum_{\varsigma_i \leq \varsigma_0} (\varsigma_0 - \varsigma_i)^2 \qquad \text{…………………………..(13)}$$

where, ς is the damping ratio of the i^{th} eigenvalue. This will place the closed- loop eigenvalues in a wedge-shape sector in which $\varsigma \geq \varsigma$ as shown in Figure.5.

ISSN- 2394-5125 VOL 7, ISSUE 02, 2020

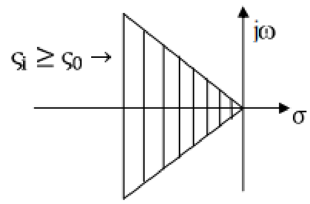

Figure .5 Region in the Left-Side of the S-plane (J_2)

In the case of J2, the optimal damping ratio needed to be obtained is the optimal necessary. It is important to note here that if it is only appropriate to migrate unique eigenvalues, then only such eigenvalues should be taken into account in the estimation of the objective property. In dynamic equilibrium, this is commonly the case where the electromechanical modes of oscillations are needed to be moved.

The parameters of the PSS may be selected to minimize the following objective function:

$J_3 = J_1 + aJ_2$ …………………………………………..(34)

This will place the system closed-loop eigenvalues in $\sigma i \leq \sigma$ and as shown in Figure .6.

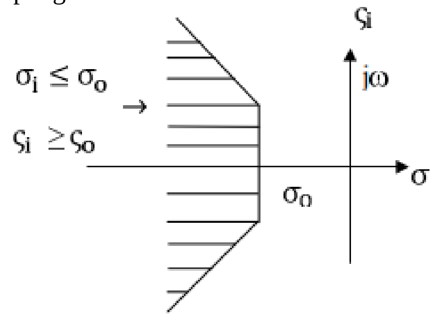

Figure .6 Region in the Left-Side of the S-plane (J_3)

The optimized parameter boundaries are the problem constraints. It is also necessary to formulate the architecture problem as the following optimization problem.

The goal function (J), according to the following restrictions, is reduced.

$$K_i^{min} \leq K_i \leq K_i^{max}$$

$$T_{1i}^{min} \leq T_{1i} \leq T_{1i}^{max}$$

$$T_{3i}^{min} \leq T_{3i} \leq T_{3i}^{max}$$

………………………….(35)

The time constant T and T values are set to provide damping across the frequency range in which oscillations are expected to occur. The step lag which is caused by the computer should be compensated across this period. [0.01 and 50] for K and [0.01 and 1.0] for T and T, defined by Abel-Magid et al (1999), are the standard ranges of these parameters. As defined by Abel-Magid w et al (1999), the time constants T, T and T are set as 5, 0.05 and 0.05 seconds respectively.

6. OBJECTIVE OF THE STUDY

1. The stabilization algorithms for the proposed power system are contrasted with the efficiency of the Genetic Algorithm power system stabilization solution.
2. Approaches are tested based on such parametric output criteria, such as Electromechanical Mode Eigenvalues, Objective Function, Load Disturbance Device Reaction and Terminal Voltage Responses.

7. CONCLUSION

This paper explores the design of the power system and the parameters of the controller that describe the power system working under different conditions. For transient stability study of the power device, a 3-machine, 9-bus multi-machine power system structure is used. This paper explains the objective function and control system stabilizer tuning parameters.

8. REFERENCES

[1] Abel-Magid, Y.L., Abido, M.A., Ai-Baiyat, S. and Mantawy, A.H. "Simultaneous Stabilization of Multi-Machine Power Systems via Genetic Algorithms", IEEE Transactions on Power Engineering Society, Vol. 14, No. 4, pp. 1428-1439, 1999.

[2] Abido, M.A. "Robust Design of Power System Stabilizers for MultiMachine Power Systems using Differential Evolution", IEEE Transactions on Energy Conversion, Vol. 1, No. 2, pp. 654-660, 2010.

[3] Adel M. Sharaf and Adel A.A. EL-Gammal, "A MOPSO Tri-loop Self Regulated Variable Structure Sliding Mode Self Regulating Coordinated Controller for Tidal Wave Energy Conversion", European Symposium on Computer Modeling and Simulation, Vol. 1, No. 1, pp. 389-394, 2009.

[4] Adil Baykasoulu, Lale Ozbak r and Pinar Tapkan, "Artificial Bee Colony Algorithm and its Application to Generalized Assignment Problem", Itech Education and Publishing, Vol. 1, No. 1, pp. 532, 2007.

[5] Ahmed AI-Ani, "Feature Subset Selection using Ant Colony Optimization", International Journal of Computational Intelligence, Vol. 2, No. 1, pp. 461-465, 2005.

[6] Ajith Abraham, Ravi Kumar Jatoth and Rajasekhar, A. "Hybrid Differential Arti cial Bee Colony Algorithm", Journal of Computational and Theoretical Nanoscience, Vol. 9, No. 1, pp. 1-9, 2012.

[7] Al Habri, W., Azzam, M., Chaklab, M., Al Dhaheri, S., Lamont, L.A., Faisal, S.F. and Abdel-Magid, Y.L. "Design of PID Controller for Power System Stabilization using Particle Swarm Optimization", International Conference on Electric Power and Energy Conversion Systems, Vol. 4, No. 5, pp. 1-6, 2009.

[8] Alcalde, V.H.C., Fernandes, A.A. and Soares, L.R. "Electrical Power Systems Stabilization through Series Compensation by using Variable Structure Control", International Workshop on Variable Structure Systems, Vol. 1, No. 1, pp. 98-103, 2006.

[9] Ali T. Al-Awami, Abdel-Magid, Y.L. and Abido, M.A. "A ParticleSwarm based Approach of Power System Stability Enhancement with Unified Power Flow Controller", International Journal of Electrical Power and Energy Systems, Vol. 29, No. 3, pp. 251-259, 2007.

[10] Amirhossein Chambari, Seyed Habib Rahmaty, Vahid Hajipour and Aida Karimi, "A Bi-Objective Model for Location-Allocation Problem within Queuing Framework", World Academy of Science, Engineering and Technology, Vol. 54, No. 7, pp. 2378-2385, 2011.