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Power System Stability Analysis of Single Machine Infinite Bus System using Firefly Algorithm

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Abstract – **With the growth of interconnected power systems and particularly the deregulation of the industry, difficulties related to low frequency oscillation have been widely reported, together with major incidents. As the most economical damping controller, power system stabilizer (PSS) has been widely used to suppress the low frequency oscillation and enhance the system dynamic stability. Traditional methods for determining PSS placements are based on the analysis of the interconnected system. Though, the design of the PSS is based on a simplified single machine infinite bus (SMIB) model. Traditional methods for determining PSS placements are based on the analysis of the interconnected system. In this paper, the design of the PSS is based on a simplified single machine infinite bus (SMIB) model using Firefly Algorithm. SMIB with PID controller is also implemented.**

Keywords –**FACTS, Firefly, PID, PSS, PSO, SMIB, TCSC. SVC.**

I. Introduction

The analysis of eigenvalues and the modal analysis of the linearized power system are powerful tools for studying the dynamic properties of the system. These methods are techniques that are used to determine whether the system is stable or unstable. The following sections describe these techniques in detail. Which are devices based on the recent advanced in power electronics, can be modified to participate in the damping of electromechanical oscillations. FACTS systems, such as static var compensator (SVC), thyristor controlled series capacitor (TCSC), static synchronous series compensator (SSSC) are mainly placed in the power system for various reasons, Reactive power exchanges, network voltages, etc.). However, a controller and a signal.

Additional stabilization can be added to improve stability. In addition to these main roles, FACTS can satisfy the problems of stability [1].

These systems remain very expensive to be installed solely for a reason of damping of the oscillations.

Yousef et al. [2], use LQR and LQG to design the PSS. In the literature, several research on heuristic techniques and artificial intelligence has been proposed and successfully implemented to enhance the dynamic stability of the system [3-4].

Different approaches using the genetic algorithm [5-6]. The advantage of GAs over other optimization techniques is their independence from the complexity of the problems. In addition, he works on a population set [7-8]. Also, the Particle swarm optimization (PSO) technique inspired by the movement of insects, birds and fish [9]. It reads genetic algorithms and evolutionary programming. Particle swarms are a new class of algorithms for solving optimization problems [10].

II. Proposed Methodology

Single Machine Infinite Bus System

The power system is a high order complex nonlinear system. In order to simplify the analysis and focus on one machine, the multi-machine power system is reduced to the single machine infinite bus (SMIB) system. In the SMIB system, the machine of interest is modelled in detail while the rest of the power system is equated with a transmission line connected to an infinite bus.

As shown in Figure 1, Single machine is connected to infinite bus system through a transmission line having resistance r_e and inductance x_e.

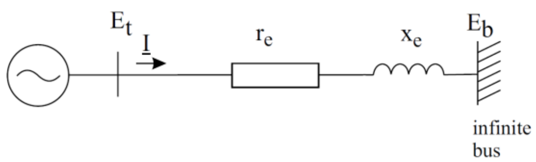

Figure 1: Single machine infinite bus system

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The generator is modelled by transient model, according to the following equations. All system data can be found.

Stator winding equations:

$$v_q = -r_s i_q - x'_d i_d + E'_q \quad (1)$$

$$v_d = -r_s i_d - x'_q i_q + E'_d \quad (2)$$

Where

r_s is the stator winding resistance

x'_d is the d-axis transient resistance

x'_q is the q-axis transient resistance

E'_q is the q-axis transient voltage

E'_d is the d-axis transient voltage.

Rotor winding equations:

$$T'_{do}\frac{dE'_q}{dt} + E'_q = E_f - (x_d - x'_d)i_d \quad (3)$$

$$T'_{qo}\frac{dE'_d}{dt} + E'_d = E_f - (x_q - x'_q)i_q \quad (4)$$

Where,

T'_{do} is the d-axis open circuit transient time constant,

T'_{qo} is the q-axis open circuit transient time constant

E_f is the field voltage.

Torque equation:

$$T_{el} = E'_q i_q + E'_d i_d + (x'_q - x'_d)i_d i_q \quad (5)$$

Rotor equation:

$$2H\frac{d\omega}{dt} = T_{mech} - T_{el} - T_{damp} \quad (6)$$

Then

$$T_{damp} = D\Delta\omega \quad (7)$$

Where

T_{mech} is the mechanical torque, which is constant in this model.

T_{el} is the electrical torque.

T_{damp} is the damping torque and

D is the damping coefficient.

For the study of single machine infinite bus system a Heffron-Phillips model can be obtained by linearizing the system equations around an operating condition. The obtained Heffron model is as in figure 2 and the parameters are:

$K_1 = 0.5320$, $K_2 = 0.7858$, $K_3 = 0.4494$, $K_4 = 1.0184$, $K_5 = -0.0597$, $K_6 = 0.5746$, $K_A = 20$, $M = 7$.

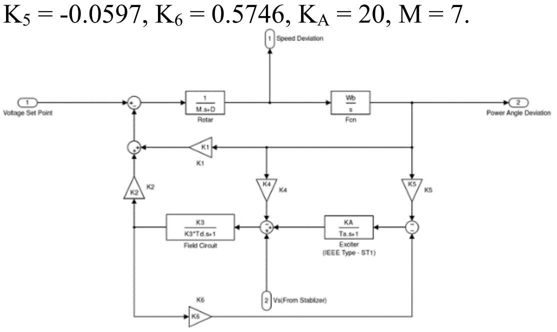

Figure 2: Heffron-Phillips model – SMIB

Figure 3 showing the SIMULINK Implementation of Phillip-Heffron model stated above.

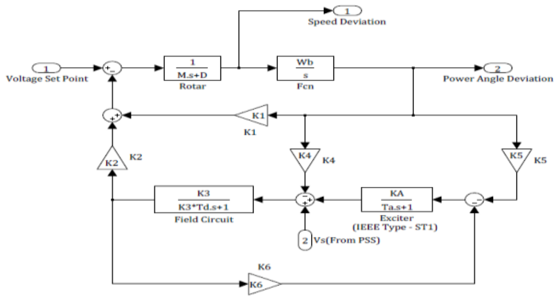

Figure 3: Simulink implementation of SMIB

The parameters of Heffron-Phillips model are optimized using Firefly Algorithm which is explained in following sub-section.

Firefly Algorithm

Fireflies are small flying beetles capable of producing a cold flashing light for mutual attraction. In the common language between fireflies, they are also used synonymous lighting bugs or glow worms. These are two beetles that can emit light, but fireflies are recognized as species that have the ability to fly. These insects are able to produce light inside their bodies through special organs located very close to the surface of the skin. This light production is due to a type of chemical reaction called bioluminescence [11]. Females can mimic the light signals of other species in order to attract males to capture and devour them. The fireflies have a capacitor type mechanism, which slowly discharges until certain threshold is reached, they release the energy in the form of light. The phenomenon is repeated cyclically. The firefly algorithm developed by Yang [12] is inspired by the attenuation of light over distance and mutual attraction, but he considers all fireflies to be unisex.

Principle of operation of the algorithm of Fireflies

The Firefly algorithm [12] [13] [14] [15] was presented by XS Yang in 2008. The algorithm is based on the principle of attraction between fireflies and simulates the behaviour of a group of fireflies in nature.

The algorithm takes into account the following three points [14]:

All fireflies are unisex, which makes the attraction between these is not based on their gender.

The attraction is proportional to their brightness, so for two fireflies, the less bright will move towards the brighter. If no firefly is luminous that a particular firefly, the latter will move randomly.

The luminosity of the fireflies is determined according to an objective function (to be optimized).

Based on these three rules, the Firefly algorithm is as follows:

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Define an objective function $f(x),\ x = (x_1, \dots, x_d)^T$
Generate a population of fireflies $x_i\ (i = 1, 2, \dots, n)$
Define the intensity of light I at a point x_i by the objective function $f(x_i)$
Determine the absorption coefficient γ
As long as (t <Max Generation)
  For $i = 1$ to n
    For $j = 1$ to n
      If $(I_i < I_j)$
        Move the firefly j to the firefly i
      End if
      Vary the attraction as a function of the distance r via $exp[-\gamma r]$
      Evaluation of new solutions and updating light intensity
    End For j
  End For i
  Classify fireflies and find the best solution
End as long as
View results

Figure 4: Pseudo code for Firefly Algorithm [14]

Proposed SMIB with Proportional-Integral-Derivative (PID)

It is fascinating to note that more than half of the industrial controllers being used today use PID based control techniques.

Mathematical expression for the output of PID controller is given by:

$$u(t) = K_p e(t) + K_i \int_0^t e(\tau)d\tau + K_d \frac{de(t)}{dt} \quad (8)$$

Figure 5 and Figure 6 show the Simulink model for PID and SMIB system connected with PID respectively.

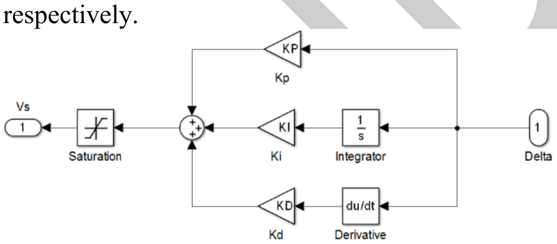

Figure 5: Simulink model for PID

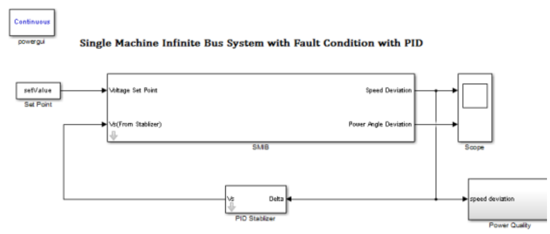

Figure 6: Simulink model for SMIB with PID

III. Simulation Results

MATLAB/SIMULINK model is used to implement proposed model.

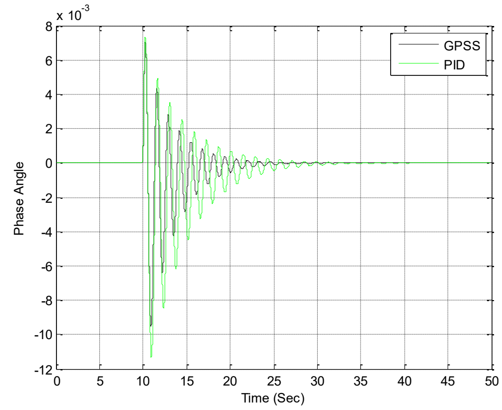

Figure 7: Comparison of phase angle in SMIB for GPSS and PID

Above figure shows a comparative graph of phase angle deviations in SMIB for GPSS and PID against an impulsive fault at t=10 second. Above figure shows that PID based approach outperforms GPSS approach.

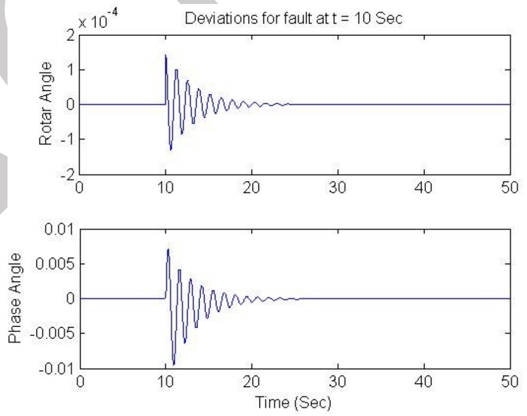

Figure 8: Speed deviation in SMIB-Firefly for rotor angle and phase angle

Above figure shows the response of SMIB-Firefly against an impulsive fault at t=10 second. The fault duration is only one sample of time and then fault has been cleared. On the fault inception rotor of the generator starts deviation from a constant speed, which is shown in form of deviation (sub-graph 1). Deviation is received at the device on very next sample of time in form of non-zero deviation error and device responses in form of compensation signal. Above figure shows that deviations settle down to zero around 25 seconds, which is a fair amount of time. Since phase angle is proportional to rotor deviation, it also settles on same time.

IV. Conclusion

In this paper, ensuring system stability, in order to provide faster responses over a wide range of power system operation a power system stability (PSS) of

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single machine infinite bus system (SMIB) was developed and its parameters was tuned by a robust evolutionary algorithm that offers flexibility to designers for achieve a compromise between conflicting design objectives, the power angle and speed deviation in SMIB. The design problem of robustly tuning PSS parameters is formulated as an optimization problem according to the time domain based objective function which is solved by the Firefly Algorithm technique. The effectiveness of the proposed Firefly based PSS is demonstrated on a SMIB power system. It was found that the Firefly based SMIB outperforms than the SMIB-PSS system.

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