EFFECTS OF MACHINE CONSTANT TO ROTOR ANGLE STABILITY IN SINGLE MACHINE INFINITE BUS POWER SYSTEMS

1Bilgehan TOZLU, 2Fatin SONMEZ

1 Osmancık Omer Derindere Vocational School, Hitit University, Corum, TURKEY
2 Artvin Vocational School, Artvin Coruh University, Artvin, TURKEY
E-mail: 1bilgehantozlu@hitit.edu.tr, 2fatinsonmez@atvin.edu.tr

ABSTRACT

This paper treats the effect of inertia constant of machine (machine constant) which is synchronous generator in single machine infinite bus power systems, to rotor angle stability. The system is modeled by an equation named swing equation and it is simulated in computer by using Matlab/Simulink. It is observed that how the rotor angle stability is affected by changing machine constant when all values of the system except for machine constant were assumed to be permanent. In this study, it is investigated that how the rotor angle stability changes with synchronous machine constant in SMIB power systems.

Keywords: Rotor angle stability, machine inertia constant, SMIB.

1. INTRODUCTION

Especially since the beginning of the 1990s, environmentally friendly energy production has been a promoted area on technological research-development and making investment in parallel with it by many international institutions throughout the World.

However, most of this new generation electricity production facilities that defined as renewable energy technologies are doing variable production, so integration between the existing electricity network and this type of power stations is very difficult.

Renewable energy power stations usually land regions where network is not strong, and it requires that these power stations usually connect to the electricity system from the end points of network. This situation significantly modifies the network's existing energy flux and especially flexible energy production characteristics of wind power stations affect negatively the voltage and frequency values of the system [1].

Another negative effect in the power system stability is overload. Economic-environmental pressures and continuous load increment forced to work power systems more closest points in stability limit and so reduction in limits of stability and voltage stability has become a critical issue [2,3].

A large nonlinear interconnected power system shows some complex acts when operating point moves away from a continuous state. Power systems become more and more multi-loaded for that economic and environmental pressures narrow the raise of new transmission and production capabilities.

Under these stressed conditions, a power system can exhibit a new type of dynamic unstable behaviors such as slow voltage drops or even voltage collapse. Therefore, requirements for dynamic analysis of power system has grown significantly in recent years [4,5].

Committees of the IEEE and CIGRE have defined power system stability as an ability of an electric power system, for a given initial operating condition, to regain a state of operating equilibrium after being subjected to a physical disturbance, with most system variables bounded so that practically the entire system remains intact [6].

Transient instability has been the dominant stability problem on many systems. As power
systems have evolved through continuing growth in interconnections, using of new technologies and controls, and the increased operation in highly stressed conditions, different forms of system instability have emerged. For example, voltage stability, frequency stability and inner oscillations have become greater concerns than in the past [7,8].

Disturbing effect may be small or large. Small distortions such as load change are continuously and the system adapts to changing conditions. The power system should be ready to short-circuited transmission line, a large generator-load loss or deterioration of various types, such as disconnection of the line between two bars. Voltage stability is defined as the ability to be within acceptable limits, of voltage magnitude on all bars, after a disturbance on a power system [9,10].

It is expressed that, frequency is controlled by balancing the load with generation [11].

Frequency instability results from unbalance of active power between the load and generation.

The rotor angle stability is the ability to stay in synchronized of all synchronous machines in a power system [6]. This stability problem is concerned with the electromechanical oscillations in a power system. For understanding the stability problems, it needs to classify the stability to parts [12]. The classification of power system stabilities is shown as in Figure 1.

![Figure 1. Classification of power system stability.](image)

2. SINGLE MACHINE-INFINITE BUS (SMIB) POWER SYSTEM AND ROTOR ANGLE STABILITY

Synchronous generators seldom operate in the isolated mode, most of all are usually connected in parallel to supply the loads, forming a large power system known as a grid. When a synchronous generator connects to the grid, its rotor speed and terminal voltage are fixed by the grid and it is said to be operating on infinite bus. A change in field excitation results in a change in the operating power factor while a change in mechanical power input causes a corresponding change in the electrical power output [13].

![Figure 2. A SMIB Power System](image)

The equation called as swing equation of a conventional SMIB power system that is shown in figure 2, is as follows:

$$\frac{2H}{\omega_0} \frac{d^2\theta}{dt^2} = P_m - P_e$$  \hspace{1cm} (1)

Where:

- $H$ is the inertia constant,
- $\omega$ is the angular velocity of machine,
- $\theta$ is rotor angle,
- $P_m$ is the mechanical power,
- $P_e$ is electrical power

Inertia constant of synchronous machine changes depending on size of machine which is huge or small. Even the inertia constant could change depending on type of material used.

The inertia constant (H) is obtained as:

$$H = \frac{0.5 \cdot J \cdot \omega_{m0}^2}{S}$$  \hspace{1cm} (2)

Where:

- $J$ is total inertia of rotor and turbine,
- $\omega_{m0}$ is mechanical angular velocity,
- $S$ is total power (MVA) of machine

Inertia constants of different types of synchronous machines are given in Table 1 [12].
Table 1 – Typical values of H for different types of synchronous machines

<table>
<thead>
<tr>
<th>Type of Synchronous</th>
<th>Inertia Constant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal Power</td>
<td></td>
</tr>
<tr>
<td>- Steam Turbine</td>
<td>4.9</td>
</tr>
<tr>
<td>- Gas Turbine</td>
<td>7.10</td>
</tr>
<tr>
<td>Hydro Power</td>
<td></td>
</tr>
<tr>
<td>- Slow (&lt;200 min⁻¹)</td>
<td>2.3</td>
</tr>
<tr>
<td>- Fast (&gt;200 min⁻¹)</td>
<td>2.4</td>
</tr>
<tr>
<td>Synchronous Compensators</td>
<td>1.15</td>
</tr>
<tr>
<td>Synchronous Motors</td>
<td>≈ 2</td>
</tr>
</tbody>
</table>

3. SIMULATION RESULTS

Holding fixed all parameters of synchronous generator, the rotor angle stability has been seen by the change of the machine constant value at the MATLAB/SIMULINK simulation which has been composed to view the effect of inertia constant (H) of synchronous machine to rotor angle stability in a single-machine infinite-bus power system.

At the simulation;

Constant of damping winding is 0.02, electrical power before error is 1.86 pu, electrical power after error is 1.26 pu, cleaning error time is 6 cycles and reclosing time is 1000 ms.

For H=3

Rotor angle is unstable for H=3. Rotor angle doesn’t come to a fixed value, it flies after 130°.

For H=3, 2

The system starts coming to stability for H=3.2. The rotor angle makes the first oscillation at 2.5 seconds. Rotor angle starts to recover after 125°.

For H=4
4. CONCLUSION

In the SMIB system given above, it is changed the inertia constant of the machine by holding fixed all parameters of the synchronous generator, and it is examined the effect of the inertia constant of the synchronous generator to rotor angle stability. Figure-3 and Figure-4 are showing that the rotor angle stability hasn’t been provided for machine constant is 3 (H=3).

It is seen that; the rotor angle stability has been very difficult provided after 125° for machine constant is 3,2 (H=3,2) in figure5-6, however the rotor angle stability has been more easily and more quickly provided when the value of machine constant grow in figure7-8 and figure9-10. In this study, it is determined by the simulations that after repairing an error in a single-machine infinite-bus power system, the rotor angle stability improves when the inertia constant of synchronous machine grows.

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