UNIVERSITI TEKNIKAL MALAYSIA MELAKA

ASSESSMENT OF RENEWABLE ENERGY EFFECT OF GRID TRANSIENT STABILITY IN MALAYSIA

This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Electrical Engineering Technology (Industrial Power) with Honours.

by

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APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Electrical Engineering Technology (Industrial Power) with Honours. The member of the supervisory is as follow:

………………………………
(Sir. Adlan bin Ali)

ABSTRAK

. Kajian ini membincangkan tentang implikasi penggunaan tenaga yang boleh diperbaharui di guna pakai di Malaysia seperti biomas, biogas, solar,geoterma dan hidro skala kecil terhadap kestabilan sementara keatas penjana segerak. Kajian ini juga mengkaji perilaku penjana di mana apakah kestabilan penjana dapat dikekalkan apabila diletakan dan tidak diletakkan tenaga yang dapat diperbaharui ini. Pengiraan dan simulasi bagi mendapatkan kestabilan penjana menggunakan bantuan perisian ERACS.

ABSTRACT

The effect of renewable power sources that is available in Malaysia such as biomass, biogas, solar, geothermal and small hydro on the grid, on transient stability of a synchronous generator is discussed in this research. The study is about the behaviour of the synchronous generator weather it can maintain synchronism with and without the implement of distributed generation. The transient stability of the system is determine by performing calculation and simulation using ERACS software

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P	-	Electrical power
P_{max}	-	Maximum power
DG	-	Distributed generation
T	-	Torque
T_m	-	Mechanical torque
T_e	-	Electromagnetic torque
ω	-	Angular speed
T_a	-	Accelerating torque
δ	-	Power angle
δ_o	-	Initial power angle
δ_{max}	-	Maximum power angle
V	-	Voltan
Wh	-	Watt hour
X_{th}	-	Equivalent reactance
S	-	Second
PU	-	Per-Unit system
VA	-	Volt Amp

CHAPTER 1
INTRODUCTION

1.1 Background of the study

This project is focussing on the assessment of renewable energy effect on grid transient stability in Malaysia. Maintaining the synchronous generator's operation toward reliable power is the main point of this topic. Renewable energy are used instead of the conventional generator. The renewable energy mentioned above is called distributed generation. Distributed generation are wind turbine, photovoltaic systems, biomass, biogas and geothermal power. The amount of grid-connected renewable energy sources is expected to increase continuously according to the viewpoint of environmental conservation. However, a significant impact by expanding the installation of the renewable power sources is detected stated by (Yagami *et al.*, no date). While, the stability mention above is the transient stability. According to (Tavukcu, 2017) the impact of disturbances on power system examined by considering the operating conditions.

According to (Grigsby and Morison, no date), transient stability was recognized as a problem back to 1920s at which time the characteristic structure of the systems consisted of remote power plants feeding load centre over long distances. These early stability problems, due to the lack of synchronizing torque, were the foremost emergence of transient instability. Despite of the problematic about issues of power system stability, transient stability is still remains a basic and crucial consideration in power system design and operation

According to (Salam, 2009), in power system, the stability is the capability of the system to remain in the state synchronism or equilibrium after disturbances occur on the system. There are three classifications of power system stability. First is the steady state stability. The ability of the system to regain synchronism after slight and slow disturbances is what define the steady state stability. Next is the dynamic stability. This stability is the capability of the system to react to the production of the oscillations on the system due to the small disturbances. Lastly is the transient stability which is the main topic as mention above. Transient stability is the ability of the system to keep up the synchronism after large disturbance in a short time of period. This is due to the unexpected change of load, power transfer and line switching. Usually, it takes within one second for the system to response to the disturbance

Factors which influence the transient stability of a generator stated by (Grigsby, 2007) are as follow:

a) The generator post-disturbance system. The maximum power (P_{max}) will be lower if the post-disturbance system is weak.
b) The fault-clearing time duration. The rotor will accelerate longer if the fault applied is longer and at the same time, more kinetic energy will be gained. However, it is more difficult to dissipate during the deceleration if more energy gained during acceleration.
c) The inertia of the generator. The rate of change of rotor is slow if the inertia is high and less kinetic energy gained during the fault.
d) An infinite bus voltage and the internal voltage of the generator. The maximum power (P_{max}) will be low when these voltages get low.
e) The generator loading before the disturbance. The closer the unit will be to P_{max} when the loading is high. This shows that during acceleration, it is seem to become unstable.
f) The internal reactance of the generator. The higher the peak power, the lower the reactance and the lower the initial rotor angle
g) The output of the generator during the fault. This is depend on the type of the fault and the function of the faults location.

The use of renewable energy instead of using the conventional system has been taken seriously in Malaysia. According to (Hussin *et al.*, 2012), through the Third Outline Perspective Plan 2001-2010 and the small Renewable Energy programmed, the renewable energy at national level stated in in Eight Malaysia Plan (2001-2005) was introduced. The dedication of Malaysia in term of the uses of alternative sources has been prove in a voluntary commitment. With the spirit, Malaysia has made a conditional Voluntary Commitment in the 2009 United Nation Climate Change Conference in Copenhagen. This aim of this voluntary is to reduce its GDP emission intensity levels by 40 percent by 2020 relative to the 2005 levels stated by (Hashim *et al.*, 2001).

According to (Dhoot, 2016), the impact of the distributed generation are :

a) Improve consistency
b) Reduce power losses
c) Improve power quality
d) Decrease environmental pollution
e) Shrink the network for the network expansion

1.2 Problem statement

Malaysia is still very much dependent on fossil fuels, mainly natural gas, coal and oil, in its commercial energy demand and electricity generation. Coal, oil and gas consist largely of carbon and hydrogen and the process of burning causes the release of carbon dioxide. These gases released causes the greenhouse effect which lead to global warming. Therefore, with those reasons, renewable energy is introduced. However, the implementation of these sources may effected the stability the generator on the grid. The transient stability is known as the ability to maintain its synchronism after the large disturbances. Thus the aim of this research is to determine whether the synchronism of the generator are able to maintain or not. In this research, an approach has been done to stabilize the system.

1.3 Objective

The objectives are as follows:

a) To design and construct a theoretical modelling for synchronism on radial network for synchronous machine.
b) To perform a simulation on the theoretical modelling for synchronism on radial network for synchronous generator.
c) To execute a simulation of models with different values of distributed generation on different fault location
d) To provide potential mitigation approach technique for any disturbances occur at each model connected with different place of distributed generation on different fault location

1.4 Work scope

The scope of this study is based on the objective which are:

The main purpose of this research is to maintain the synchronism of the synchronous generator in the radial network. The distributed generation will be installed to the grid in order to identify whether the transient stability of the system is disturbed or not. The grid consist of two lines which are transmission line and distribution line. So, the work scopes are as below:

I. The obtain stability of the synchronous generator on grid with and without the distributed generation (DG).
II. The use of ERACS software for analyzation on the transmission line with and without DG implementation.
III. The implement of distributed generation (DG) based on the renewable energy available in Malaysia
IV. The mitigation approach that will be used in order to eliminate potential problems occur after the installation of distributed generation.

CHAPTER 2
LITERATURE REVIEW

The literature review is done in order to relate the information and apply the principles of a viability related to transient stability and the installation of the distributed generation on the grid. This literature review also involve the information from the previous research where it can help to do the project smoothly during development process plus a crucial source to be used as a reference.

2.1 Related theory of transient Stability

2.1.1 Transient stability

The term "stability" is related with the unit protection system and refers to the capability of the protection schemes to continue unaffected by circumstances external to the protected zone such as external fault conditions and through load current. As mention before, the transient stability is the is the ability for the power system to maintain its synchronism when there is involvement of major disturbances for examples line-switching operations, faults, loss of generation and unexpected load change. There are two concept in understanding the concept of transient stability. First is the swing equation while another is the power-angle curve. These criteria also used to define the equal area criterion which a graphical method to evaluating transient stability.

2.1.2 Swing equation

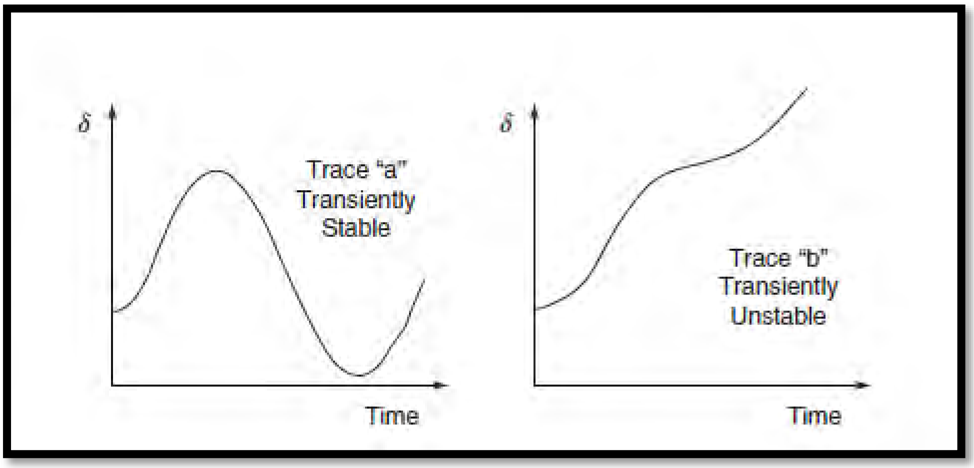

Figure 2.1: The trajectory plot of generator rotor angle through time for transient stable and unstable cases (Grigsby, 2007).

The relative position of the rotor axis and the resultant magnetic field axis is fixed under normal operating situation. This is known as torque angle or power angle. The rotor will accelerates or decelerate during the disturbance proportional to the synchronism rotating air gap MMF, and begins the relative motion. The generator will remain its stability if the oscillations, the rotor locks back into synchronism speed after the oscillation. While, if there is no any involvement of net changes in the power, the rotor return to its original positions. On the other hand, the rotor comes to a new operating power angle relative to the synchronously revolving field if the disturbance is created by a changes in load, network conditions or generation.

The rotor angle δ and the acceleration power P_a is identified as Swing Equation. This solution will help in showing how the rotor angle changes related to time following a disturbance. The figure of 2.2 shows the flow of mechanical and electrical power in a generator and motor

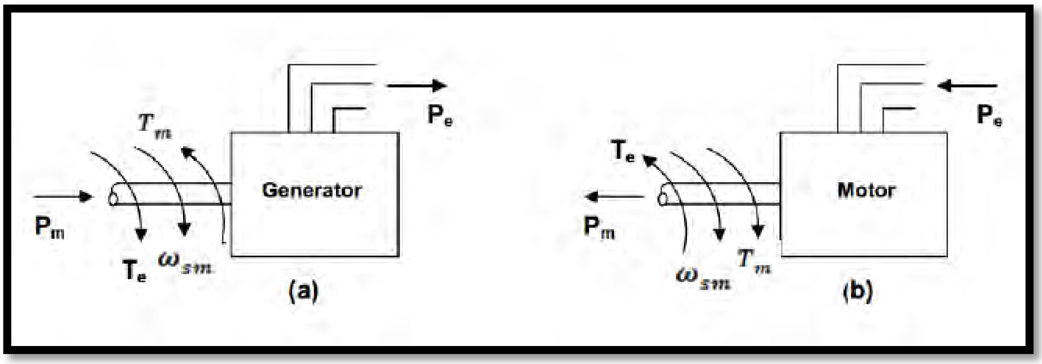

Figure 2.2: The mechanical and electrical power flow in a generator and motor (Raj and Jain, 2016)

The prime mover exerts a mechanical torque T_m on the shaft of the generator and produce an electromagnetic torque T_e and the angular speed, ω. It delivers power P_e to the power system via bus bars, under steady-state operation with losses neglected

$$T_m = T_e \qquad (8.1)$$

The mechanical torque is larger than the electromagnetic torque, as a result of a disruption. An accelerating torque T_a exists and given by

$$T_a = T_m - T_e \qquad (8.2)$$

With the ignorant of other torques caused by core loss, friction and wind age in the machine, T_e has the influence of accelerating the machine, which has an inertia J ($kg.m^2$) made up of the inertia of the generator and the prime mover and hence

$$J\frac{d^2\theta_m}{dt^2} = T_a = T_m - T_e \qquad (8.3)$$

Where θ_m is the angular displacement with respect to stationary reference axis on the rotor. The angular reference is elected relative to a synchronous rotating reference frame moving with constant angular velocity ω_{sm} which is

$$\theta_m = \omega_{sm} t + \delta_m \qquad (8.4)$$

Where δ_m is the position before fault disturbance at time t= 0. The rotor angular velocity given by the derivation of equation in (8.4)

$$\omega_m = \frac{d\theta}{dt} = \omega_{sm} + \frac{d\delta_m}{dt} \qquad (8.5)$$

The rotor acceleration is,

$$\frac{d^2\theta_m}{dt^2} = \frac{d^2\delta_m}{dt^2} \qquad (8.6)$$

(8.6) substitute into (8.3)

$$J\omega_m \frac{d^2\delta_m}{dt^2} = T_m - T_e \qquad (8.7)$$

(3.7) is multiplying by ω_m,

$$J\omega_m \frac{d^2\delta_m}{dt^2} = \omega_m T_m - \omega_m T_e \qquad (8.8)$$

The above equation can be compose in equation in terms of inertia constant because of the angular velocity times torque is equivalent to the power and becomes

$$J\omega_m \frac{d^2\delta_m}{dt^2} = P_m - Pe \qquad (8.9)$$

M is the quantity J ω_m called as the inertia constant. The equation in terms of inertia constant turn out to be

$$M\frac{d^2\delta_m}{dt^2} = P_m - Pe \qquad (8.10)$$

Such.

M = inertia constant, which is not really constant when the rotor speed deviates from the synchronous speed

P_m = Shaft mechanical power input, corrected for wind age and friction losses

Pe = Pa sin δ = electrical power output, corrected for electrical losses

P_a = amplitude for the power angle curve

δ_m = mechanical power angle

2.1.3 Power angle curve

By consider a simple model of a synchronous generator associated to an infinite bus through a transmission system as shown in figure 2.3. By substituting the generator with a constant voltage behind a transient reactance, the model can be reduced. There is a maximum power which be able to be conveyed to the infinite bus in such a network. The connection between the rotor angle of the machine d and electrical power of the generator P_e is given by

$$P_e = \frac{E' E_B}{X_T} \sin\delta = P_{max} \sin\delta \qquad (8.11)$$

Where

$$P_{max} = \frac{E' E_B}{X_T} \qquad (8.12)$$

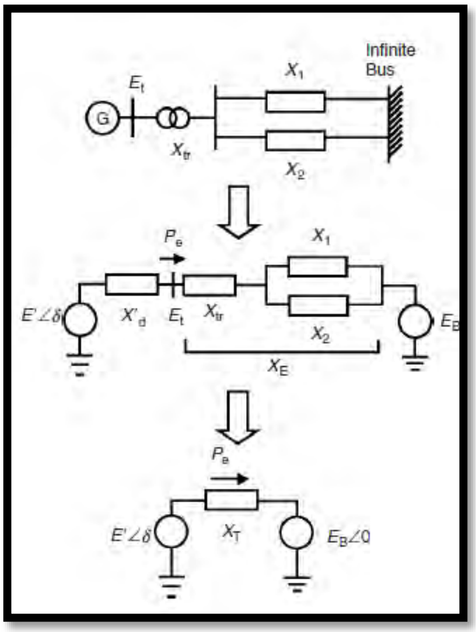

Figure 2.3: The simple model of a synchronous generator associated to an infinite bus (Grigby, 2007)

2.1.3 Equal area criterion

Based on (Aghamohammadi, Khormizi and Rezaee, 2010) , (Raj and Jain, 2016) stated that for a quick prediction of stability, a technique known as equal-area criterion is used. In order to conclude if the machine keep up its steadiness after a disruption, a graphical interpretation is deliberated. However, this method only valid to one –machine system or two machine system connected to an infinite bus. Therefore, based on the swing equation

$$M\frac{d^2\delta_m}{dt^2} = P_m - Pe = P_a$$

Such P_a is the accelerating power

The increasing of δ causes the increasing in electrical power, which lead to the $\delta = \delta_1$, therefore the new input power P_{m1} matches with the electrical power. Figure 2.4 shows the sudden load change based on equal area criterion(Raj and Jain, 2016). The rotor is running above synchronous speed although the accelerating power is zero at the point. Thus, the electrical power P_e and δ continue to increase. The rotor decelerates toward synchronous speed until $\delta = \delta_{max}$ with $P_m < P_e$, as a result

$$\text{Area } A_2 = \text{area bde} = \int_{\delta}^{\delta_{max}} (P_{m1} - P_e)\, d\delta$$

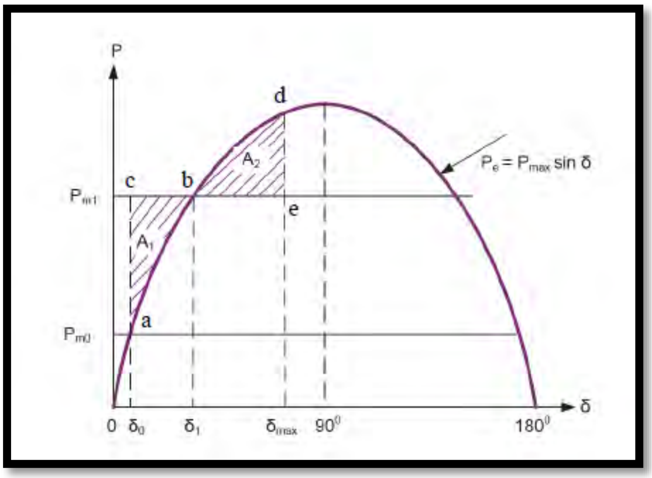

Figure 2.4: Sudden change of load

$$|\text{area } A_1| = |\text{area } A_2|$$

By referring to (Aghamohammadi, Khormizi and Rezaee, 2010) , (Raj and Jain, 2016) stated that this known as equal area criterion where the rotor angle then would oscillate back and forth between δ_0 and δ_{max} at its natural frequency. The new steady state operation will be established at point b because of the damping present in the machine will cause these oscillations to subside.