VOL. 12, NO. 4, FEBRUARY 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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PHASOR DIAGRAM ANALYSIS FOR NON-SALIENT POLE SYNCHRONOUS GENERATOR

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ABSTRACT
This paper presents the analysis of non-salient pole synchronous generator using phase or diagram. The design of non-salient pole synchronous are developed by using MATLAB software. From the design of the non-salient pole synchronous generator, the output characteristic of the generator can be determined. From the output of the generator, the performance of the generator such as speed, current, voltage and power can be analyzed.

Keywords: pole synchronous generator, Matlab, load source.

INTRODUCTION
Electricity is still being biggest issue around the world because of the consumption of the electrical power has been increased tremendously in recent years. A power system right now has been crowded by network because of electrical lines interconnection the generating power system in to support high demand of consumer. The generator usually operates in long time due to accommodate the user around the area that cover. The power rating of the generator will be damage because of the increasing of heat and the magnet saturated. The effect of the long time user of the generator can affect the efficiency of the generator. The percentage of the electricity produces decrease because of the temperature for long time operation [1]. Before this, the result of the maximum time to disturbed errors. The power system of the model can be damage or the output that create have high ripple. The simulation model of this type of pole have been created. Based on the simulation, the power system of the generator has been derived. So that, based on this model the maximum time of disturbed have been analyzed [2]. Limited to use as synchronous, turbo generator are designed as two or four pole machines. Enough space forming relatively high amount of rotor slot. Design and finite element analyses information of two possibilities of cylindrical rotor synchronous machine, excitation winding design [3].

The temperature is the most critical issue for the stator part of the generator. Because of this, will lead to the performance deterioration of the generator. The studied are focused on the how to cool the generator and to overcome the increasing of temperature when the generator are running [4]. The generator start failure with short circuit of the generator. From the failure, the damage of mechanical part generator is highly increase based on the operation of the generator. Mathematical model of the generator had been used as the method in the paper [5].

This paper discuss guidelines to choose parameter for directly connected permanent magnet synchronous machine design and for the winding design. By using simulation, will indicates the difference value for resistance in operation in short time. By using manually, the voltage is leakage have been measured [6].The problem from this paper is the performance equation from phasor diagrams of the non-salient pole. By using phasor diagram of the non-salient pole, the various formula can be created to get the parameter output of the generator. The software Matlab/Simulink had been used to create the simulation of the generator [7].

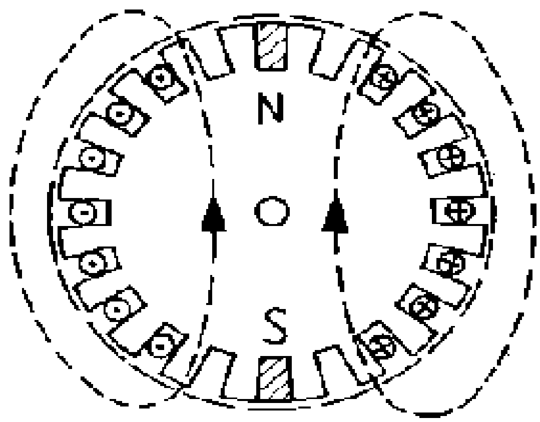

Figure-1. Two-pole non-salient pole rotor.

Figure-1 shows the two pole non-salient pole rotor. The structure of the synchronous machine based on the position of the rotor. This is one of example of the structure for the non-salient pole. This figure show that the generator only uses 2 poles. The different between non-salient pole and salient pole based rotor of the generator. The non-salient rotor gives high voltage, high speed and high power to the electricity.

PHASOR DIAGRAM
The phasor of the generator are refer to the RMS maximum value of the positive or negative half cycle of the sinusoid. Phasor are efficient method to analyze AC circuit such as generator when the frequency of the load are same .Each of the characteristics have their own criteria based on the value of the resistance, capacitive and inductive factor. The factor will affect the phasor diagram. It is important to know the phasor diagram. This is because based on the phasor diagram the power factor of

VOL. 12, NO. 4, FEBRUARY 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

the non-salient pole can be analyzed. For electromagnetic force (Ef) denotes excitation voltage, Vt which denotes terminal voltage. Ia is the armature current, ϴ is the phase angle between Vt and Ia, ᴪ the angle between the Ef and Ia, δthe angle between the Ef and Vt and lastly is Ra is the armature per phase resistance.

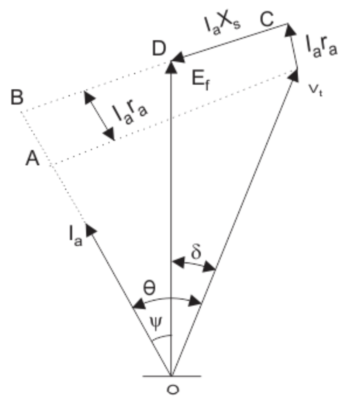

Figure-2. Phasor diagram for leading power factor.

The Figure-2 shows the leading phasor diagram of power factor. It happens when the current are lead the voltage. It will make the current waveform are comes first before the voltage waveform. Besides that, the power angle for this type of power angle is negative. It show that the element of Ia are toward to Vt cos ϴ. When the Ia toward to Vt the total voltage drop is (Vt cos ϴ + IaRa).

So that the equation can write expression for the voltage drop along the direction perpendicular to Ia. The total voltage drop comes out to be (Vt sin ϴ - Ia Xs). With the help of the triangle BOD in the first phasor diagram, the expression for the Ef as:

$$E_F^2 = (Vt\cos\theta + Ia\ x\ Ra)^2 + (Vt\sin\theta - Ia\ x\ Xs)^2 \quad (1)$$

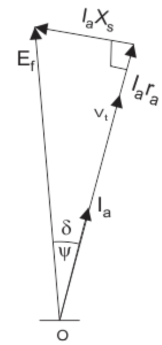

Figure-3. Phasor diagram for unity power factor.

The Figure-3 shows the phasor diagram for another type of power factor which is unity power factor of the synchronous generator by using non-salient pole. It happens when the current and voltage are in phase. For this phasor diagram the value of the theta is zero. That means the the value of the ᴪ = δ. By using the triangle of the phasor diagram the expression for Ef as:

$$E_f^2 = (Vt + Ia\ x\ Ra)^2 + (Ia\ x\ Xs)^2 \quad (2)$$

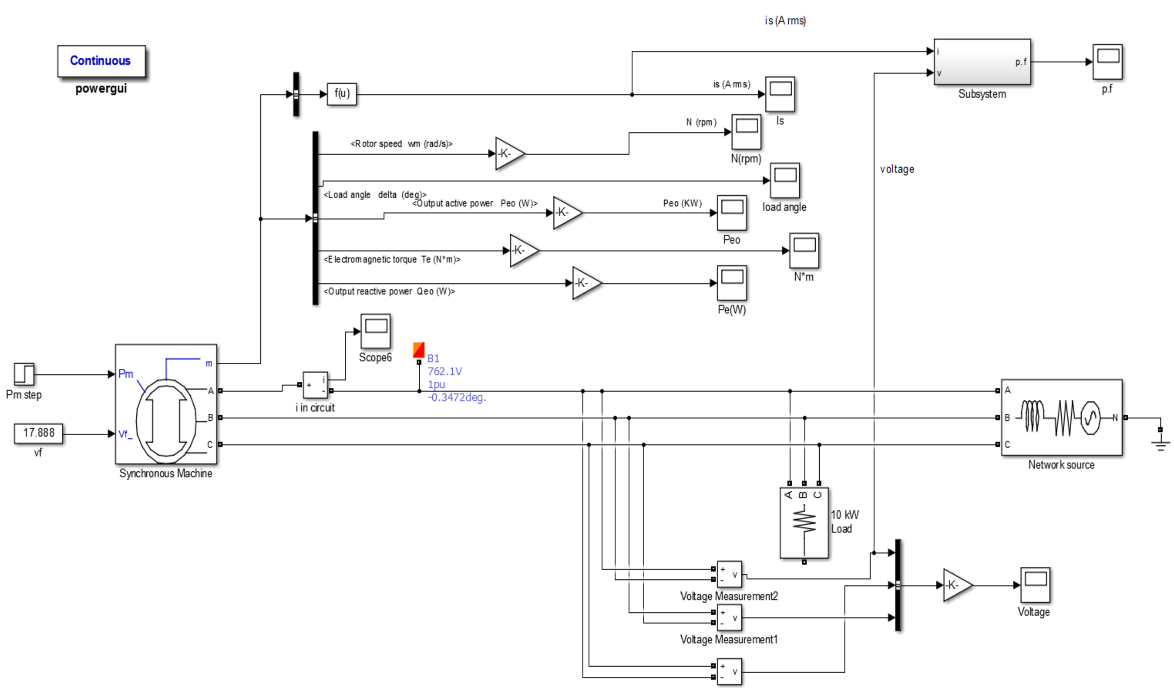

Figure-4. Simulation of the non-salient pole.

VOL. 12, NO. 4, FEBRUARY 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

DESCRIPTION OF THE SIMULATION

The Figure-4 shows the simulation circuit for the non-salient pole synchronous generator by using MATLAB software. By using the library that already in the simulation, the synchronous block is use. The synchronous block is suitable to use in this simulation because it can change to non-salient rotor.

The different between motor and generator in this simulation are depending on the value of the mechanical power of the block. If the value is negative, the block become motor and if the value is positive the synchronous block will be generator. The constant block use is the input of the synchronous block. For the voltage field, the value of the input is use to voltage field in the block. The

The load source are uses to shows the value of the load that generator can supply. The Three-Phase series RLC load block implements a three-phase balanced load as a series combination of RLC elements. The power that absorbed are active and reactive when the applied voltage. The three-phase source with internal R-L impedance is a balanced three-phase voltage. The power is connected to Y with neutral connection that can be internally grounded or made accessible. For the no load condition, the value at both of the load are zero. So that there is no load that is connected to the generator.

The output for synchronous generator come out in this simulation is depending on the bus bar. The bus bas can be set so that the output that needed can be displaced in the graph. The gain is use for the formula. For the voltage, the measures are taken at the load line. But the other measures are taken direct to the generator output.

SIMULATION AND RESULT

There are two condition of the generator in this simulation. The condition is based on the situation when the generator runs in load and without load. The result for both of the simulations are different based on the condition of the generator. Therefore the comparison of the result can be analyzed.

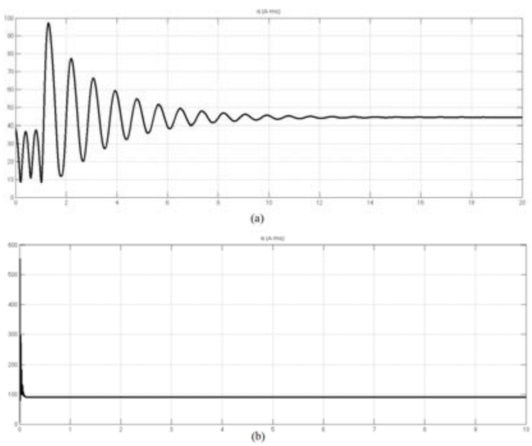

Figure-5. The graph for the current. Current for load (a), current for the no-load (b).

The figure 5 shows the graph for the current for both condition of the non-salient pole synchronous generator. The current for load have ripple a few second before it stable at 12 seconds. For the no-load generator, it takes a few seconds to stable. This show that there are noise in the generator. The graph also shows the difference between load and no-load condition for the generator. The current in the generator can be determined using the formula.

$$Ia = \frac{Eo - Vt}{Zs} \tag{3}$$

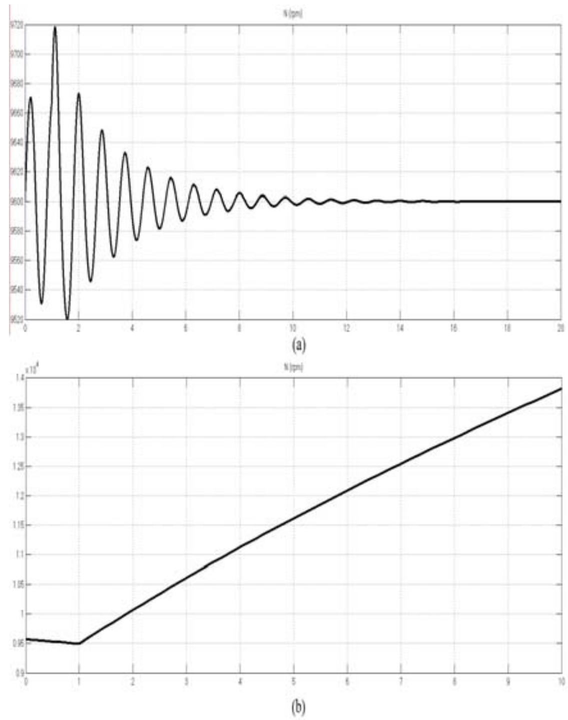

Figure-6. The graph for the speed. Speed for load (a), speed for the no-load (b).

The Figure-6 shows the speed of the output for the both condition of the non-salient pole synchronous generator. The generator output characteristics are depend on the speed of the prime mover. Therefore for the non-salient pole, the structure of the generator is built to resist with high speed to avoid the damage. For the graph 6(a) show the speed when there load for the generator. Before 12 seconds there are ripple in the graph. This show that the function of automatic voltage regulation (AVR) in the generator. So that after 12 seconds the speed come from generator are maintain. The AVR are needed in the generator because the speed will be not stable for long time. The speed of the generator are high speed that one of the factor of for non-salient pole. But in the no-load synchronous generator in graph 6 (b), the speed are decreased a few seconds before the speed increase with the time. This is because there is no load to hold the speed

VOL. 12, NO. 4, FEBRUARY 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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of the generator. The structure of the generator needed to be strong enough to hold the high speed of the generator. The speed come from the prime mover so that the generator can produce the flux based on the speed that come from prime mover. For no-load, the generator are free running but not produce any type of the output characteristic. Equation 4 is the formula for the speed of the non-salient pole synchronous generator:

$$\text{Speed (RPM)} = (\text{F-N}) \text{ X } 120 \tag{4}$$

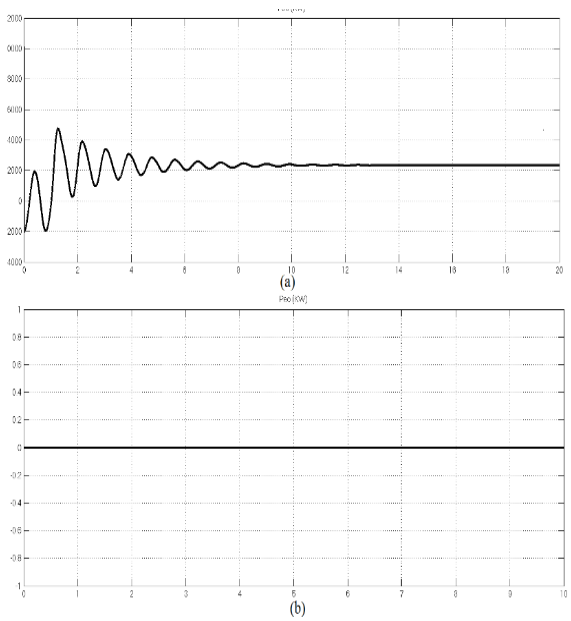

Figure-7. The graph for the active power. Active power for load (a), active power for the no-load (b).

The figure 7 shows the graph for the active for both of the synchronous generator. The active power are depend on the value of the load resistance. So, it need the high load to produce high active power of the generator. The active power for load non-salient pole had been shown in the graph 7(a) and the no-load in the graph 7(b). The graph for the load is unstable before 12 seconds and after that it stable. This show that the active power are depend on the speed of the generator. The active power are affected by the speed of the generator. When the speed of the generator is stable, the active power of the generator is also stable. The value of active power is high so this type of generator is suitable to supply the active in high power rating. Not like salient pole, it only can supply the active in low power. In the no-load, the graph is zero. The generator will not produce the active power because there is no load to be supply the active power. It shows when there is no resistance the active power are zero. The no-load in this case is when there is no consumption of electricity. So the generator is in free running but not produce the any output characteristic. The active power for the non-salient pole synchronous generator can be determined using these formula:

$$P = I^2 R \tag{5}$$

$$P = \frac{E^2}{R} \tag{6}$$

$$Pt = \sqrt{3} E_L I_L \cos \theta_i^l \tag{7}$$

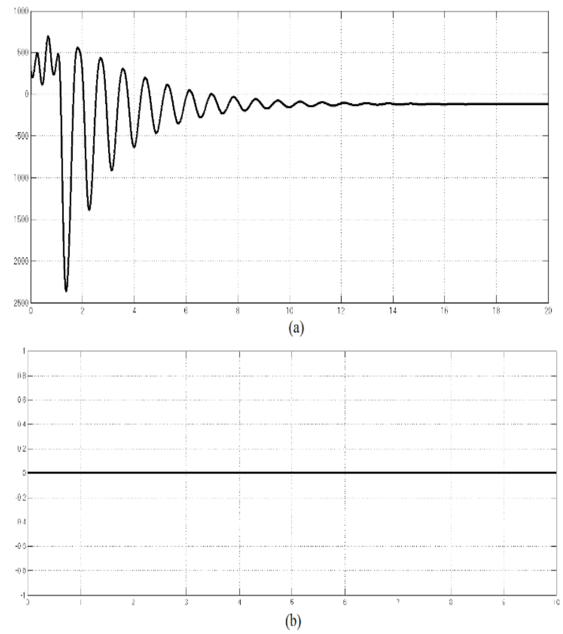

Figure-8. The graph for the reactive power. Reactive power for load (a), reactive power for the no-load (b).

Another type of the output characteristic in this analysis are reactive power. The reactive power are in the volt-ampere (VA). When the value of the active and reactive power has been recorded, the value of the apparent power of the generator can be calculated manually. The apparent power also known as volt-ampere resistance or VAR. The power triangle of the generator can be created based on this three of the power. The power triangles are important to the generator to show the value of the resistance, capacitance and inductance of the load. The figure 8 shows the reactive power for the both non-salient pole synchronous generator. The reactive is the power are affected by capacitive and inductive load. The capacitive will be affected of the leading power factor and inductive affected the lagging power factor. This graph shows that the graph 8(a) for non-salient pole synchronous generator with load. The graph is in negative power. This shows that the generator is in capacitive power. Based on the graph, the output characteristic with load for non-salient pole synchronous generator, the value of the reactive power are in negative value. This show that the value of the load in capacitive are small. The reactive power of the generator can show that the value of the impedance that come from the load. For the graph no-load, it shows that the reactive power is zero. This shows that in no-load there are no capacitive or inductive

ARPN Journal of Engineering and Applied Sciences

affected in this synchronous generator. Based on this formula show reactive power for the non-salient pole synchronous generator:

$$Q = I^2X \tag{8}$$

$$Q = \frac{E^2}{X} \tag{9}$$

$$Qt = \sqrt{3}E_L I_L \sin \theta_i^l \tag{10}$$

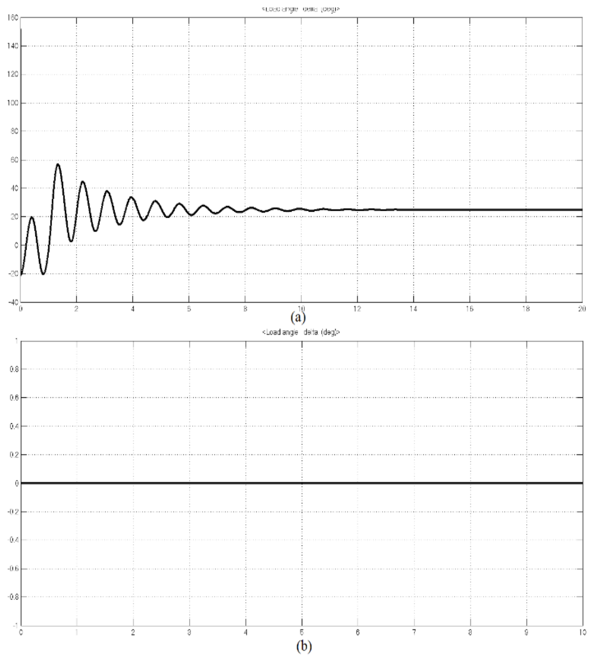

Figure-9. The graph for load angle. Load angle for load source (a), load angle for no-load.

The Figure-9 shows the graph for the load angle for both situations in the simulation. The load angles are the angle between line voltage and load voltage. The angles are important to verify the voltage in the circuit. Based on the load angle delta, the value of the real voltage that supply to the load can be analyzed. The performance of the generator also can be predict based on the load angle delta of the non-salient pole synchronous generator. Besides, the load angle also can be defined from angle between stator and rotor (field) in the generator. It is a function of power and excitation current in general. The load angle for load non-salient pole in the graph 9(a) and the no-load in the graph 9(b). The graph for load is not stable before 12 second and after that it stable. Same with other output characteristic, the load angle are dependent on the speed of the prime mover. It will stable when the speed of the generator are stable. In the graph of no-load 8 (b), the value of the output characteristic are zero. This is because there are no line voltage and phase voltage to measure the load angle. Therefore the value of the graph is zero.

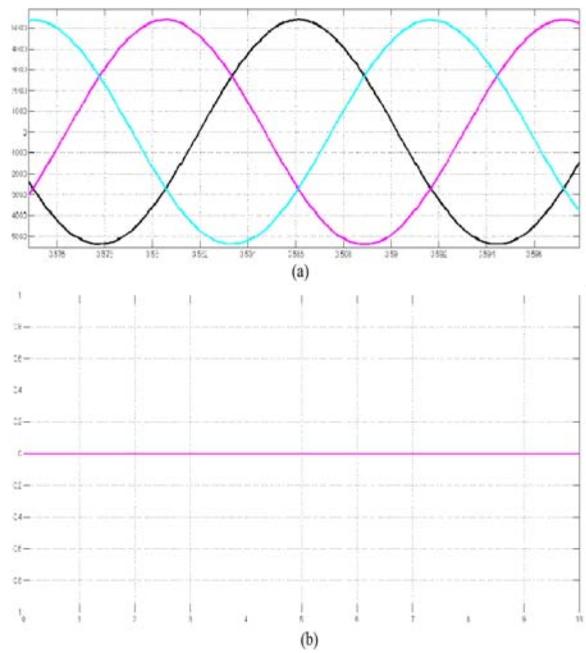

Figure-10. The graph for output voltage. Output voltage for load (a), output voltage for no-load (b).

The Figure-10 shows the graph for output voltage for non-salient pole synchronous generator. In the graph 10 (a) shows the graph with load for non-salient pole. The output voltage that produced from non-salient pole are high voltage compare to the salient pole. The graph for load non-salient pole with load shows the output voltage is more than 1000 KV. The phase of the waveform are in synchronous type and the range between the waveform are same. This type of generator produces the voltage more than 1000 KV. These types of the generators are suitable to be used in the power plant because it can produce high power of the electricity. But in the graph for no-load 9 (b), the value for the voltage are zero. From this graph of free running of the generator, show that there are no voltage that supply to the load as there are no-load to be receive the voltage. The speed of the generator will be running without giving the voltage to the load. This means this type of generator is not producing the voltage when there is no load to supply. In this situation the generator are free running.

CONCLUSIONS

As conclusion, the analysis of non- salient pole generator using phasor diagram had been analyzed and simulated using MATLAB. The non-salient pole synchronous generators are suitable to use for the high power consumption based on the result from the simulation. The speed of the prime mover of the generator needs to increase so that it can consume the high power. Non-salient pole are different compare to salient pole based on the power that supply and the speed of the prime mover.

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