

STABILITY ANALYSIS OF A SALIENT POLE ALTERNATOR USING MATLAB(FOR DIFFERENT TYPES OF LOAD i.e. R, RL, RLC LOADS)

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Abstract -) This paper sets to present the steady state stable operating zone for salient pole alternator using MATLAB simulation. For stability analysis we have taken different types of loads like resistive, capacitive and inductive.

We have plot the relation between active power and torque angle for different loads and observe the graph to conclude the stable operating zone of an alternator. Torque angle have an essential role while using any alternator. The angle can be easily found from the swing equation i.e. which gives the relation between angular momentum, moment of inertia, real power, sending and receiving end voltage and load angle also. Although in theory we can describe steady state stability operation using the swing equation.

Key Words: Stability analysis, Swing equation, Salient pole alternator, MATLAB simulink

1. INTRODUCTION

We are living in an era where continuous supply of power is very much essential. So the power system operations should be in stability limits. Distributed Generation (DG) and Grid system for power transmission is popular in worldwide. An alternator connected to a grid needs to be remained in the system under all operating conditions and also needs to be well protected or disconnected from the system in case of any severe fault or abnormal conditions. Although from theory we can say that torque angle implies very much important role in stability. Load angle is the angle between the alternator voltages from no-load condition to the voltage during loaded condition which actually represents the deviation of the alternator rotor's angle from no load to loaded condition. Load angle provides information about the alternator operating point position in relation to the stability limit. Real power in the alternator is a function of sine of the torque angle, that means we can get max power output at 90°. But in practical this is not the scenario. The reason behind this can be easily understood by the concepts of synchronising power i.e. the derivative of the real power. In the fault analysis portion we are observing the rotor behaviour when a three phase to ground fault is occurred using MATLAB simulink. When any fault occurs in the DG system, the islanding operating is done. When islanding occurs, the power supplied from main grid is closed and only the near generating station supplies the load power. Hence monitoring of alternator voltage, current, frequency, harmonic distortion of the alternator is very much essential.

However, frequency monitoring may not be sufficient to protect the alternator. Hence the estimation of rate of change of frequency is also necessary. Rate of change of frequency is now most commonly used for protection technique. In that case load angle estimation is necessary. The angle can be easily found from the swing equation i.e. which gives the relation between angular momentum, moment of inertia, real power, sending and receiving end voltage and load angle also.

1.1 SALIENT POLE ALTERNATOR

In salient pole type of rotor consist of large number of projected poles (salient poles) mounted on a magnetic wheel. Construction of a salient pole rotor is as shown in the figure at left. The projected poles are made up from laminations of steel. The rotor winding is provided on these poles and it is supported by pole shoes.

- Salient pole rotors have large diameter and shorter axial length.
- They are generally used in lower speed electrical machines, say 100 RPM to 1500 RPM.
- Typically number of salient poles in between 4 to 60.
- Flux distribution is relatively poor than non-salient pole rotor, hence the generated EMF waveform is not as good as cylindrical rotor.
- Salient pole rotors generally need damper windings to prevent rotor oscillations during operation.
- Salient pole synchronous generators are mostly used in hydro power plants.

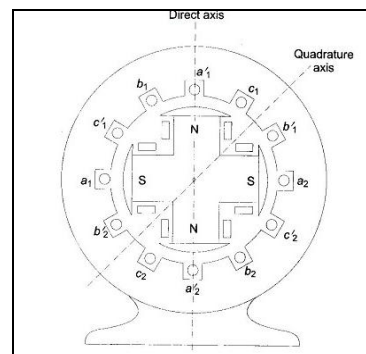


Figure 1 : Salient Pole Alternator

1.2 STABILITY

The ability of a system to reach to a normal or stable condition after being disturb, is known as stability.

Steady state stability :- The steady state stability is the ability of a system to bring into a stable system after a small disturbance has occurred. It concerned with the effect of gradual variation of load.

Transient stability:- is the ability of the system to bring it to a stable condition after a large disturbance has occurred. It concerned with sudden and large disturbance in the network.

Dynamic stability:- It is an extension of steady state stability i.e. concerned with small disturbances lasting for long time.

Stability limit:- It is the maximum power that can be delivered in a network between source and load or it is a max. Power that can be delivered to the load without the loss of synchronism.

Synchronizing power:- The derivative of active power with respect to torque angle is known as synchronizing power.

This power indicates the degree of magnetic coupling between the rotor and the stator of the alternator.

$$P = \frac{V E_f}{X_d} \sin \delta + \frac{1}{2} V^2 \left(\frac{1}{X_d} - \frac{1}{X_q} \right) \sin 2\delta$$

$$P_{syn} = \frac{V E_f}{X_d} \cos \delta + V^2 \left(\frac{1}{X_d} - \frac{1}{X_q} \right) \cos 2\delta$$

P= Active Power

P_{syn} = Synchronizing Power

The maximum power will flow from source to load when $\delta = 90^\circ$ but at 90° the synchronizing power is zero. There is weak magnetic field or weak magnetic coupling between the rotor and the stator winding. at $=90^\circ$.

B. ACTIVE POWER VS TORQUE ANGLE

δ angle of the rotor, it is the phase difference between the internal voltage E of the generator and the voltage of infinite bar. Any changes affecting the electrical power will cause a variation of the electrical angle δ .

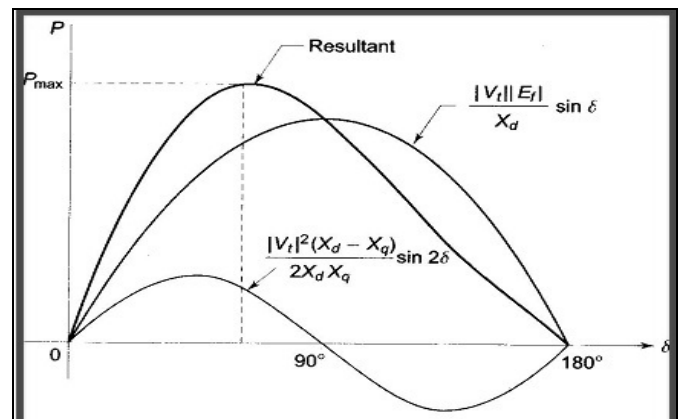


Figure 2 : Active power vs Torque Angle Characteristics

The active power equation of salient pole alternator is:

$$P = \frac{V E_f}{X_d} \sin \delta + \frac{1}{2} V^2 \left(\frac{1}{X_d} - \frac{1}{X_q} \right) \sin 2\delta$$

Where,

δ = Torque angle

X_d = Direct axis reactance

X_q = Quadrature axis reactance

The power produced by reluctance torque is,

$$\frac{1}{2} V^2 \left(\frac{1}{X_d} - \frac{1}{X_q} \right) \sin 2\delta$$

1.3 SWING EQUATION OF ROTOR

In practice cases, for determining the stability of a system, it comes to the variation graph of the angle δ in time. If this curve shows that the angle δ begins to increase after passing through a maximum, it is generally accepted that the system will remain stable. And if the curve does not pass through a maximum, it indicates that the generator will become unstable and losing synchronism with the network.

The equation we are going to use is called "swing equation". It expresses the acceleration or deceleration of the rotor generator according to the load variations.

This equation is as follows:

$$\frac{2H}{\omega_s} \frac{d^2\delta}{dt^2} = P_a = P_m - P_e$$

Such that: $M=2H/W_s$

Where

M = the angular momentum

H = the constant inertia

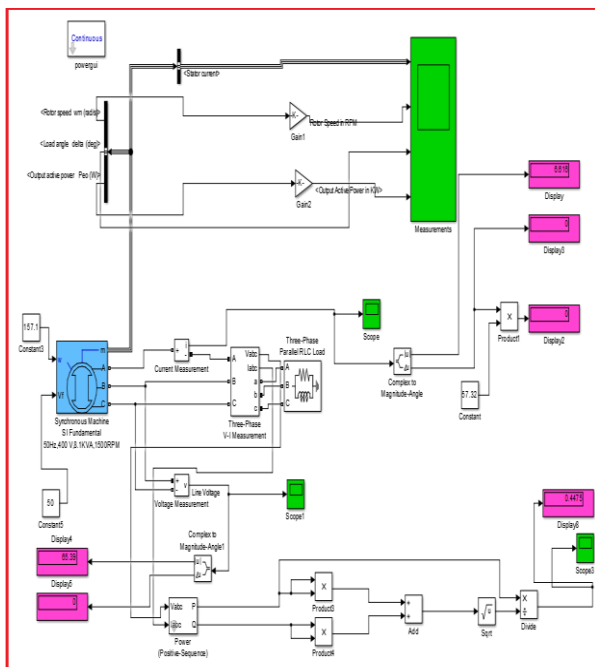
P_m = Mechanical power

P_e = Electrical power.

1.4 METHODS OF IMPROVING STEADY STATE STABILITY

- If we have to increase the active power then reduce the reactance between the stations by using bundle conductors.
- By using parallel transmission lines.
- By using machines of low impedance.
- By adding capacitor in series to the transmission line.
- By using higher excitation voltage or by increasing the voltage rating of the machine.

2.1 BLOCK DIAGRAM REPRESENTATION OF STABILITY ANALYSIS IN MATLAB



2.2 OUTPUT GRAPHS OF STABILITY ANALYSIS

R LOAD :-



Figure 3 : ((i)Stator current vs time (ii)Rotor Speed vs time (iii) Load angle vs time

(iv)Output active power vs time)

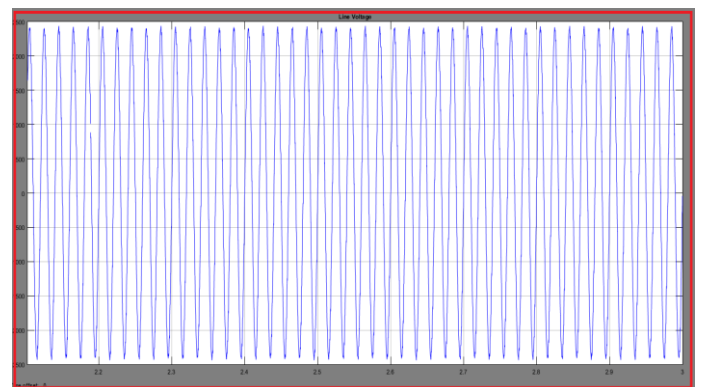


Figure 4 : Line voltage vs Time

RL Load :-

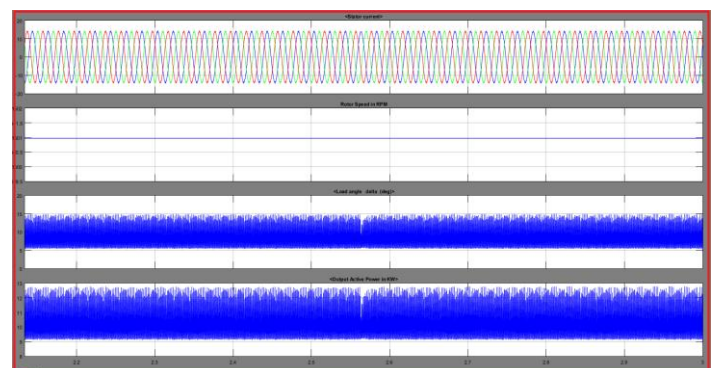


Figure 5 : (i)Stator current vs time (ii)Rotor Speed vs time (iii) Load angle vs time (iv)Output active power vs time.

RLC LOAD:-

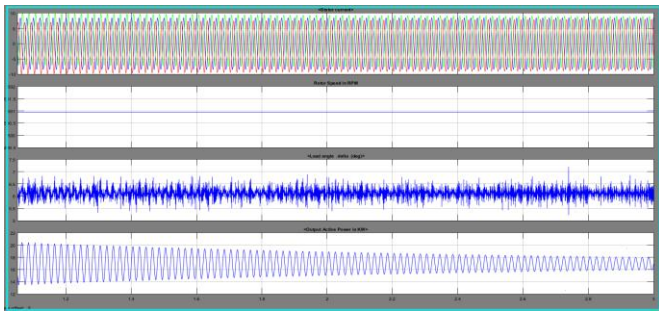
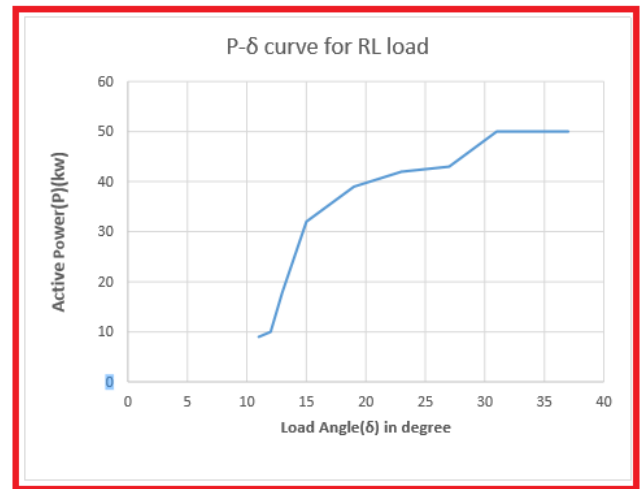


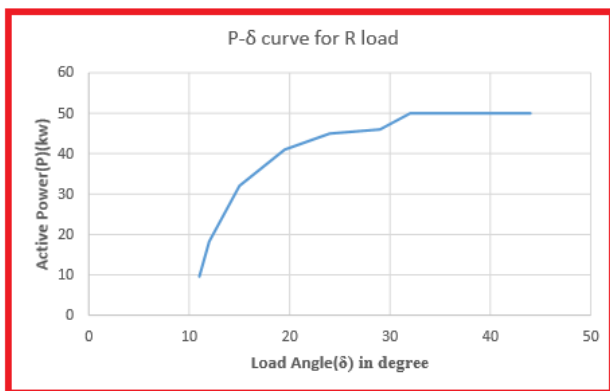
Figure 6 : (i) Stator current vs time (ii) Rotor Speed vs time (iii) Load angle vs time (iv) Output active power vs time



2.3 POWER VS LOAD ANGLE CURVE

i) R LOAD

Load angle	11	12	15	19.5	24	29	32	38	40
Power	9.6	18.3	32	41	45	46	50	50	50

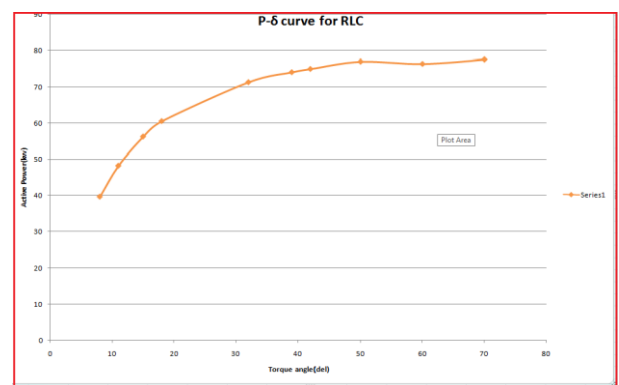


ii) RL LOAD

Load angle	11	12	13	15	19	23	27	31	35	37
Power	9	10	18	32	39	42	43	50	50	50

iii) RLC LOAD

Load angle	8	11	15	18	32	39	42	50
Power	39.6	48.2	56.2	60.5	71.3	74	75	77



3. CONCLUSIONS

We have made a model of the alternator in MATLAB and measure the parameter such as terminal voltage current resistance speed and frequency. The values of the active power and measure and could not reactive power due to lack of time.

We have also plotted P-Delta .We have learned details about alternator as well as how to use MATLAB and came to know about its importance and its applications. In future we can estimate the stability of the system. For that reactive power estimation is essential and obtaining this reactive power vs. load angle characteristics for different loading condition is necessary. Therefore the stable operating zone of an alternator from the real power vs. reactive power plot will be helpful for stability analysis .The real power vs. reactive power vs. load angle three dimensional graph can be plotted .By varying the excitation of the alternator we will observe

the adverse effects arise in different abnormal condition, like over-excitation, under- excitation so that adequate protection will be provided for the system stability .We can calculate the various kinds of fault that occurs in an alternator system by using proper relay and circuit breaker in the system.

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