Frequency Stability For Two Generators Using Robust Control (H∞ Controller)

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Abstract—**The purpose of this paper is to design a robust control using H ∞ controller theory to obtain a frequency stability of two different synchronous generator engines. Where the condition of power change from nominal conditions 96.81KVA to a minimum value 60.5KVA or maximum value120.03KVA. Besides, it is used a PID controller as a Coordinator in collaboration with H ∞ controller to obtain the minimum phase angle between the two generators. Based on the analysis show good results where the output voltage lost from the system is minimal.**

Keywords—Generator (genset); identification system; frequency; robust control (H∞ controller); PID controller.

I. INTRODUCTION

The frequency of power system is an important index that indicates of imbalance between generation and loads. For safe and reliable operation the frequency must be mention nearly constant at nominal values of 50/60Hz, since frequency is proportional to the rotational speed and the numbers of poles of the alternator when the controlling frequency is equivalent to controlling the engine speed and will saw that is common way to get frequency stability to achieve both frequency and voltage regulation, control inputs to the engine and alternator are available.

Despite obvious coupling between the engine speed governor and automatic voltage generator (AVR) for the alternator , separate single input single output system (SISO) control loop were typically used to independently control engine speed and hence frequency via the engine throttle and also the voltage amplitude via the field current[1]. Several control methods have been applied to engine speed controller in[2] the digital PID controller showed us to provide good and better performance when compared analog PID controller, in[3] the information from the voltage loop it was used to achieve better frequency control.

From [4], after the use of STATCOM it was shown the perfect control of system bus voltage to 1 pu and frequency control within the range of 49.95- 50.15 Hz. In addition, the steady state error is also a problem in conventional STACOM if there is interference with the control system and the system uncertainty, Previous works [5],[6],[7]H∞ controllers have larger bands than by the standard droop controllers it can give perfect performance for frequency.

Form hence we are going to design H-infinity controller for two generators in order to find the synchronization for both H-infinity because any generator has dependent H-infinity controller, we use this process to reduce the phase difference between the two generators.

II. PROBLEM FORMULATION

It is how to design method H_∞ controller to get perfect stability frequency and design the synchronization for both H-infinity controllers to make the different angle between generators is so small, used PID controller.

A. Problem Boundary

Based on parameters in the generator when the load is changed (resistance load) and upon which we'll apply H_∞ controllers (for both generators) and Synchronization (Coordinate) finding PID controller.

III. SYSTEMS MODEL AND IDENTIFICATION

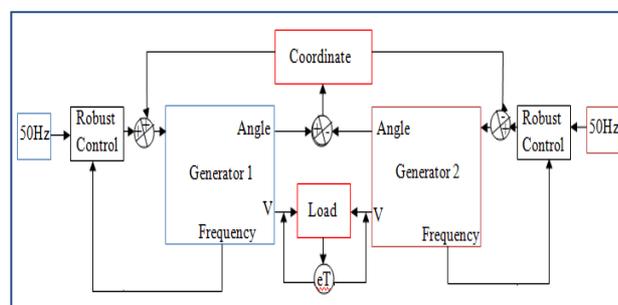Figure (1) illustrates the general shape of the overall system

Fig 1. General System

Regarding to [1] for modeling generator and engine can simulate it like figure.2 bellow for generator 1

Engine parameter should calculate from equations bellow it can use also to calculate the engine parameter for generator 2 will show in figure .3.

$$C_1 = \frac{H_u}{z V_h v} \tag{1}$$

$$C_2 = \frac{z V_h}{K T_b \pi} \tag{2}$$
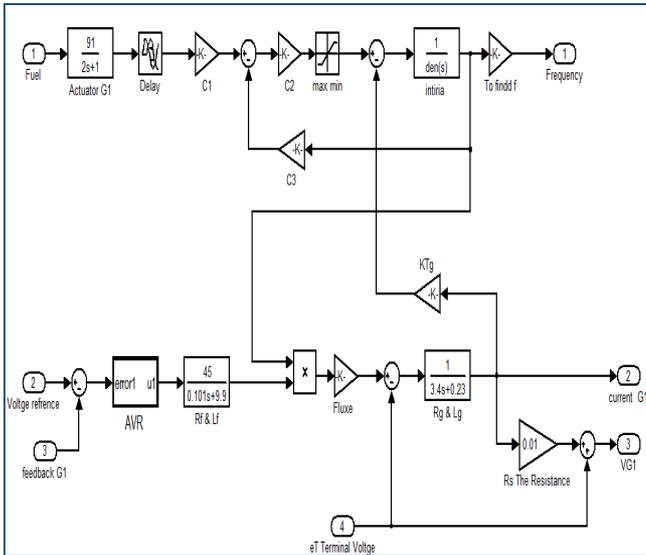
$$C_3 = \frac{2P_s}{P\pi}$$
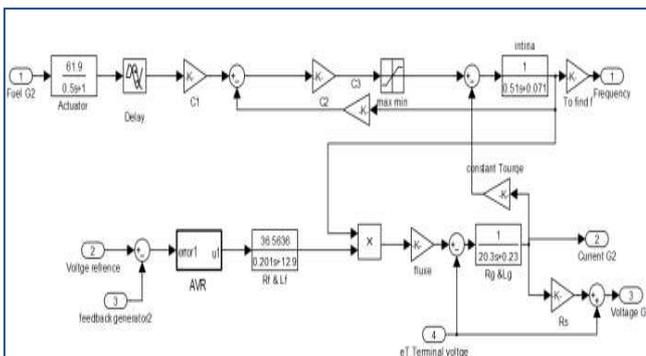
(3)

Fig.2. Generator 1

Fig.3. Generator 2

A. System identification depending on generator 1

From figure4 bellow the identification system from input (fuel) to output (frequency) when the other parameters should be uncertainly it done to get system has signal input 105.2 and output range 49.9-50.01Hz, the new system to be in state space.
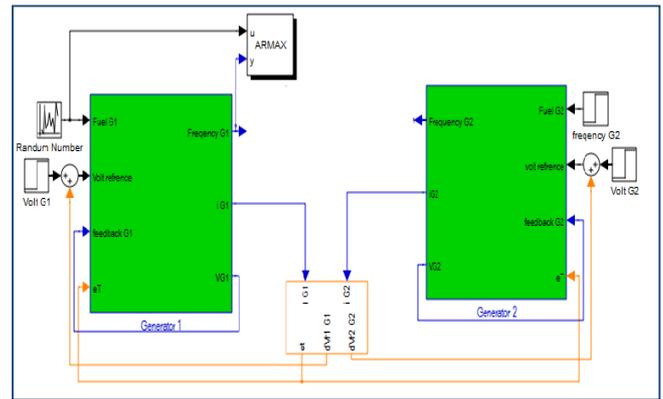

Fig.4. Identification generator 1

The identification results is

$$\dot{x} = Ax + Bu$$
$$y = Cx + Du$$

Where

$$A = \begin{bmatrix} -3.3040 & -2.7170 & -0.0289 \\ 1.0000 & 0.000 & 0.0000 \\ 0.000 & 1.000 & 0.0000 \end{bmatrix}$$

$$B = \begin{bmatrix} 1.000 \\ 0.000 \\ 0.000 \end{bmatrix}$$

$$C = \begin{bmatrix} -0.0374 & 0.3476 & 0.0029 \end{bmatrix}$$

$$D = \begin{bmatrix} 1.8898e - 004 \end{bmatrix}$$

B. Identification the system depending of generator 2

From figure5 bellow the identification system from input (fuel) to output (frequency) when the other parameters should be uncertainly it done to get system has signal input 496.6 and output range 49.99-50.03Hz, the new system has be in state space
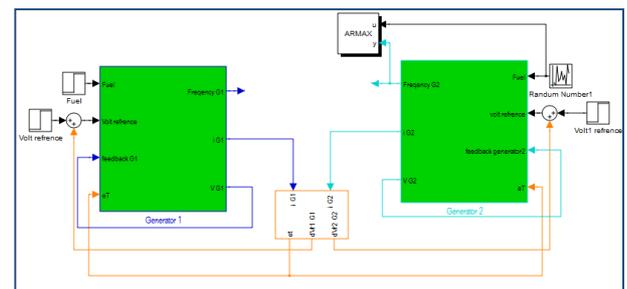

Fig.5. Identification generator 2

The identification results is

$$\dot{x} = Ax + Bu$$
$$y = Cx + Du$$

$$A = \begin{bmatrix} -2.3040 & -1.7170 & -0.3806 \\ 1.0000 & 0.000 & 0.0000 \\ 0.000 & 1.000 & 0.0000 \end{bmatrix}$$

$$B = \begin{bmatrix} 1.000 \\ 0.000 \\ 0.000 \end{bmatrix}$$

$$C = \begin{bmatrix} -0.006 & 0.0129 & 0.1808 \end{bmatrix}$$

$$D = \begin{bmatrix} 2.9881e - 004 \end{bmatrix}$$

C. Load Connector

Fig .6. System load.

From figure 6 above we can find of all the equations bellow as:

$$I_1 = \frac{emfG1 - eT}{L_{g1}s + R_{g1} + R_{s1}} \tag{4}$$

$$I_2 = \frac{emfG2 - eT}{L_{g2}s + R_{g2} + R_{s2}} \tag{5}$$

$$I_l = I_1 + I_2 \tag{6}$$

$$eT = R_l * I_l \tag{7}$$

When $R_l = 0.5k\Omega$ and the total power is equal to 96.81KVA we can find the equations bellow, since we are doing it for nominal plant just, but actually the H-infinity controller should work under all situations from equations bellow we looking for the feedback of generator 1 and feedback of generator 2

$$R_l = \frac{1}{2} \rightarrow P = \frac{48400}{0.5} = 96.8KVA \tag{8}$$

$$I = \frac{220}{0.5} = 440A \rightarrow \frac{I_1}{I_2} = \frac{4}{1} \rightarrow I_1 = 4I \tag{9}$$

$$I = I_1 + I_2 \text{ and } I_1 = 4I_2 \rightarrow I_1 + I_2 = 5I_2 \tag{10}$$

$$I = \frac{v}{R} = \frac{220}{R} \rightarrow I_2 = \frac{220}{R} = \frac{220}{5R} \tag{11}$$

$$V_2 = R_s I_2 \rightarrow 220 + R_s I_2$$

$$V_1 = 220 volt \tag{12}$$

$$V_{r1} = 220 + \frac{4}{5} i_R * R_{s1} \tag{13}$$

$$V_{r2} = 220 + \frac{1}{5} i_R * R_{s2} \tag{14}$$

This form it can be in matlab like the figure bellow, it becomes our load in this case. The last two equations (13) and (14) are what we looking for voltage references.

Fig.7.Conection load

After that we have acquired the two systems now will work on drawing/plot the frequency, Power and angle for the two generators before we use H-infinity controller for the two systems .

Figure (7) frequencies response before using controller.

table 1 bellow description for what happened for frequency when the loads is changing.

Table 1 frequency response without controller

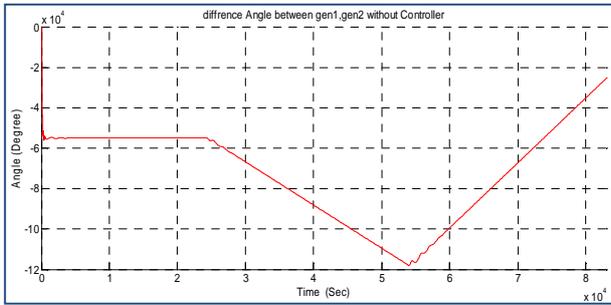|	P.KVA	Situation	T.sec	KΩ	F.Hz
G1	96.8	nominal	100	0.5	50
	121.01	maximum	100	0.4	49.68
	60.50	minimum	100	0.8	50.48
G2	96.8	nominal	100	0.5	50
	121.01	maximum	100	0.4	47.78
	60.50	minimum	100	0.8	54.34

Fig.8. Difference Angle

shows The amount of divergence angle between the two systems (generator1, generator2).it's so big that means the generator2 is will be has over shoot and even it can lost the power, can saw it from equation (3.1) bellow, if the difference angle between two generators is around eight degree that is mean we are going to lost around 30.61810094 volts

$$V = 220 volt \times \sin(\Theta \times 3.142/180) \tag{15}$$

IV. PROBLEM SOLUTION

A. *Design H$_\infty$ Controller*

General Control problem shows in figure (9) and sensitivity (S) and K (controller) shows in figure (10) bellow The mixed S (Sensitivity)/KS problem can be illustrated with the block diagram shown in Figure s and regarding to [8] bellow the closed loop transfer function T = F$_l$(P,K) from w to z can be found by visual inspection as:

$$\begin{bmatrix} z_1 \\ z_2 \end{bmatrix} = \begin{bmatrix} W_s S \\ W_{ks} KS \end{bmatrix} r \tag{16}$$
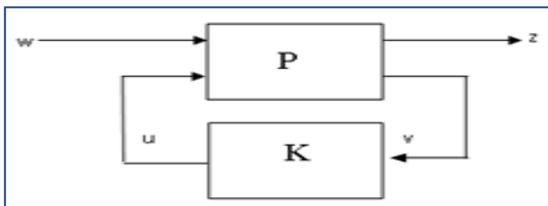
Fig.9. H-infinity shape

The generalized plant P(s) (see Figure (10)) is can be written as

$$\begin{bmatrix} z_1 \\ z_e \\ \hline e \end{bmatrix} = \begin{bmatrix} W_s & -WG_s \\ 0 & W_{ks} \\ \hline I & -G \end{bmatrix} \begin{bmatrix} r \\ \hline u \end{bmatrix} \tag{17}$$
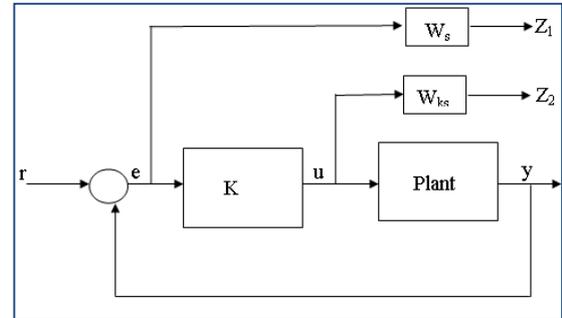

Fig.10. generalized H-infinity

Already we can put our systems and scalar of sensitivity and K(Controller) in state space realizations depending of G (plant),W$_s$(weight sensitivity) and W$_k$(weight controller)

$$G = \begin{bmatrix} A & B \\ \hline C & D \end{bmatrix} \tag{18}$$

$$W_s = \begin{bmatrix} A_s & B_s \\ \hline C_s & D_s \end{bmatrix} \tag{19}$$

$$W_{ks} = \begin{bmatrix} A_{ks} & B_{ks} \\ \hline C_{ks} & D_{ks} \end{bmatrix} \tag{20}$$

Shown that a possible state space realization for P(s) (general plant) is given by equation bellow

$$P = \begin{bmatrix} A_s & 0 & -B_s C & B_s & -B_s D \\ 0 & A_{ks} & 0 & 0 & B_{ks} \\ 0 & 0 & A & 0 & B \\ \hline C_s & 0 & -D_s C & D_s & -D_s D \\ 0 & C_{ks} & 0 & 0 & D_{ks} \\ 0 & 0 & -c & I & -D \end{bmatrix} \tag{21}$$

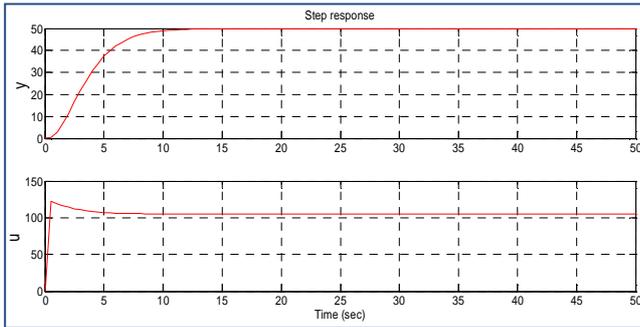Figure (11) bellow show the results of design H-infinity controller for step response frequency generator1.

Fig.11.frequency response generator 1

Where the infinity norm for sensitivity function and complementary sensitivity function must be less than Gamma ,for GK must be not large value ,was done already in this steps bellow

$$\gamma = 12.7041 \tag{22}$$

$$\|S\|_\infty = 1.2499 < \gamma \tag{23}$$

$$\|T\|_\infty = 0.99999 < \gamma \tag{24}$$
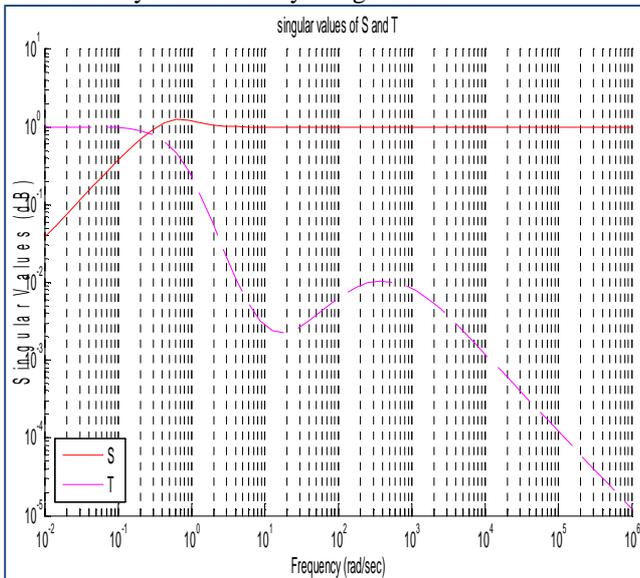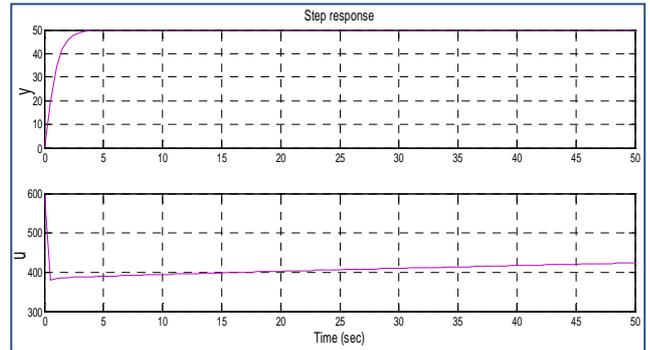
It can be easy shows exactly in figure .12.

Fig .12. S and T

Figure (13) bellow show the results of design H-infinity controller for step response frequency generator2 , this result was done when the load was nominal .

Fig.13. frequency response generator 2

Where the infinity norm for sensitivity function and complementary sensitivity function must be less than Gamma ,for GK must be not large value ,was done already in this steps bellow and easy can be achieved in figure (14) bellow.
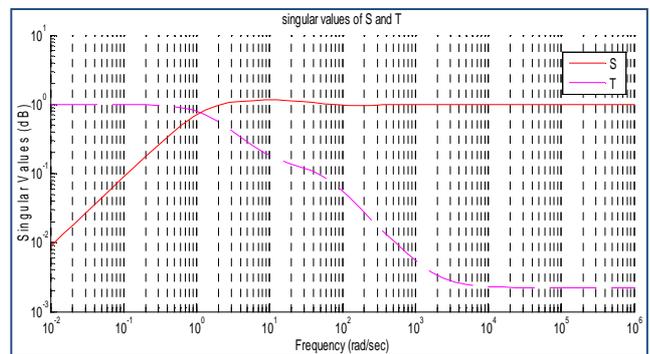

Fig.14. S and T generator 2

$$\gamma = 1.5459 \tag{25}$$

$$\|S\|_\infty = 1.1543 < \gamma \tag{26}$$

$$\|T\|_\infty = 0.9997 < \gamma \tag{27}$$

B. Design the Coordinator (PID controller)

Summed up the process in the divided mange signal input to the system, we find that in the case of the first-system, we need to decrease the signal to reduce the available work by H-infinity controller either in the case of second generators we reduce the control signal input to the system from H-infinity controller We need this process to reduce the angle difference between the two systems to lower the value of what can be. Having been in this search PID controller use to conduct this purpose. I've been choosing all of the constants K_p, K_i, K_d by trying and try, values change several times until we were able to get teams to the appropriate angle to a large extent
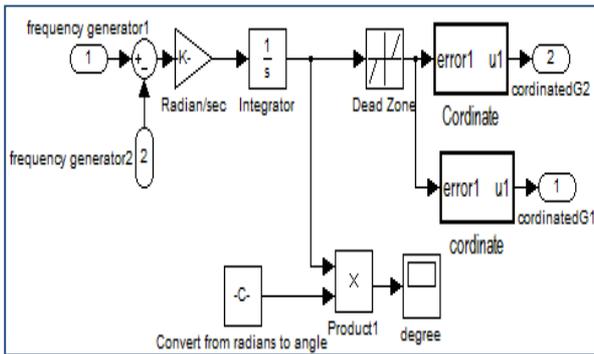
Fig.15. Coordinator

Contains controller type PID where the first PID controller must send a negative signal to H-infinity controller in generator 1, and the second PID controller must send a positive signal to H-infinity controller in generator 2, knowing that the starting frequency switching to Radian was conducted because the integration process in ra/sec still with time and the other has been converted to radians angle which is the difference between the two generators.

Table 2 PID controller values

	K_p	K_i	K_d
Generator 1	1e-48	0.1e-2	0.238e-1
Generator 2	90	390	90

C. *Simulation Results*

Table 3 Simulation parameters.

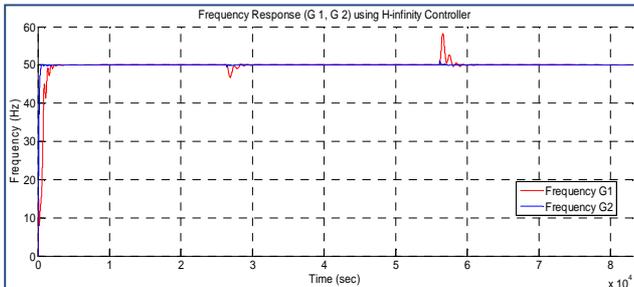| Generator1		Generator2	
J	0.19 Hz/sec	J	0.51 Hz/sec
B	0.087 Hz/sec	B	0.071 Hz/sec
R_f	0.101 KΩ	R_f	0.201 KΩ
R_g	3.4 KΩ	R_g	20.3 KΩ
L_g	0.23H	L_g	12.9 H
L_f	9.9 H	L_f	0.23 H

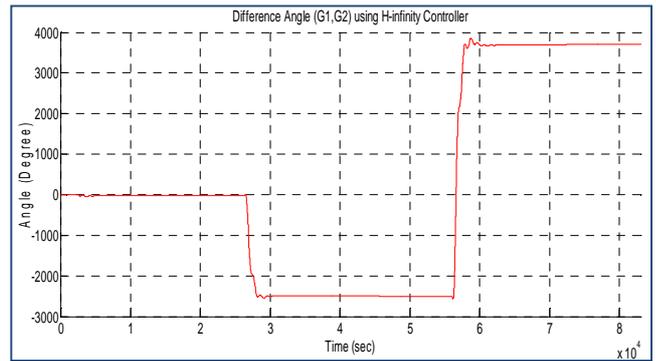Fig.16. Frequencies response using H-infinity

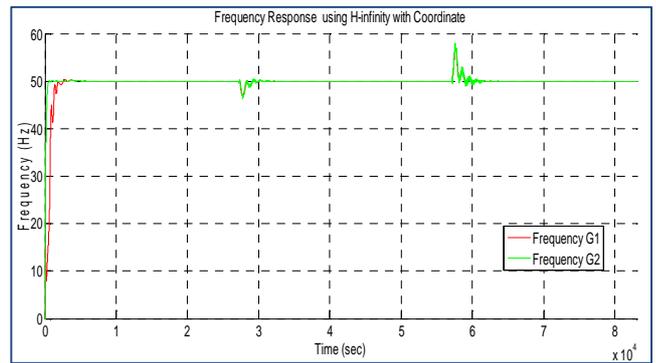Fig.17. Difference Angle using H_∞ controller before using coordinate PID controller.

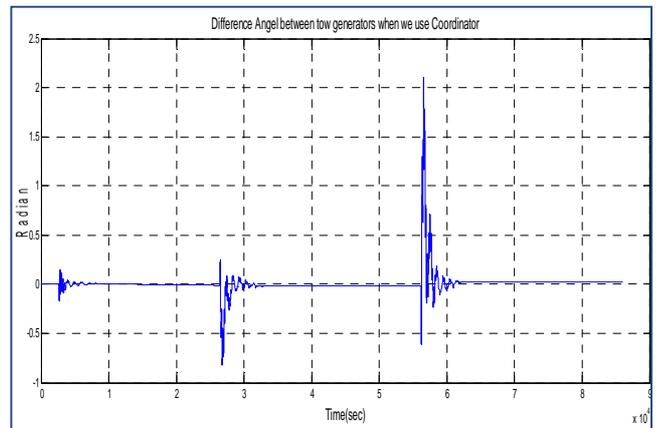Fig.18. Frequencies response using H-infinity and Coordinate
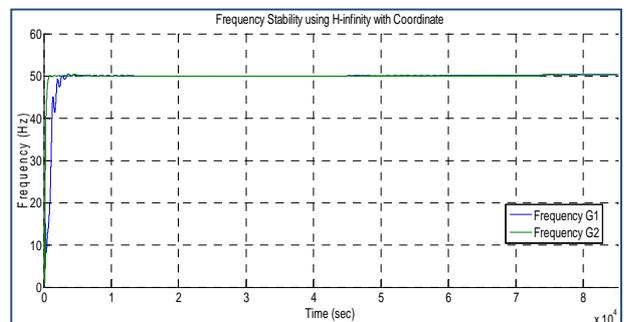

Figure.19.Difference Angle with Coordinate

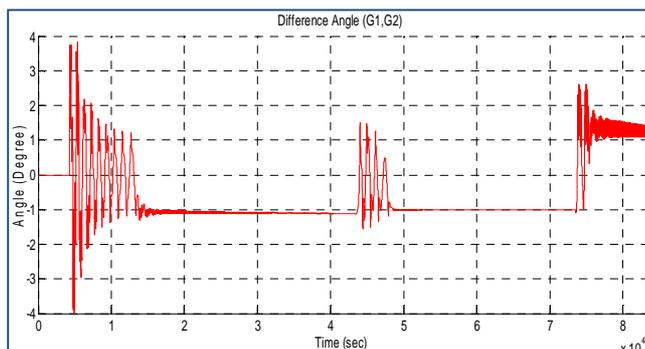Figure .20. Frequency response when the load changed slowly

Fig.21. Difference Angle with Coordinate (load change slowly)

V. CONCLUSION

Description of the discussion about this thesis of stability frequency for two generators using robust control (H-infinity controller) following these conclusions: Robust control (H-infinity method) controllers for the system have been presented this thesis presented frequency stability for two generators using H∞ controller in a different loads from 60.5KVA to 121.003 KVA. In the proposed method, H∞ control theory is used for the stability frequency and difference angle with Angle coordinator that means the controller has ability to receive signal from the coordinate. Therefore can obtain the frequency response and robustness.

The simulation results show H∞ control makes the frequency range within 49.99Hz-50.05Hz which is good enough for isolated plant and even the Load is change during 100sec from Maximum Power to Minimum Power

PID Controller works with H∞ controller (increase and decrease the signal control input) had Give good results where teams work to minimize the angle between the generators we saw that from the simulation result difference angle been from more than 2000 degree to 1.304 degree.

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NOMENCLATURE

J	= inertia generator pu MW·sec/Hz
B	= damping pu MW/Hz
R_l, Z_l	= resistance load (KΩ)
R_f	= resistance flux (KΩ)
L_f	= conductor flux (H)
Q_m	= torque mechanical (N.m)
Q_e	= torque electric (N.m)
R_g	= resistance generator (KΩ)
L_g	= conductor generator (H)
I_{G1}	= current generator 1(A)
I_{G2}	= current generator 2 (A)
I	= total current (A)
V_{G1}	= volte generator1 (V)
V_{G2}	= volte generator2 (V)
eT	= terminal voltage (V)
AVR	= automatic voltage regulator
Kggl	= Emf (V)
R_s	= distance resistance (KΩ)
f	= frequency (Hz)
Hu	= the heat value of the fuel in kilojoules per kilogram
Z	= the number of cylinders
V_h	= one stroke volume in cubic,
K	= the number of strokes, e.g., $k = 4$ in a four-stroke cycle,
T_b	= the base mechanical torque in Newton meters
v	= the stroke cycle per second
Ps	= the piston stroke in millimeters
P	= the number of poles in the generator.
S	= sensitivity
T	= complementary sensitivity
KS	= signal input to Generator
GK	= signal of loop transfer function
Sd	= desired sensitivity
KSd	= desired output signal controller