DETECTION OF FAULT IN GAS TURBINE USING MATLAB SIMULINK

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Abstract - *Gas turbines are one of the important equipment in the field of power. They are very much used in power generation, factories, industries and many other platforms. However, G.T's are not being monitored manually in most of the cases. Safety is considered as one of the important factor for smooth working of gas turbines. If any fault occurs in the system then it can be very serious. There is a much need of new technologies and techniques to be developed for fault detection. In this paper, we we will make an automatic or non manual system for the detection of fault in Gas Turbines. Also in this paper, simulation modelling of the G.T is being performed. This model is primarily used for generating simulated fault data.*

***Key Words*: Gas turbine, Mu- law compressor, Throttle and Manifold, Over vibrations, Modelling and Simulation**

1. INTRODUCTION

Gas turbines are operated on Brayton cycle. Air is considered as the fluid for the system which is compressed and mixed with fuel and then being sent for combustion process. Then this gas goes to the turbine to generate power. G.T play an important role in various domains and gas sectors, and also for effective generation of electricity in the power sector. G.T was first came in use in 1939 for power generation. Combustion continuously occurs in gas turbines as compared to the IC engines, in which it occurs intermittently.
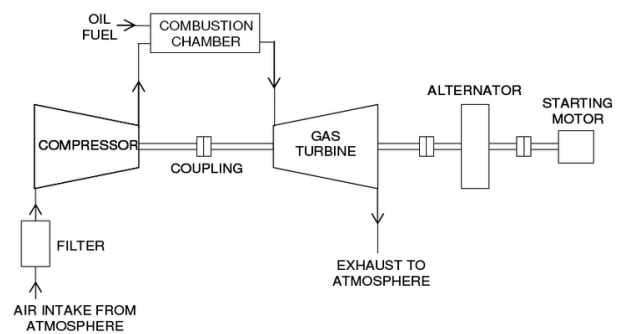
1.1 Block Diagram

Figure 1

From Figure 1 we can see that a Gas Turbine has four basic components including Compressor, Combustion Chamber, Turbine and Alternator. Generally compressor is being set upwards the stream, the rotating turbine is set downwards the stream and the C.C(Combustion Chamber) is connected in between the both. At the end we have an Alternator which is also connected on the same shaft. As discussed earlier Gas Turbine is operated on "Brayton Cycle. First of all, fresh atmospheric air is taken in the Compressor and after compression it gets into high pressure, next comes the C.C in which fuel is sprayed continuously that ignites the air so that combustion generates a high-temp flow. In the next stage, this high temp and high pressure gas enters into turbine and releases its energy to turbine and the turbine starts to rotate. A synchronous generator is connected to the turbine and when turbine gets to its rated rpm, then synchronous generator starts to generate electricity. Gas Turbines are of different size and ratings. The operation of a Gas Turbine includes to monitor a large no of parameters. For example when a G.T is operating, many other components are also operating simultaneously and there is always a chance of fault occurrence and some abnormal vibrations. Although we have a large no of primary and secondary protection equipments installed but we still need to be careful and alert in the monitoring of the system for its safe operation

1.2 System Description

In the model various components are used that are briefly discussed below:
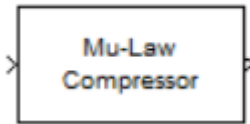
A) Mu- Law Compressor

Figure 2

The Mu-Law Compressor block gives a μ-law compressor for the input signal. The formula for the respective term is

$$y = \frac{V \log(1 + \mu |x|/V)}{\log(1 + \mu)} \operatorname{sgn}(x)$$

where μ = μ-law parameter of the compressor,
    V =peak magnitude of x
    Log=natural logarithm
    sgn = signum function

The input can be of any shape. Also each vector element is being processed independently in the block.

B) Throttle and Manifold

Throttle and Manifold control model observes the air intake dynamics of the gas turbine. If you double click on the block, a new window will open which shows the embedded close loop system of 'Throttle and Manifold ' control, as we can see in Figure 3
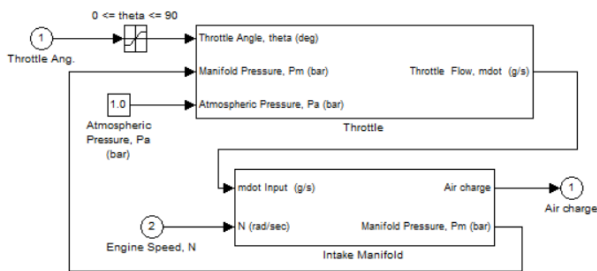

Figure 3: Air Intake Dynamics

At first there is the throttle angle control of gas turbine. It has three inputs, the first one is the Throttle angle 'Theta' measured in 'degrees'. Second input is the atm pressure which is measured in 'bar', also shown in the above figure. Third input is of the 'Manifold Pressure' which is also measured in bar. Manifold is actually the output of second control system which is also embedded in the same system .From the above figure, we can see that in the next stage, output of 'Throttle Control' is actually the input of 'Manifold Control' system and second input of manifold system is

Engine Speed which is actually the speed of Gas Turbine measured in rad/sec .The output of the whole system is Air Charge and as described earlier that when fresh atmospheric air is burned in the C.C then high temp and high pressure air charge is produced.
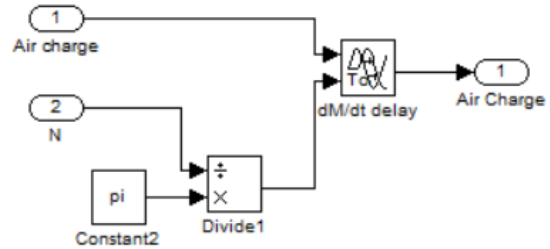
C) Induction to Power stroke delay

Figure 4

This control system has 2 inputs, first one is the Air charge and second one is the running speed of the turbine. If we closely observe the figure then we will notice that we have place 2 inputs to control model named 'Divide1'. It is actually a comparator that is continuously comparing the actual running speed of the turbine and the constant reference value. An error will be generated whenever speed will deviate from its reference value. Both these inputs goes to the next control box named 'variable time delay'. It continuously monitors the ratio of air charge flowing into the system and the corresponding turbine speed. For example, whenever the pressure or temp of the inlet steam varies then, turbine speed will vary and will generate an error, which tells us that some abnormalities are going on in the system.

D) Engine Torque Control

This control system also has 2 inputs, the first one is of the Air Charge and second is the speed of the turbine. If we double click on this control model then a new window will open representing its internal parameters as shown in Figure 5
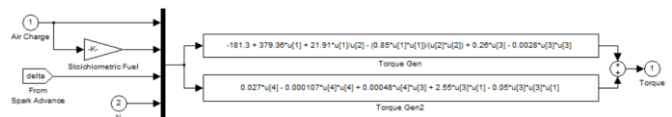

Figure 5

Engine Torque is defined by 4 input parameters. First is the Air charge and it goes to the Stoichiometric Fuel burning mechanism of C.C. This is becoz the combustion chamber burns the fuel according to already existing temp and pressure of the charged air. If temperature of the air that is entering the C.C is much lower then, it will burn more fuel to

get the proper temperature and pressure of the air. The third input is the 'Spark Advance' that monitors whether the spark plug is igniting the fuel with proper timing or not. If it doesn't ignite the fuel on exact time then, unburnt fuel particles will come through the exhaust hole and there will be no smooth running of the engine. Fourth and the last input is of the speed of the turbine. Engine Torque control also monitors the existing speed of the turbine and if the turbine is not running with the proper speed then, it will decide whether it requires to open more fuel to attain proper speed or there is some issue going on with spark ignition system. All the parameters discussed above defines the Engine's torque. If there is any problem with any of the input then output torque will vary accordingly.

E) Gear Box

Figure 6

Gear box is the most important control model of Gas Turbine. It has only one input i.e RPM of turbine which is coming from the tachogenerator. We can see in the above given figure that this control model monitors RPM, Vibrations, Over Vibration, Dangerous Vibration and Bearing factor errors.

2. SIMULATION MODEL

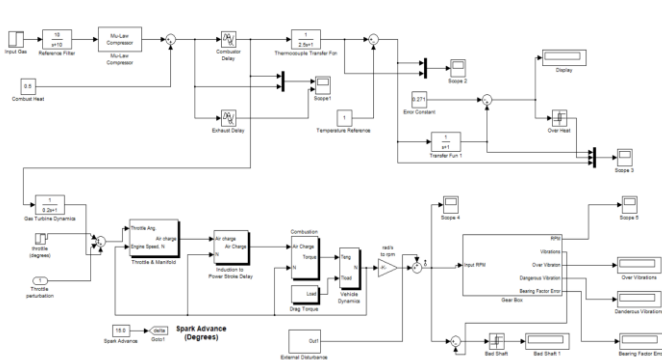The complete simulation modelling of the system is shown below:

Figure 7

3. RESULTS

PART (A)

When the simulation is run, then the system monitors the complete simulation model completely from the first step to the final step i.e from inlet fresh air to RPM of the Gas Turbine. If there in the system, any problem occurs then turbine speed will vary. The best thing about the Project's simulation is that we can put abnormalities in our system to monitor the system's behaviour. This helps to improvise new technology and leading us to a better design of the system.
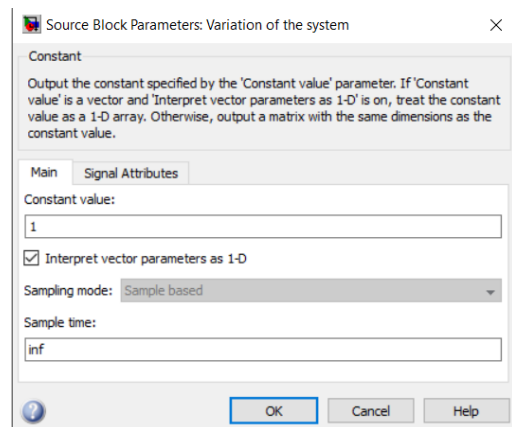

Figure 8

In the Gear Box model of the system when we double click on it we can see the internal parameters of the block. In it there is a control model titled 'variation of the system'. In it there is other small window, as shown in figure 8. If we look closely to the window opened there is an option named "Constant value" where we can change the vibrations inserted in the system. Here we changed the value according to our own choice and started from 1 to maximum value (12) to observe the behaviour of Gas Turbine. Now some abnormalities is done on the above system's to see their results to conclude either they are dangerous or not.
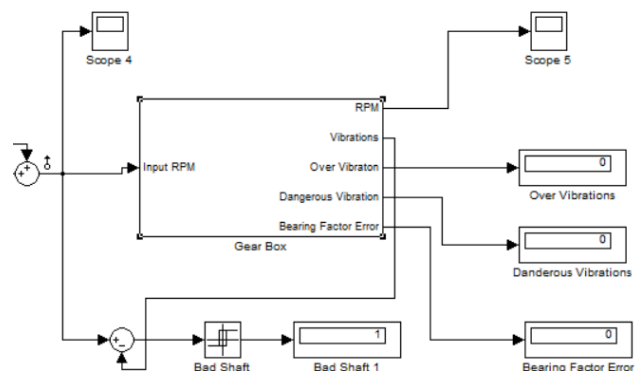

Figure 9

First of all, we kept the vibrations of the system at 1 and then run the simulation. From Figure 9 we see that as we set the vibration value to 1 no error is being generated by the simulation or we can say that the G.T is running smoothly without occurrence of any error. Now the vibrations of the system is being increased and keep its value 10. After this we see that system is generating over speeding error and Bearing Factor error but they are not Dangerous yet and system can also run under these conditions. In the next stage, make its value 12. Now we observe the output of the system in Figure 10. We can easily see that after increasing the vibrations of the turbine upto an extend that it has generated the Dangerous alarm. Now we must quickly stop the system and if we dont do that, then the system will collapse.
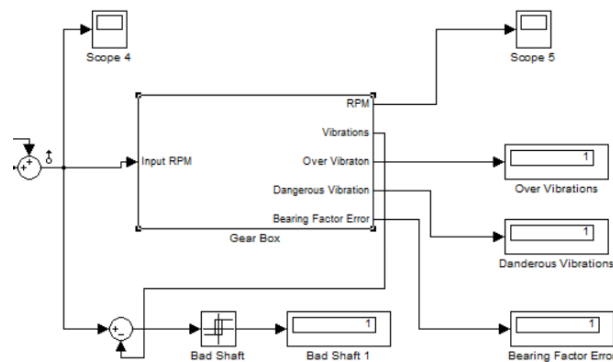

Figure 10

PART (B)

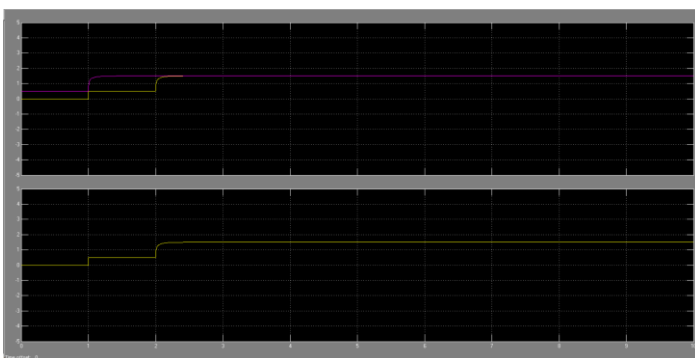After performing the simulation of the model following results were obtained through scopes:
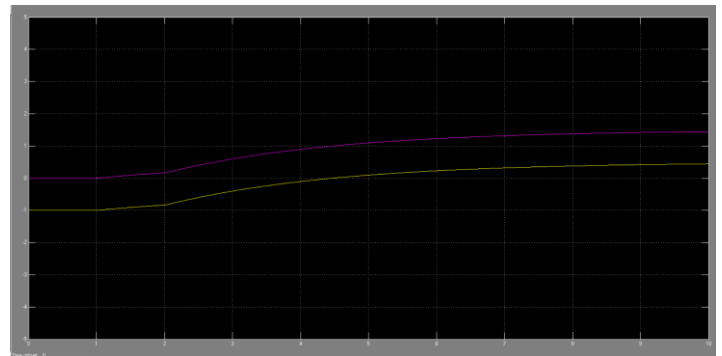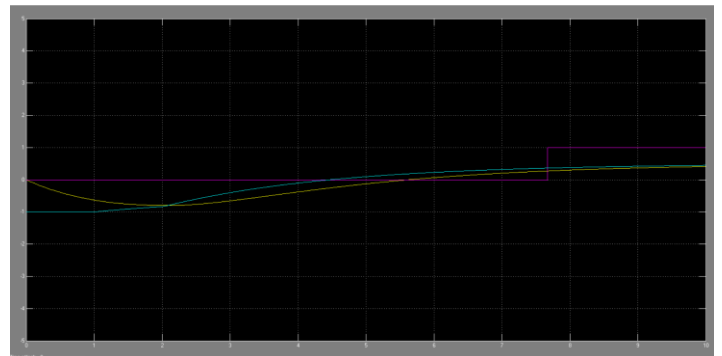

Figure 11: Scope 1

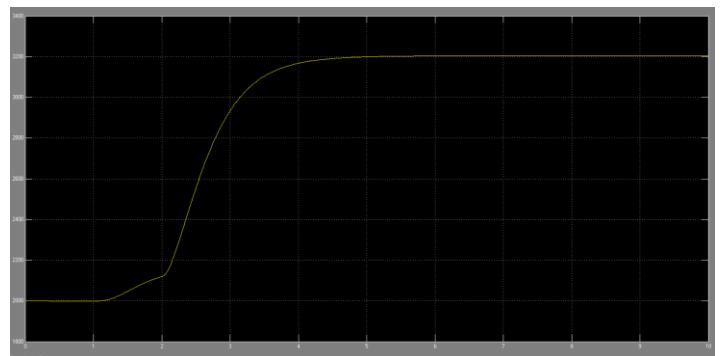**Figure 12: Scope 2**

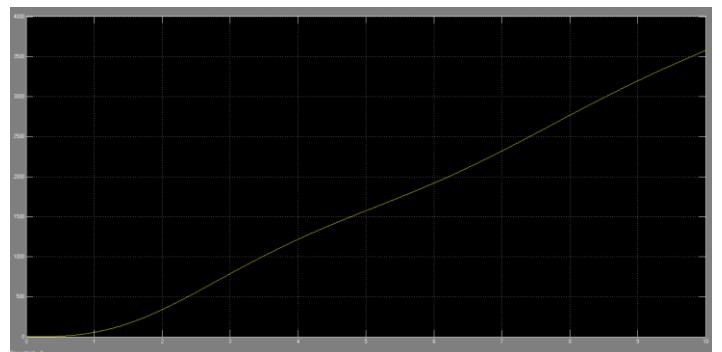**Figure 13: Scope 3**

Figure 14: Scope 4

Figure 15: Scope 5

4. CONCLUSIONS

The development of the MATLAB SIMULINK model of a gas turbine has been presented. Although this is an application based study on a gas turbine, the methods and principles are applicable to almost any industrial system with dynamic behaviour. Automatic fault detection and diagnosis are highly desirable in many industries, such as offshore oil well drilling platforms where systems are self-monitoring without man on duty. In this work, we design an intelligent abnormality detection and fault recognition technique for gas turbines based on simulation modelling. Although this method gives an effective framework for automatic fault detection, the proposed technique is not being tested on large-scale works. We have developed a automatic state monitoring and fault diagnosis system. In the future, these techniques will be much better and will develop a reliable diagnosis system.

5. REFERENCES

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