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STUDY OF THE CHARACTERISTIC RESPONSE OF PRESSURE CONTROL SYSTEM IN ORDER TO OBTAIN THE DESIGN PARAMETERS OF THE NEW CONTROL SYSTEM MARK VI TURBINE IN COFRENTES NUCLEAR POWER PLANT

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ABSTRACT

This paper presents the results obtained from the IBE-CNC/DAQ-090827 project, conducted by the company "Titania Servicios Tecnológicos, S.L." in collaboration with the "Instituto de Seguridad Industrial, Radiofísica y Medioambiental" (ISIRYM), in the "Universidad Politécnica de Valencia", for the company "Iberdrola Generación S.A".

The objective is the acquisition of the pressure sensor signal and the measurement at points C85 and N32 from the cabin of the Turbine Control System in Cofrentes Nuclear Power Plant. With the study of previous data, one can obtain the Bode plot of the crossed signals as requested in the technical specification IM 0191 I. Frequency response (i.e. how the system varies its gain and offset depending on the frequency) defines the dynamics.
Keywords: Bode, Turbine Control System, frequency response.

1. INTRODUCTION

In August 2009 the IBE-CNC/DAQ-090827 project started. Under the terms of the contract it was necessary to provide an instrumentation and digital control system to the BWR Nuclear Power Plant of Cofrentes (hereafter referred to as CNPP), owned by Iberdrola S.A. The Nuclear Power Plant needed a new control system since they had to replace their old turbine control by a new one, purchased from General Electric, the American enterprise.

General Electric detailed its supplies as following: an integrated Mark VI digital control, monitoring equipment Bently Nevada 3500 and the System R optimization software, which enable to replace the analog control system of the turbine, the surveillance and monitoring system of the turbine and control system reactor pressure and steam bypass.

Specifically, the SPEEDTRONIC™ Mark VI turbine control is the current state-of-the-art control for GE turbines. It is designed as a complete integrated control, protection, and monitoring system for generator and mechanical drive applications of gas and steam turbines. It is also an ideal platform for integrating all power island and balance-of-plant controls. Hardware and software are designed with close coordination between GE's turbine design engineering and controls engineering to ensure that the control system provides the optimum turbine performance and one receive a true "system" solution.

Thus, the Mark VI turbine control has a triple redundancy by providing the improvement of security conditions, the bugs elimination and a capacity of 100% of repairs online. This will result in shorter stop time of the turbine and increased confidence in correct operation.

To perform the replacement of the control system, it was necessary to study the characteristic response of the old pressure control system in order to obtain the design parameters for the new control system, Mark VI. These parameters had to fulfill the technical specification "IM 0191 I" of Cofrentes Nuclear Power Plant (CNPP).

2. DESCRIPTION OF THE TEST CONDITIONS

The test was carried out by introducing a simulated signal that represents the manifold pressure equalizer.

The input has the simulated pressure signal; it had a small AC variation that representing a change in the amount of pressure on constant value through pressure.

This variation leads to a change in the current output of the servo control valves Turbine N32. To complete the study a measuring point through to the output of the first stage of electronics was needed, the point selected was identified as C85.

The amplitude and phase of the output signal with respect to the input pressure signal, was registered through the interest frequency range.

Frequency response, i.e. how the system varies its gain and offset depending on the frequency, defines the system dynamics.

For the test execution it was necessary to simulate some specific turbine parameters:

- Pressure of the manifold equalizer.
- Speed of Turbine.
- Position of a Control valve.

Some assemblies and connections were conducted, in order to achieve the following conditions of plant simulation: CV1 position of 75%, and a simulated speed of 1,500 rpm. These assemblies and connections are summarized below:

- The signal generated and entered should be equivalent to an average constant pressure value of about 900 psig (approximately 9.00 VDC) with stability higher than ± 0.0015 VDC. Besides, it should have a small sinusoidal AC variation superimposed, representing a change from 1 to 2 psig (± 0.005 to ± 0.01 Vac) in the pressure amplitude. This signal must be entered and registered by the equipment provided for the test.
- The variation of AC superimposed on DC leads to a change in the current output of the servo control valves. This current should also be measured and recorded by the equipment, simultaneously to the previous one. For the measurement a 250 Ohm (± 0.1%) resistor was inserted in the circuit of the servo valve. In this way, a voltage measurement point of ± 5 VDC ± 0.1% was provided.
- The amplitude and phase of the output with respect to the inlet pressure should be registered through the interest frequency range, from 0 to 1 Hz at intervals of 0.01 Hz and from 1 to 20 Hz at intervals of 0.1 Hz, during the time required to get representative data. As it has been explained previously, the frequency response defines the system dynamics.
- Finally, from the measurement values obtained, two logarithmic plots were drawn, one for the amplitude and one for the phase.

3. PROJECT STEPS

The steps followed to prepare the system for the project were as follows:

- Step 1: Looking at the technical features and the equipment needs to carry out both the measurement and the generation of the signal injected into the cabin, based on the Nuclear Power Plant specifications: IM 0191 I.
- Step 2: Study of the connections between the equipment and the systems involved in the tests. The aim was to reduce and /or eliminate any disturbance in order to acquire and generate signals, wiring, and land.
- Step 3: Programming the application to carry out the necessary tests depending on the frequency and data recording and display preliminary results for verifying the proper performance of the tests.
- Step 4: Excitation and Measurement in the cabin of the Turbine Control System in CNPP. This stage was subdivided into:
    - § Connection and preparation of the measurement and generation system. This work was done in collaboration with CNPP technicians.
    - § Check the validity of the acquired signals. This was a critical point in the test execution mainly because the data observed in the acquisition system did not have coherent meaning. Therefore long time was spent making different connections both on measurement points and on the wiring used in the test. In that phase CNPP staff participated in fieldwork, as well as Titania and ISIRYM staff, working as technical support.
- Step 5: Preliminary analysis of results.
- Step 6: Analysis of the acquired data and calculation of Bode diagrams. There had been three parallel studies in order to obtain Bode Diagrams:
    1. Bode Diagram Calculation from Temporal Signal Analysis. In this analysis it was necessary to resample the signal with a factor of 50 to eliminate the

noise in N32 signal. By this way, the delay time was determined and then the gap between phases was calculated.

2. Bode Diagram Calculation from Frequency Analysis. This method provides more consistent data since it was easier to calculate the gap between phases by the domain change.
3. Measurements have been made from an injected signal, a multi-frequency one, which was composed by the sum of signals with the same frequencies as those signals used for conducting the test. This test was performed to check whether the system behaved in the same way to a single-frequency signal and to a multi-frequency signal. The last one is more similar to a real field signal.

To obtain the answer of the turbine control system, signals from two measurement points were acquired. The information provided by these acquired signals let to analyze the two stages of the control electronics.

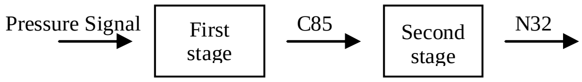

Figure 1. Set point of measurements

Therefore, a comparative analysis of the acquired signals was required in order to get the various responses. The analysis sequence was as follows:

- Pressure signal versus C85.
- C85 versus N32.
- Pressure signal versus N32.

4. TECHNICAL REQUIREMENTS

The stability test of the Control System Pressure Reactor C85/N32 was held in the Control Room, specifically in C85P600 and H13PP724 panels. The generated signal, representing the manifold pressure equalizer, was introduced in the analog input C85 System. The system consisted of one input and two output signals, which were used by the following equipments:

- 1 digital multimeter (4 ½ digits).
- 1 Function generator Hewlett Packard model 3310B; with 50 Ohm output impedance, (oscillator).
- Equipment Data Acquisition with these features:

• Chassis National Instruments PXI-1042Q.
• NI-PXI 8360.
• Data acquisition card NI-PXI 4462:
    - 4 analog inputs
    - 24-bit resolution with 118 dB dynamic range
    - 204.8 kS / s maximum sampling frequency
    - input range ± 316 mV to 42.4 V

• NI-PXI card generator 5421:
    - 1 analog output
    - 16-bit resolution, 100 MS / s sampling rate
    - 12 Vpp into 50 O load

5. RESULTS

The results are organized distinguishing the single-frequency signal analysis from the multi-frequency signal analysis.

Regarding to the single-frequency signals, graphs showing the data acquired in Cofrentes Nuclear Power Plant are showed in first place for different frequencies.

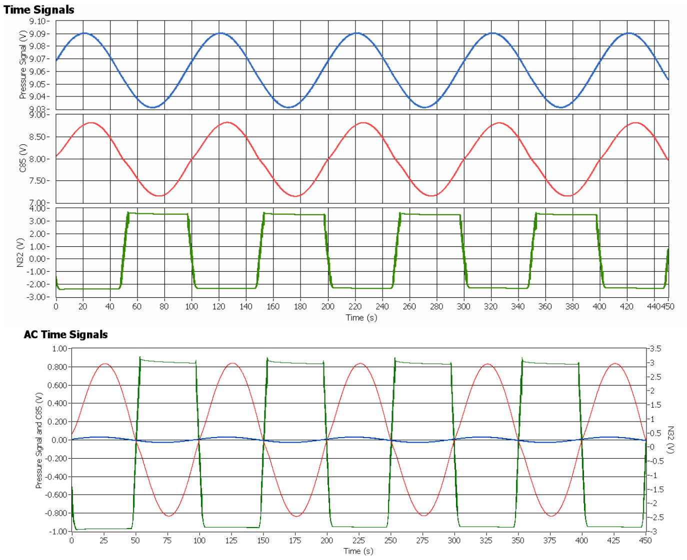

Figure 2. Results for 0.01 Hz

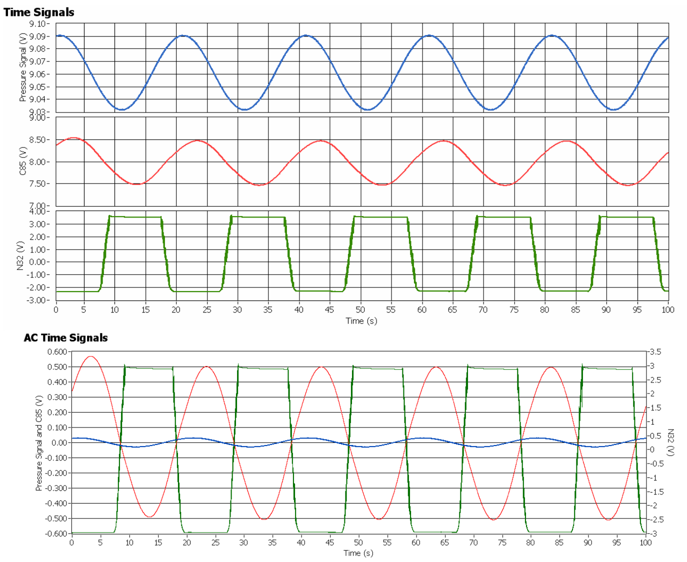

Figure 3. Results for 0.05 Hz

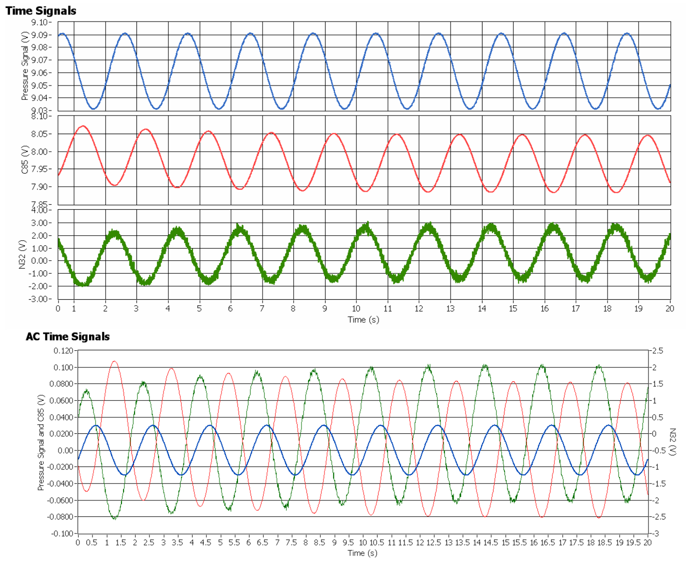

Figure 4. Results for 0.50 Hz

As can be seen for frequencies below 0.50 Hz the system is saturated and does not respond according to the injected sinusoidal signal but as a square wave. This is due to control system design of the turbine; there is also a wide variation in the AC signal that varies with the frequency injected into the system.

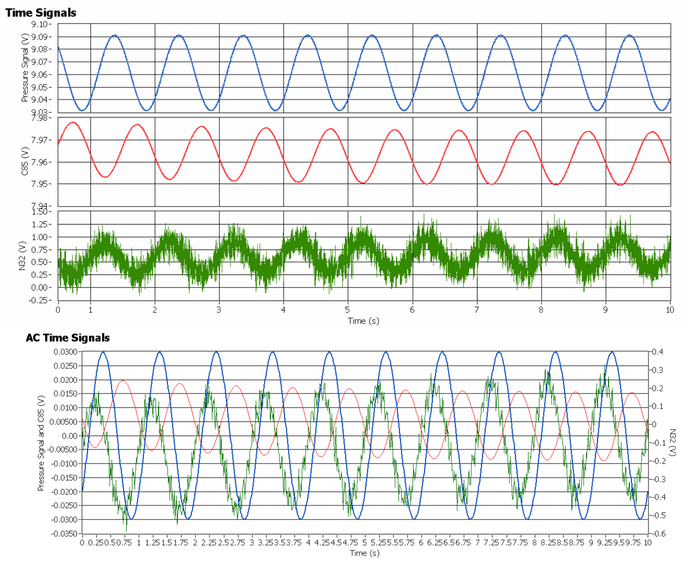

Figure 5. Results for 1.0 Hz

Moreover, when the injected frequency exceeds 1 Hz, the system responds with a signal with a high level of noise. This signal had to be re-analyzed to obtain data necessary for the correct phase.

This noise level is also caused because the measuring point N32 was placed in a different control room cabin and therefore the grounding point and cable lengths were different from the other measurement points.

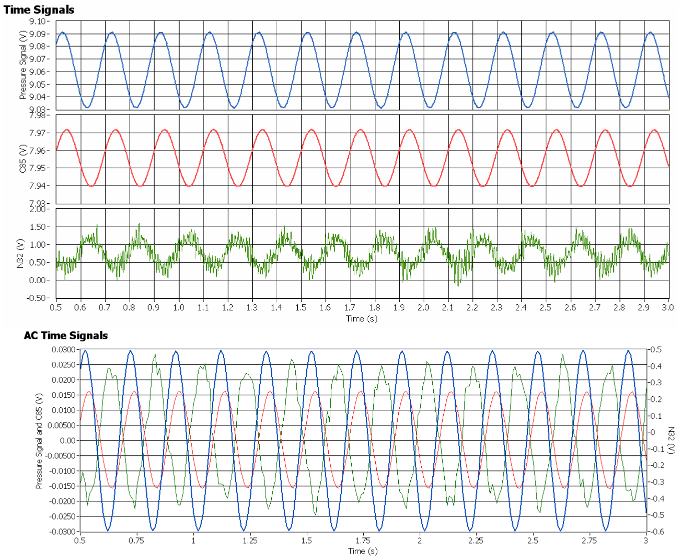

Figure 6. Results for 5.00 Hz

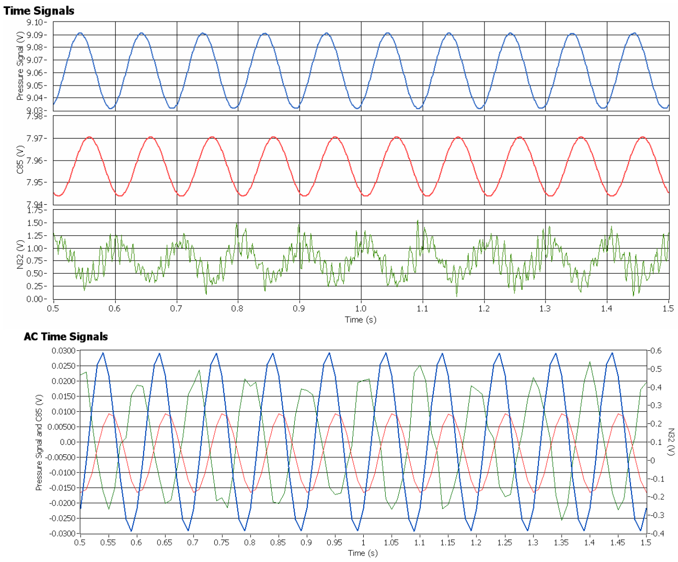

Figure 7. Results for 10.00 Hz

To finish with the results of single-frequency signals, the Bode diagrams of each comparative are showed.

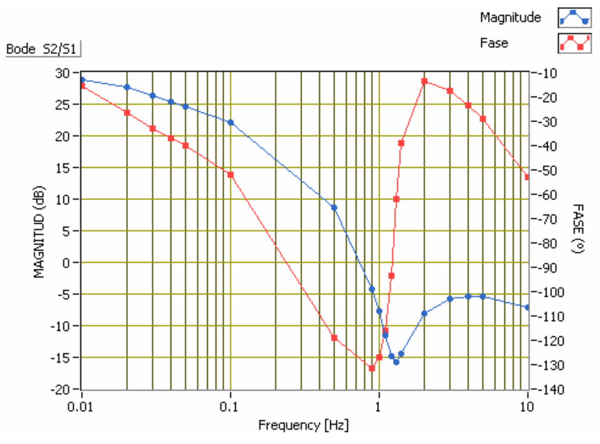

Figure 8. Bode diagram Pressure signal vs. C85

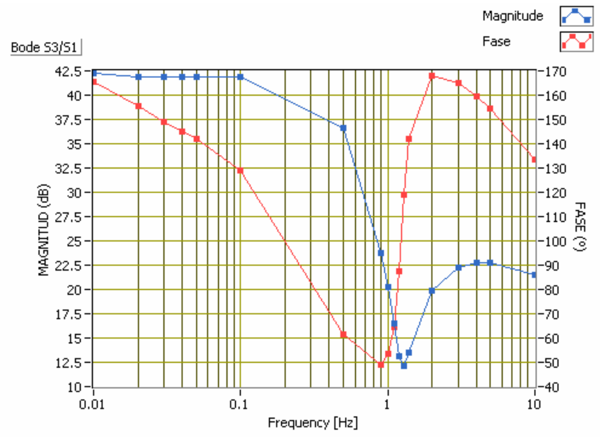

Figure 9. Bode diagram Pressure signal vs. N32

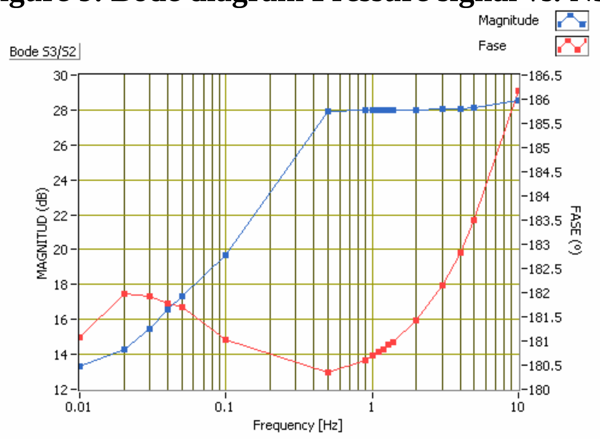

Figure 10. Bode diagram C85 vs. N32

These diagrams are those that have been used as reference for the adjustment of the new controller and that indicate how the system behaves at different frequencies.

As shown in the figures 8 and 9, the behavior of the first stage of the controller (pressures signal-C85) and the whole system (Pressure signal-N32) are similar in shape but for the phase values differ by almost 180 degrees. This difference is introduced in the second stage (C85-N32), where the behavior is completely different from the previous comparisons.

As it has been mentioned a multi-frequency signal was generated, this signal was introduced in the turbine control system with these results:

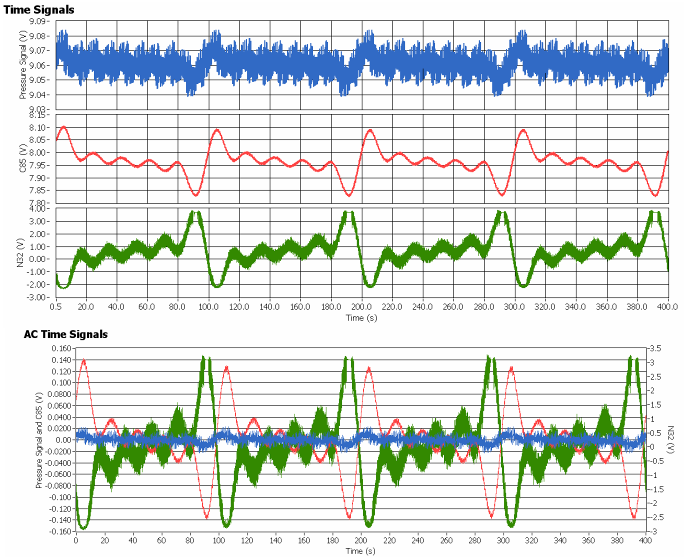

Figure 11. Results for multi-frequency input signal.

It is easily noticeable that the multi-frequency signal evolution is very different from the evolution of single-frequency ones. There is saturation of the system but not the same as when the system is based on a single frequency signal.

From the results we conclude that it was important to know how the system responds. That is why data were provided by General Electric. These data are close to real behavior; therefore, introducing them in the simulation system of Mark VI controller, the obtained response is more accurate than the one based on single frequency signals.

6. CONCLUSIONS

After the measurements and analysis of the data acquired in plant, a report of findings and conclusions was submitted to the Cofrentes Nuclear Power Plant that sent it to the General Electric responsible for changing the turbine controller MARK VI.

In view of the results, it appears that the Bode Plot obtained for the comparison between the simulated pressure signal and the output of N32 turbine controller is similar to the theoretical curve proposed by Cofrentes Nuclear Power Plant. It should be noted that the input and analysis of the first stage, turbine C85 controller, was not in the original project, so no parameters were available to compare the Bode plot.

In addition to providing the report with the Bode diagram results, both generated and acquired data were provided in order to be used in the turbine control simulator of General Electric. Thus, there is greater assurance to adjust the parameters of the MARK VI electronic control of the Cofrentes Nuclear Power Plant and the Plant could start operating with full guarantee.

Cofrentes Nuclear Power Plant started operating in November 2009 without impacts on the turbine functioning, thus confirming that the migration of the system was performed with all the safeguards and controls in the system response.

ACKNOWLEDGMENTS

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