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SINUSOIDAL SIGNAL GENERATOR FOR PELTON TURBINE IDENTIFICATION

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Abstract: With the ongoing liberalization of the European Interconnected Network, developed dynamic models for the power plants and power systems are necessary. These models, including that for hydro turbines, have to be generated in such a way that they are reliable for all operating points of the system from zero to full operation. But, only the dynamic identification of the system will validate or deny the proposed models.
This paper represents the first step in the dynamic identification of the Pelton turbine. That mean I need to choose the right system for generate sine wave signals for the testing rig.

1. INTRODUCTION

Because of the obvious importance of the steady and unsteady characteristics of the automated systems, the issue is to determine them, as accurate as possible, and synthetically express them as a mathematical model. This model must be most illustrative, and – in the same time – easy enough to use it in calculus.

Pelton turbines are impulse turbines, which are specifically suitable for high heads and low discharge. The impulse turbine, of Pelton type, is one in which all available energy of the flow is converted by a nozzle into kinetic energy at atmospheric pressure before the fluid contacts the moving blades. Also, the free surface jet flow out of the nozzle of a Pelton turbine is highly dynamic and belongs to the most important components affecting the efficiency of the entire turbine system.

Taking into account these particularities of the flow, it is very difficult to establish an exact model for Pelton turbines. Only the dynamic identification of the system will validate or deny the proposed models. The performances of a dynamic model can open the new perspectives to simulate the complex operating cases of a hydroelectric power plant.

In order to experimentally identifying the Pelton turbine, the testing rig must be thoroughly prepared for unsteady state measurements. Based on the measurements, we can determine the variation in time of all Pelton turbine parameters. These variations result when the position of nozzle's needle is modified upon a sinusoidal law. Using the measurements we determine the frequency responses for Pelton turbines.

For this purpose, in this paper I present the sinusoidal signal generator for dynamic identification of hydraulic turbine of Pelton type.

2. SOME ASPECTS ABOUT DYNAMIC IDENTIFICATION

The real meaning of identification is to conceive the model of the process by modeling, with the help of a simple and efficient mathematical instrument, some experimental results obtained in term that can assure information to be able to describe the considered process.

One of the methods for experimental determination of dynamic characteristics is the identification method using sinusoidal test signals. Beside the advantages of the methods that use sinusoidal testing signals, these methods need special equipment to generate the signals and process the data and – also – a large period of time to perform the experiment.

To determine the frequency response, we examine the processes that appear when we apply to the input parameter some harmonic signals of different angular frequency ω.

Therefore, when at the element input we apply a sinusoidal signal, described as:

$$x_m(t) = A\sin\omega t \tag{1}$$

then, at element output, after a certain period, stabilized oscillations of output parameter appears, $x_e(t)$, with the same angular frequency ω, but with different amplitude B and a phase difference related to the input oscillations:

$$x_e(t) = B\sin(\omega t + \varphi) \tag{2}$$

These signals mentioned above are represented in figure 1. For the frequency response determination, it's adequate only a comparative analysis of the two signals, represented for different angular frequency ω. Therefore we are able to obtain gain-phase characteristics and also the gain – frequency and phase – frequency characteristics for the analyzed system.

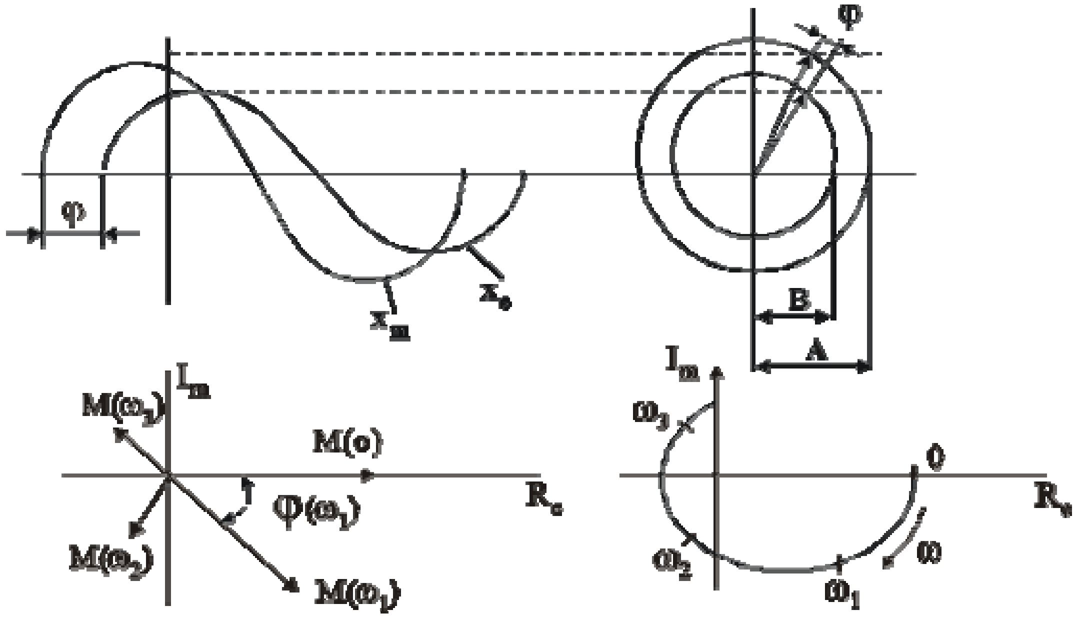

Figure1 Gain – phase characteristic for signals recorded

The input parameter for a Pelton turbine is the needle stroke and the output parameter is the speed of the turbine – generator assembly. Therefore, in order to give a harmonic movement to the needle, we designed a sinusoidal signals generator.

Also, in order to experimentally identifying the Pelton turbine, the testing rig must be thoroughly prepared for unsteady state measurements.

3. SINUSOIDAL SIGNAL GENERATOR

In order to prepare the testing rig for dynamic measurements, I have studied several solutions for the sinusoidal signal generators. Therefore, I analyzed the electronic generators of sinusoidal signals. They are easy to use and have the advantage of a great precision (they don't have moving parts), but I didn't choose this solution because the complicated electronic scheme. Also, I analyzed the speed variator, presented in [3]. This solution gives both the amplitude and frequency variation for the input parameter, but the size of this equipment is too large and makes it impossible to use in our testing rig. Finally, I choose a cam mechanism with cam displacement follower.

For a hydraulic turbine of Pelton type, the flow rate control is made by modifying the needle stroke that represents exactly the input parameter of the process.

To move the needle upon a sinusoidal law, I designed a cam mechanism. To be able to do that, I re-built the pipe section that has one of the turbines injectors. The new one injector has the same scale and dimensions. Also, this new injector is represented in figure 2.

Figure2. The new injector for Pelton turbine

The cam follower having a displacement movement is exactly the needle shaft (and – of course – is only one for all the cams). This new needle from the regulating nozzle has a longer needle shaft that has on the other end the roller which will move on the real profile of the five cams. The shaft on which the cam is mounted has a conical form for the easiness of cams changing when the measurements take place. All of these are represented in figure 3.

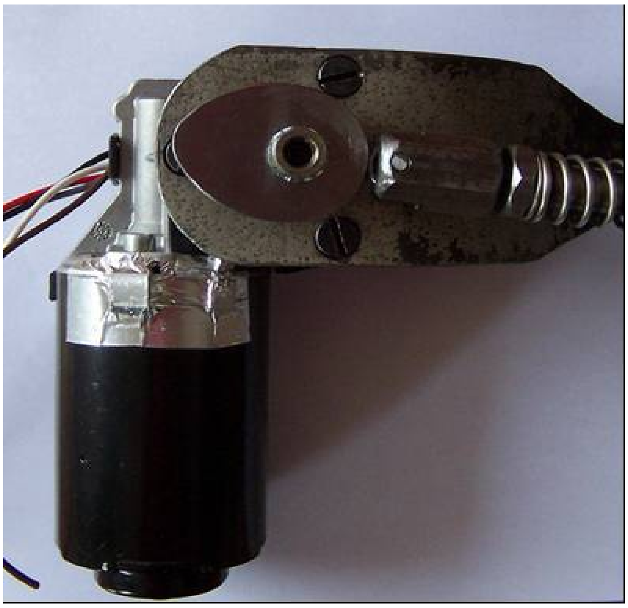

Figure3. Needle shaft as cam follower

As I said above, in dynamic identification with sinusoidal signals, we need for the input parameter a harmonic variation with different amplitude and frequencies. To obtain different frequencies of the signal, the cam mechanism is run by a d.c. motor having a continuous variable voltage supply. The connection between the electric motor and the cam mechanism is done through a worm driving-gear. For realizing this device, we used a d.c. motor because its speed is a function of voltage. In figure 4 I represent the electric part of the cam mechanism, with the d.c. motor and his power supply.

Figure4. D.C. motor and power supply for cam mechanism

To give different amplitude for input signal, first of all I designed five sinusoidal cams, having 4, 6, 8, 10 and 12 mm stroke. For this purpose I used mechanism theory equations. In figures 5, 6, 7, 8, I represented, for one of these cams, the acceleration, speed, displacement and the real profile of the sinusoidal cam, as these result from calculus.

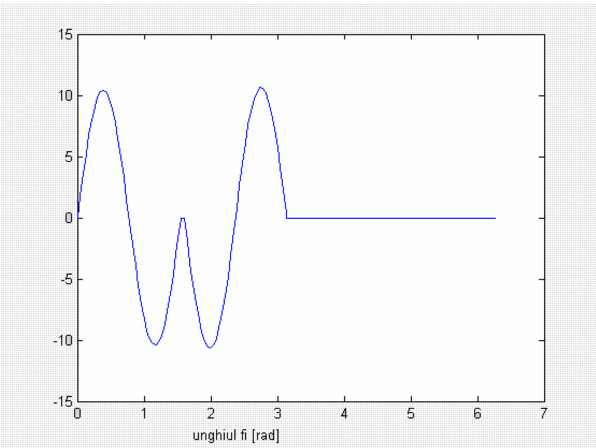

Figure5. Acceleration versus φ angle for a stroke h=4 mm

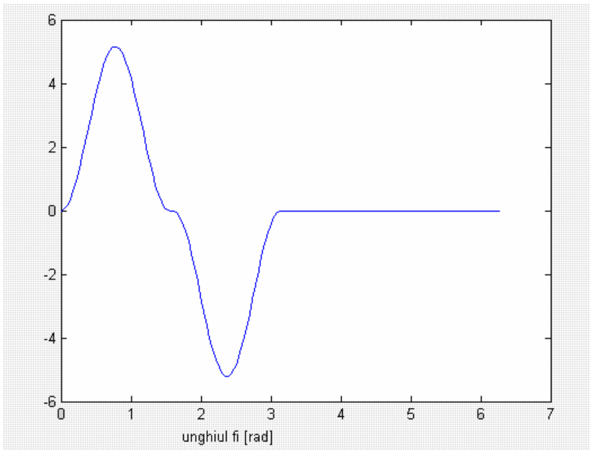

Figure6. Speed versus φ angle for a stroke h=4 mm

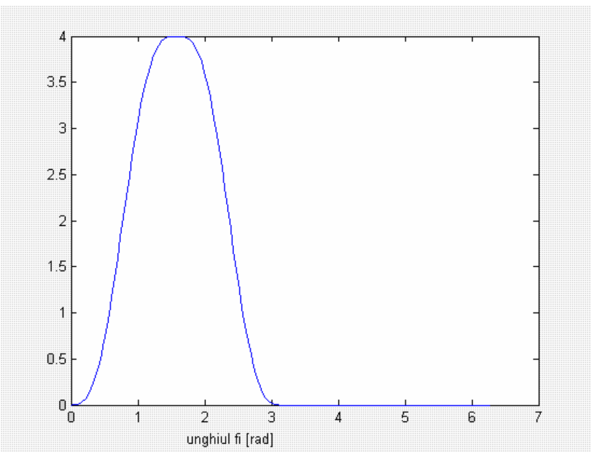

Figure7. Displacement versus φ angle for a stroke h=4 mm

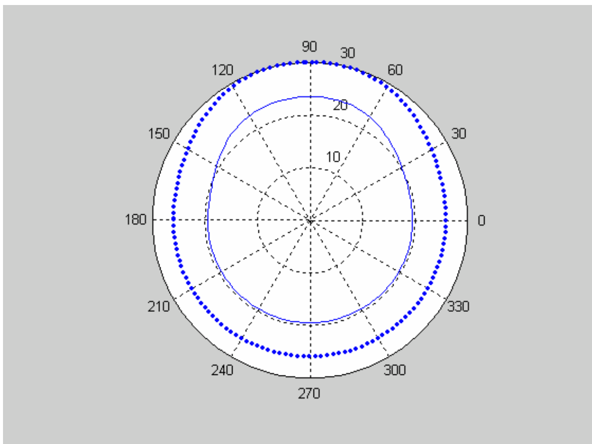

Figure8. Real profile of the sinusoidal cam for a stroke h= 4mm

So, in order to perform the dynamic measurements, the cam mechanism was mounted in the testing rig. Also, I installed the transducers and the data acquisition device. In figure 9, with one of the sinusoidal cam, I represented the variation in real time of the main characteristics of Pelton turbines.

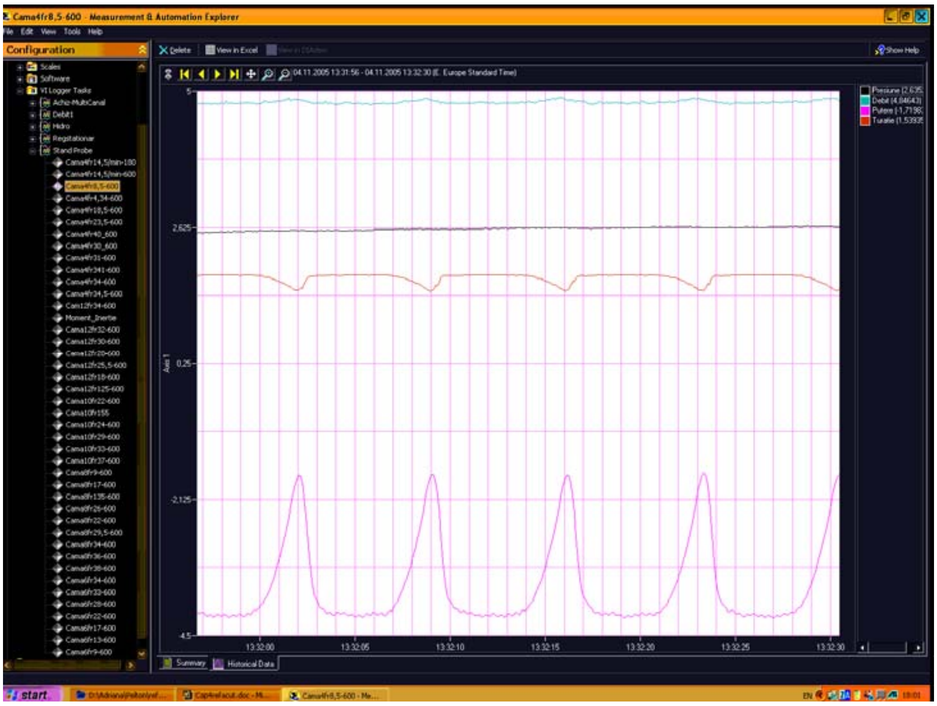

Figure9. Real time variation of the main characteristics of Pelton turbine.

Analyzing this figure and also the cam follower displacement with φ angle, represented in figure 7, I determined that those sinusoidal cams I designed can't insure a pure sinusoidal signal for the whole rotation of the cam. With these cams, the input parameter has both sinusoidal and steady variation.

To obtain a continuous sinusoidal signal for the input parameter, finally I designed five cylindrical cams but with different eccentricity of 2, 3, 4, 5 and 6 mm.

4. CONCLUSIONS

This paper represents the first step in the dynamic identification of the Pelton turbine. One of the methods for experimental determination of dynamic characteristics is the identification method using sinusoidal test signals. Beside the advantages of the methods that use sinusoidal testing signals, these methods need special equipment to generate the signals. For this purpose, I have studied several solutions for the sinusoidal signal generators.

For a hydraulic turbine of Pelton type, the flow rate control is made by modifying the needle stroke that represents exactly the input parameter of the process. To move the needle upon a sinusoidal law, I designed a cam mechanism. To be able to do that, I re-built the pipe section that has one of the turbines injectors and I mounted in the testing rig.

Also, I analyzed both sinusoidal cams and cylindrical cams, for a proper sinusoidal variation of the input parameter.

Using the measurements I can perform with the cam mechanism described above, in a proper testing rig, I determine the frequency responses for Pelton turbines.

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