Hydraulic pitch control including virtual instruments

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Abstract. The main objective of this research work is to analyse and develop elements of a controller for hydraulic system used for pitch control of a horizontal axis wind turbine. Simulation of a hydraulic system is necessary in order to discover weak points before starting the design of the system. Some elements of the system may remain virtual elements and instruments as LabVIEW offers the possibility. These elements may be analysed and developed before the experimental model is realised and finally used, as they are, as a part of the experimental equipment. For some purposes it is possible to develop specific elements using the built-in blocks.

1. Introduction

Virtual simulation systems are used on large scale. Some virtual simulation systems have functions for both processing of acquired data and reintroduction of the results as a command into the system.

LabVIEW [1, 2, 4, 5, 6, 9, 10, 11] is software that can be used for both data acquisition components and active components in a closed loop system. In this paper LabVIEW environment is proposed to be used for monitoring and control for the pitch of a horizontal axis wind turbine. Users of LabVIEW can construct instrumentation called virtual instruments (VIs) utilizing software items. These VIs can be utilized for: data acquisition, analysis, design, and control. The objective of this paper is to discuss the application of built-in VIs in LabVIEW to develop VI modules for use in hydraulic system for pitch control.

2. Structure of hydraulic system used for pitch control

The pitch angle is an important turbine parameter as it determines the wind’s angle of attack. Turning the blades around their own axes changes the relative wind flow and consequently the aerodynamic loads exerted on the rotor [3]. Figure 1 shows the diagram for the hydraulic pitch control system. In the case of three blades rotor, there are three similar circuits with a common source [8].

The common source is located in the nacelle of the wind turbine. Considering that the actuation cylinders are connected to the blades it is necessary to use flexible hoses. Proportional valve controls for the position angle of the blade. Maintaining the blade in the position is important. It may be done either mechanically with a locking circuit or hydraulically using a pilot-operated check valve. Accumulator is the safety equipment and acts in the event of an important fault of the system.

The system also assures protection of the rotor when the rods of the cylinders are fully extended and is realized stalling position which stops the rotation.

In table 1 one can see the values considered for the hydraulic elements from the diagram.
**3. Information diagram**

Figure 2 shows the information diagram of the entire system with loop control used for pitch command. In this diagram one can see the two main areas of the system: the force one and the command one. The force area includes the hydraulic and mechanic one. It assures blades rotation according to the information from the command part. The command area includes the data acquisition elements, the controller and the interface with force area.

**Table 1. Main parameters values**

| Cylinder |   Val |   UM |
|----------|-------|------|
| Stroke   |  400  | mm   |
| Piston diameter |  16   | mm   |
| Rod diameter |   10  | mm   |

| Pump unit |   Val |   UM |
|-----------|-------|------|
| Operating pressure |  100  | bar |
| Flow      |  10   | l/min|

| Hydraulic Accumulator |   Val |   UM |
|-----------------------|-------|------|
| Volume                |  10   | dm³  |
| Gas pre-charge pressure |  10   | bar |
Figure 2. Information diagram for the system.

Figure 2 is a transposition of the hydraulic diagram in figure 1 into a scheme, similar to the bond graph scheme. This scheme highlights the flow and connection of signals of different types (mechanical, hydraulic, electric).

4. PID Controller
The wind turbine pitch adjustment system was developed in LabVIEW as a virtual tool using "graphic language". First step is to state the necessary tools for the realization of a closed-loop system. The system consists of a PID-type block to which an element for the graphical visualization of the two signals (Set point, Process variables) has been added as one can see in figure 3.
The signal used to test and adjust the system is a Square type one. The frequency used for simulation is 10 Hz, and the amplitude of 1. These values are set in Simulate Signal block (figure 4).

![Figure 4. Simulate signal.](image)

The blocks connection is done with the help of the information lines (figure 5).

![Figure 5. PID controller for pitch control hydraulic system.](image)
In order to be connected, it is necessary that the blocks are compatible with the received signals. If the signals between the blocks do not stand in the same category, then signal converters must be used.

The system for pitch control of the wind turbine is shown in figure 5. It is composed of the PID block presented above (the base of the system). The system also includes a filter needed for the information processing. All blocks are inserted into a "While Loop" type with infinite iterations.

The timer in the loop has the role of logging data in the graph at a 50 milliseconds interval.

One may adjust the PID system or manually configure the parameters proportionally derivative integrators until the result (output) managed to copy the input signal (set point) as results from figure 7 and figure 8.

![Figure 6. Plant System VI Front Panel.](image)

The Plant System VI (figure 6) is a simulator created by National Instruments in order to demonstrate the capacity of the PID system, replacing in some way the power part of the system. It delays the signal in the loop to simulate the response of the considered system.

In was considered two cases for the PID gains: proportional gain \( K_c = 20 \), integral time \( Ti = 0.008 \), derivative time \( Td = 0.001 \) in the first case and proportional gain \( K_c = 100 \), integral time \( Ti = 0.008 \), derivative time \( Td = 0.001 \) in the second one. Results may be seen in figure 7 and figure 8. As one can see it was considered the influence of the proportional gain. As it grows the signal representing the system response oscillates with greater amplitude and it becomes overdamped. Future research will be developed on the simulation for the entire system integrating the Matlab/Simscap environment used for simulating the hydraulic system with the LabVIEW environment used for its monitoring and control. It will be considered the variations for integral time and derivative time in PID controller and analyse their influence on the particular case of pitch control system. It will be also analysed and applied [7] regarding pressure feedback.
Figure 7. System response for $K_c=20$, $T_i=0.008$, $T_d=0.001$.

Figure 8. System response for $K_c=100$, $T_i=0.008$, $T_d=0.001$.

5. Conclusions
The main objective of this research work is to analyse and develop elements of a controller for hydraulic system used for pitch control of a horizontal axis wind turbine.

Before testing a system with loop response with real signals, it is advisable to test it with a signal without disturbance in order to calibrate it as efficiently as possible.

In was considered two cases for the PID gains: proportional gain $K_c=20$, integral time $T_i=0.008$, derivative time $T_d=0.001$ in the first case and proportional gain $K_c=100$, integral time $T_i=0.008$, derivative time $T_d=0.001$ in the second one. Some results are included in this paper and future work will be developed on this base.
The future work is directed towards the integration of the Matlab/Simscape environment used for simulating the hydraulic system dynamics with the LabVIEW environment used for its monitoring and control. It will be considered the variations for integral time and derivative time in PID controller and analyse their influence on the particular case of pitch control system. It will be also analysed and applied pressure feedback.

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