AN ANALYSIS TOOL FOR HYDRAULIC WIND POWER TRANSFER SYSTEM USING LABVIEW

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Abstract: This paper presents a new educational analysis tool for the hydraulic wind power transfer system, which is commonly used in industrial processes. This system is complex and nonlinear and has a lot of parameters. Thus, this tool provides to teach undergraduate and graduate students without experimental laboratory setup. The nonlinear mathematical model of the system is firstly presented. Then the tool is designed for the system. Finally, some examples are demonstrated for the system.

Keywords: hydraulic, wind power, educational tool, fluid system.

1. Introduction

Renewable energy systems and, especially, the wind energy will have a greater attention in the energy market for the coming decades [1]–[5]. Over the past four decades, the consumption of fossil fuels and emission of carbon-dioxide have almost doubled [6]. One up and coming form of renewable energy is the wind power, which is produced by wind turbines which convert the kinetic energy of wind to electrical energy via rotating blades [5]. Thus, the world-wide electricity generation of wind power has grown swiftly, and wind power has become the fastest developing renewable energy technology [7]. Accordingly, the wind energy power system is an important issue in the literature. So, The Wind Power Transfer System is commonly dealt in industrial applications especially for the energy process systems, and the system has attracted attention of many researchers in the literature [8]–[13]. LabVIEW is very important analysis program for the scientific calculation, process systems, industrial applications and measurement applications since LabVIEW has a flexibility program combined with a lot of tools specifically for measurement, test, and the control such as in [14]. LabVIEW is an important program for teaching and learning since it supports and serves a wide variety of needs for many applications [15]. Nowadays, some experimental setups are quite expensive. Also, many experimental setups cannot also enable to be changed their parameters. For example, wind power system pendulum systems, robotic systems etc. Thus, a virtual laboratory is considerable in order to analyze the effects of parameters. Specially, to well comprehend some systems which haven’t experiment sets is hard in teaching and learning. In addition, in the education of the setups, to be comprehend the effects of the parameters on the system by many students are constraint. In the literature, there are many works for the educational tools for many systems such as [16]–[18]. Finally, an educational analysis tool is designed via LabVIEW program for the wind turbine power transfer system from renewable energy systems in this paper.

2. The Nonlinear Model of Wind Power Transfer System

A wind power transfer system is as in Figure 1 [8] where the hydraulic pump is in a distance from the central generation unit. The hydraulic wind power transfer system includes a settled pump driven by the wind turbine carrier and one or more settled hydraulic motors. The hydraulic pump is used by the hydraulic transmission in order to transform the input mechanical energy into pressured fluid and hydraulic water hoses and steel tube are used to transfer the accumulated energy to the hydraulic motors [19]. A scheme of a wind-energy hydraulic transmission system is as in Figure 1. As shown in the figure, a settled displacement pump is mechanically coupled with
the wind turbine and supplies pressurized hydraulic fluid to two fixed displacement hydraulic motors. The hydraulic motors are combined with electric generators in order to produce electrical power in a centric power production unit. A high displacement hydraulic pump is needed in order to flow major pressure hydraulics and to transfer the power to the generators because the wind turbine produces a great deal of torque at the low angular velocity. Also, the pump can be arranged with a settled internal speed-up mechanism. Flexible high pressure hoses or pipes attach the pump to the piping toward the central generation unit.

![Wind Power Transfer System](image)

**Fig. 1.** Wind Power Transfer System [8]

The mathematical model of the system is obtained by editing the equations of the hydraulic parts in a combined configuration. The editing equations of the hydraulic pumps and motors in order to compute flow and torque values [20] are employed to represent the closed loop hydraulic system action. The equations are detailed in [8] and thus, the nonlinear equations of the system model is as in (1) where \( Q_p \) is the pump flow delivery, \( D_p \) is the pump displacement, \( k_{Lp} \) is the pump leakage coefficient, \( P_p \) is the differential pressure across the pump, \( \rho \) is the hydraulic fluid density and \( \nu \) is the fluid kinematic viscosity, \( \eta_{mech} \) is the mechanical efficiency of the motor/pump which is calculated as in (2) where \( \eta_{total} \) is pump/motor total efficiency and \( \eta_{vol} \) is the pump/motor volumetric efficiency, \( k_{LmA} \) and \( k_{LmB} \) are the leakage coefficients of the motors, \( D_{mA} \) is primary motor displacement, \( D_{mB} \) is addition motor displacement, \( I_{mA} \) is primary motor inertia, \( I_{mB} \) is addition motor inertia, \( B_{mA} \) is primary motor damping, \( B_{mB} \) is addition motor damping, \( \beta \) is fluid bulk modulus, \( C_d \) is the flow discharge coefficient, \( A \) is the orifice area and is as in (3) where \( A_{max} \) represents the maximum orifice area, \( h_{max} \) denotes the maximum orifice opening, and \( h \) indicates the orifice opening. The inputs are also that \( \omega_p \) is the angular velocity of the hydraulic pump, \( h \) the position of the proportional valve. The auxiliary subscript-mA denotes the primary motor and subscript-mB denotes additional motor.

\[
\frac{dP_p}{dt} = \left( D_p w_p - k_{Lp} P_p - C_d \frac{A_{max}}{h_{max}} h \right) \sqrt{\frac{2}{p}} |P_p| \text{sign}(P_p) - C_d \frac{A_{max}}{h_{max}} (h_{max} - h) \sqrt{\frac{2}{p}} |P_p| \text{sign}(P_p) \frac{\beta}{V}
\]

\[
\frac{dw_{mA}}{dt} = \left( \frac{D_{mA}}{h_{max}} \frac{A_{max}}{h_{max}} h_{mB} \frac{2}{p} |P_p| \text{sign}(P_p) - \frac{D_{mA}}{mA} w_{mA} \right) \frac{k_{LmA}}{k_{LmA} - B_{mA} w_{mA}} / I_{mA}
\]

\[
\frac{dw_{mB}}{dt} = \left( \frac{D_{mB}}{h_{max}} \frac{A_{max}}{h_{max}} (h_{max} - h) \frac{2}{p} |P_p| \text{sign}(P_p) - \frac{D_{mB}}{mB} w_{mB} \right) \frac{k_{LmB}}{k_{LmB} - B_{mB} w_{mB}} / I_{mB}
\]

\[
\eta_{mech} = \eta_{total} / \eta_{vol}
\]

\[
A = \frac{A_{max}}{h_{max}} h, \quad h = h_{i=1} + x_i \text{ (the variations to orifice opening)}
\]
According to these equations, the state space nonlinear model can be presented as in (4) where the expressions are detailed in [8].

\[
\begin{align*}
\dot{x} &= f(x) + g(x)U \\
y &= h(x)
\end{align*}
\]

\( (4) \)

\[
\begin{bmatrix}
P_p \\ w_{mA} \\ w_{mB}
\end{bmatrix}
\Rightarrow \begin{bmatrix}
P_p \\ w_{mA} \\ w_{mB}
\end{bmatrix}
\]

\( (5) \)

3. The Analysis Tool for the Wind Power Transfer System

By using LabVIEW program, an educational analysis tool is designed. This tool enables the teachers to show the dynamic effects of the parameters in the wind power transfer system model without such an experimental laboratory. Such a laboratory is may be quite costly, so all of system parameters effects are analyzed thanks to the tool. Figure 3 shows LabVIEW block diagram for the educational virtual tool. Figure 2 shows control screen for the system parameters by LabVIEW program. The tool has a great deal of advantages. All of the parameters of system can be modified by this tool interface. Thus, the impressions of parameters on the system can be observed without an expensive laboratory.

![LabVIEW block diagram for the educational virtual tool](image)

**Fig. 2.** The designed control panel

By using the designed control panel, all of the parameters effects on the system outputs can be analyzed. Thanks to this tool, a designer can observe the crucial parameters for the an experimental or simulation control. The sample values of the system parameters are as in [8] for the simulation.
To observe the parameters effects on the system the tool is worked. For example, to observe which is the pump displacement, the results of the tool are in Figure (4). It is shown that, during the simulation, the effects of the parameter are observed when $D_p$ is increased 0.1 at the random time period. For another example, when it is shown in Figure (5) that the effects of the parameter are observed when $D_{ma}$ is decreased 0.1 once in a second during the simulation.
According to the results, all parameters effects can be analyzed thanks to the tool. So, the tool is very useful for the learning and teaching. Also, the tool is improved by the controller and so controller effects can be analyzed.

5. Conclusions

In this paper, an educational virtual analysis tool is designed for hydraulic wind power transfer system. The tool provides users to modify parameters of system and so the users obtain interface observe the outputs as graphical. The tool helps students to improve their scope without any laboratory. Especially, the tool allows undergraduate and graduate students to discover the effects of the parameters in the mathematical model of the hydraulic wind power transfer system wind. Finally, according to simulation results, the students can easily understand the differences of parameters and their effects via the designed virtual analysis tool.

References


