Abstract

In this poster a multiple model adaptive control (MMAC) strategy is used to mitigate the undesired effect of output power fluctuations in hydraulic wind power systems. This control structure is based on linear Kalman filters, probability block and PID controllers and aims to regulate the speed of generation unit. Nonlinearities and disturbances such as wind speed and valve position make the system work over a wide range of operating point which degrades the performance of the control loop. MMAC as an approach for these types of systems implemented and simulated to consider the control performance over the whole operating regimes.

Methods

Based on previous works, we are able to represent the nonlinear state space model. In general, the nonlinear state space model of a system is

\[ x(t) = f(x(t)) + g(x(t))u(t), \]

\[ y(t) = h(x(t)), \]

Where

\[ \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_n \end{bmatrix}, \]

\[ \begin{bmatrix} u_1 \\ u_2 \\ \vdots \\ u_m \end{bmatrix} \]

Using multiple models is necessary because of physical uncertainties and disturbances in the hydraulic wind power system which causes a wide range of operating points. These variations and disturbances are well beyond the robustness of a single Kalman filter and correspondent controller. MMAC is an adaptive technique that can overcome the robustness problems of a single filter/controller. In this method a separate Kalman filter/PID controller is developed based on each different operating point

\[ \begin{bmatrix} P_1 \\ P_2 \end{bmatrix} \]

\[ \begin{bmatrix} K_1 \\ K_2 \end{bmatrix} \]

Fig. 2. Multiple Models Adaptive Control (MMAC) structure

\[ z_j(t) = \Phi_j z_j(t) + G_j d_j(t) + G_j Q_j \]

\[ \dot{z}_j(t) = H_j z_j(t) + v_j(t), \]

\[ \dot{z}_j(t) = \dot{z}_j(t) + K_j \theta_j(t), \]

Probability Block:

\[ P_j(t) = \sum_{i=1}^{J} f_r(i, j) P_{i,j}(t), \]

Control Law:

\[ u(t) = K_p \theta(t) + \frac{1}{s} \frac{d}{dt} \theta(t) + K_i \theta(t). \]

\[ f = \left( \frac{2\pi}{T_2} \right)^2 \int_0^{T_2} \frac{1}{s} \frac{d}{dt} \theta(t) + K_i \theta(t). \]

Results and Discussion

A research facility has been developed in the form of two pump-two motor hydraulic transmission system. In this section, the mathematical model behavior is compared with the experimental results obtained from a prototype. Fig.3 demonstrates an overlay of the experimental setup and hydraulic circuitry.

Fig. 3. The experimental setup of the hydraulic wind power transfer system.

Case I: Constant Speed reference

Case II: Varying Speed reference

The performance of this control approach is highly dependent on the number of models and also accuracy of the linearization and Kalman filters. Designing poor controllers for each Kalman filter will degrade the tracking response. In this poster Kalman filters were designed by using linearized system in different reasonable operating points. Overall acceptable performance of MMAC indicates the functionality of tuned PI controllers in this structure.

Conclusion

The hydraulic wind power transfer system is comprised of various parts such as hydraulic pump and motors, proportional valve, check valves, relief valves, and etc. This configuration uses fixed displacement pump driven by the prime mover (wind turbine) and one or more fixed displacement hydraulic motors to transmit the power. Hydraulic pump converts the mechanical input energy into pressurized fluid and hydraulic hoses and steel pipes are used to transfer the harvested energy to the hydraulic motors. A schematic diagram of a wind energy hydraulic transmission system is illustrated in Fig.1. As the figure demonstrates, a fixed displacement pump is mechanically coupled with the wind turbine and supplies pressurized hydraulic fluid to two fixed displacement hydraulic motors. The hydraulic motors are coupled with electric generators to produce electric power in a central power generation unit. Finally, the proportional valve distributes a controlled amount of flow to each hydraulic motor to be converted to the electrical power by the generators.

The contribution of the present poster is to propose a multiple models adaptive control structure for a hydraulic wind power system in order to maintain high performance over a wide range of operating points. These hydraulic systems run under fluctuating disturbances i.e. wind speed profile and valve position which influence on system operating regimes. Thus, there would be a crucial need for an advance control structure to eliminate negative effects of disturbance inputs.

Multiple-model adaptive control is a promising approach to control complex, nonlinear, and time-variant systems with a wide range of operating points. In multiple model adaptive control, a bank of candidate models is designed to be used by the control structure. Then a supervisory controller selects the most appropriate model for the current conditions.