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# SIMULATION OF A HYDRAULIC SYSTEM USED FOR WIND TURBINE PITCH CONTROL

BY

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**Abstract.** A blade pitch control system is critical for turbine operation, as pitching is an important actuation for increasing energy capture, reducing operational load, stalling and aerodynamic braking. Pitching can be simultaneous for all blades or individual. In this paper will be developed simulation for such a system. In order to do this will be used FluidSIM, which is a comprehensive software for simulation of fluid control systems. Advantages of using FluidSIM for simulation of the system are seen through easy access modelling and user-friendly options. While performing the simulation of the system software allows dynamic movement of the hydraulic system components (*e.g.* cylinder extension and retraction) while performing the simulation itself. FluidSIM has also some disadvantages, although in cases where fast response rate and precision can be somewhat neglected, results can be within allowable range.

**Keywords:** simulation; FluidSIM; hydraulic system; pitch control.

## 1. Introduction

The power extracted by the rotor of the wind turbine is essential determined by the blade pitch control (Pelin *et al.*, 2018). Pitch control is also

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important in order to protect the turbine in the case of high values of the wind speed, reducing extreme loads to wind turbine rotor and structure (Bossanyi, 2003).

Active pitch control is in researchers and producers attention in our days. Collective pitch control is the traditional method and most of the wind turbines are provided with. In this case, the commanded value for the pitch is sent simultaneous to all the blades (Chen and Stol, 2014). Individual pitch control implies an independent actuating system for each blade. Hydraulic systems are suited for pitch control, mainly for large turbines (Watton, 2007).

## 2. Diagram of the Hydraulic Pitch Control System

Researchers from Aalborg University (Liniger *et al.*, 2017) identified general diagram used for hydraulic system which is presented in Fig. 1.

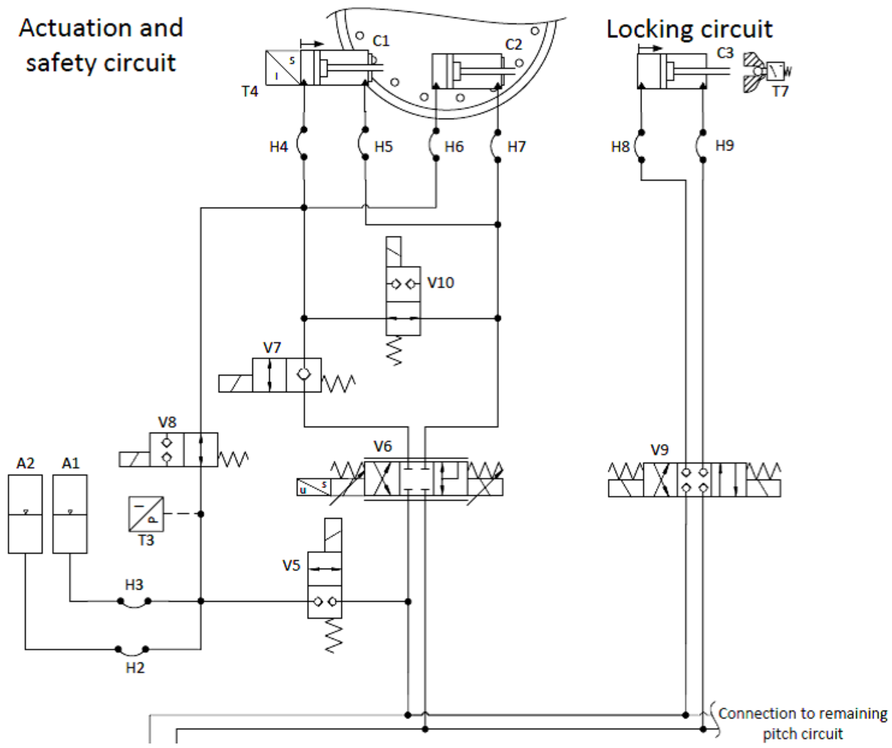



Fig. 1 – Generalized diagram of a fluid power pitch system (Liniger *et al.*, 2017).

The supply source is situated in the fixed zone of the nacelle and connected with the moving zone by a rotary unit in the main shaft. The actuator of each blade rotates with the hub.

The actuator has two cylinders C1 and C2, parallel connected and controlled with a proportional valve V6. Safety circuit is realized using one or more accumulators separated from actuating circuit with directional control valves V5 and V8, which actuate the cylinders in case of emergency shutdown. Each blade has also a locking circuit, parallel with actuating circuit separated with directional control valve V9. Usually there are four working situations: starting, power control, normal shutdown and emergency shutdown. Directional control valves V7 and V10 are used to set out speed at C1 and C2.

On these bases, authors considered the diagram for the hydraulic pitch control system consideredpresented in Fig. 2. Proportional valve controls 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 emergency situation. 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.

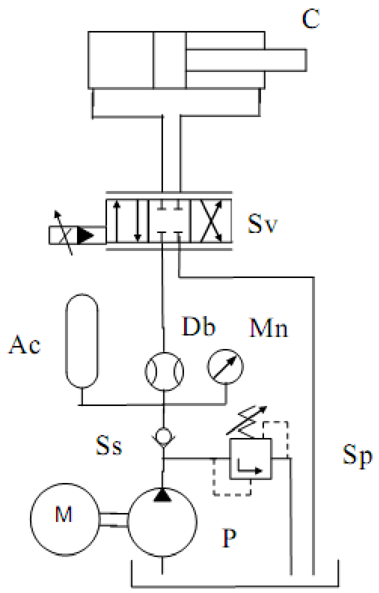


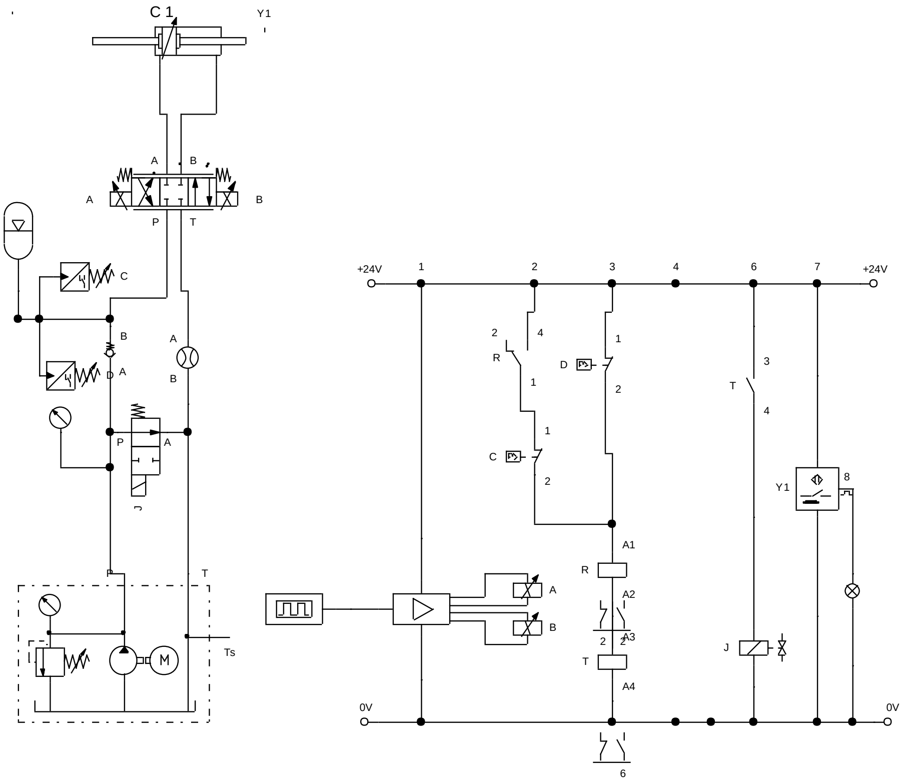

Fig. 2 – Diagram of the hydraulic pitch control system.
P – fixed displacement pump; M - electric motor; Sp – relief valve; Ss – check valve;
Ac – piston type accumulator; Db – flow meter; Mn – pressure gauge;
Sv – proportional solenoid valve; C – double acting differential cylinder.

### 3. FluidSIM Circuit of the Hydraulic Pitch Control System

FluidSIM is comprehensive software for simulation of fluid control systems. Advantages of using FluidSIM for simulation of the system are seen through easy access modelling and user-friendly options, (FESTO FluidSIM User's Guide). While performing the simulation of the system software allows dynamic movement of the hydraulic system components (*e.g.* cylinder extension and retraction) while performing the simulation itself. FluidSIM has also some disadvantages, although in cases where fast response rate and precision can be somewhat neglected, results can be within allowable range (Orošnjak *et al*., 2017).

The simulation contains two components: first is the hydraulic diagram with the specific symbols (Fig. 3*a*) and the second is the corresponding electric diagram considered according to the system (Fig. 3*b*).

The hydraulic part communicates with the pin command part of this program.




*a* *b*

Fig. 3 – FluidSIM diagrams
*a* – Hydraulic diagram; *b* – Electric diagram.

The particularity of this hydraulic system as mentioned above is that it uses a hydraulic accumulator, which plays the role of an electric battery that surpluses the energy and sends it back to the system when the system needs it.

An interesting fact is that the turbine can transmit the entire power potential to the consumers even when it changes pitch.

In the FluidSIM diagram there is an additional facility, namely the hydraulic pump may be disconnected via the directional control valve, connected in parallel to the tank. This solution helps to quickly connect and implicitly to a quick response in the system.

## 4. Results of Simulation

FluidSim visualization of the behaviour of the system, both the hydraulic and electric equipment, can be done using a block diagram as one can see in Fig. 4 and Fig.5.

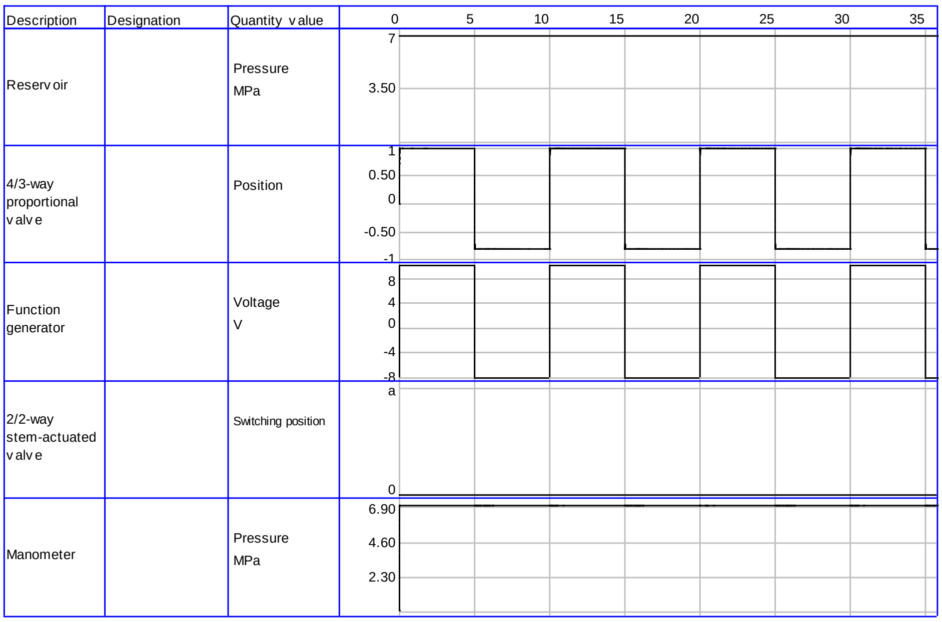



Fig. 4 – Results for a reservoir with preload pressure of 7 MPa.

For the system in Fig. 3 results of simulation are presented in Fig. 4 in the case of a reservoir (accumulator) with preloading pressure $p_0$ = 7 MPa and in Fig. 5 in the case of preloading pressure $p_0$ = 2 MPa.

Comparing the two situations it is interesting to reveal the moment that pump disconnects.

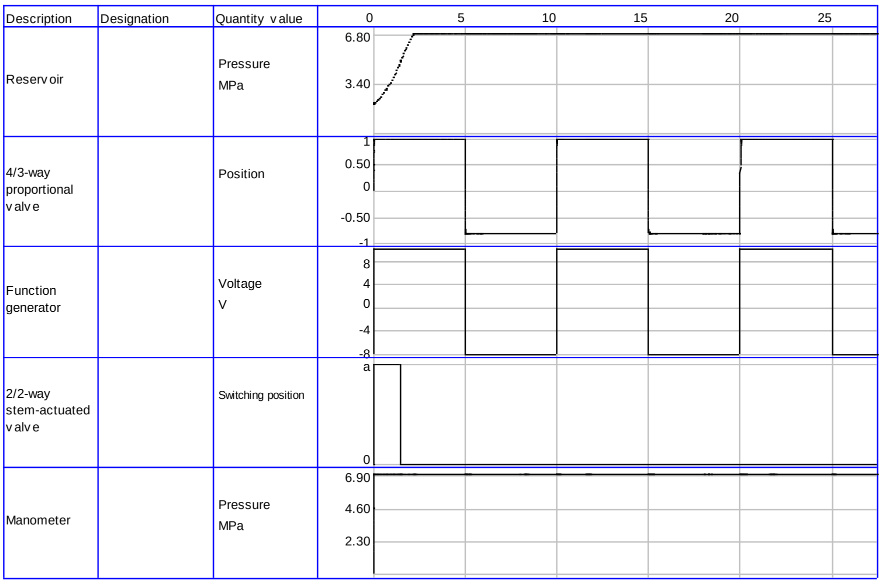



Fig. 5 – Results for a reservoir with preload pressure of 2 MPa.

## 5. Conclusions

For the general structure of a pitch control system it was configured the FluidSIM hydraulic and electric diagram and it is decided to show the evolution for: pressure in the reservoir (accumulator), position of the spool of the proportional valve, the electric command of the proportional solenoid of the valve, the position for the directional control valve on the discharge circuit and pressure at the pump. Results of simulation reveal the influence of parameters of the accumulator and a consequently a method to determine the preload pressure.

In the future work it will be considered pressure feedback and system regulator suitable in this case. It will be also considered and other parameters to be modified in the system in order to reveal their influence. It is also of interest if the hydraulic pitch control system is suited for medium and low power wind turbines for isolated consumers.

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*** FESTO FluidSIM User's Guide, https://www.festo-didactic.com/ov3/media/customers/1100/fluidsim5_enus_v1.pdf.

## SIMULAREA FUNCȚIONĂRII UNUI SISTEM HIDRAULIC DESTINAT REGLĂRII PASULUI UNEI TURBINE EOLIENE

(Rezumat)

Un sistem pentru controlul pasului este foarte important pentru o turbină eoliană deoarece reglarea pasului poate fi utilizată pentru a influența energia extrasă, poate reduce încărcarea rotorului sau poate proteja turbina. Reglarea pasului poate fi făcuta simultan pentru toate palele sau individual. Obiectivul acestei lucrări îl reprezintă analiza unor sisteme hidraulice pentru reglarea pasului. Pentru simulare este utilizat programul specializat FluidSIM care este dedicat sistemelor hidraulice de acționare. Avantajele utilizării acestuia sunt flexibilitatea, simplitatea și posibilitatea de analiză a componentelor în mișcare. Dezavantajele se încadrează în limite rezonabile în cazul fazelor incipiente de cercetare. Lucrarea include rezultate ale simulării în două cazuri diferite, concluzii și direcțiile în care se va îndrepta în continuare atenția autorilor.