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Pitch System with Double-Winding Motor

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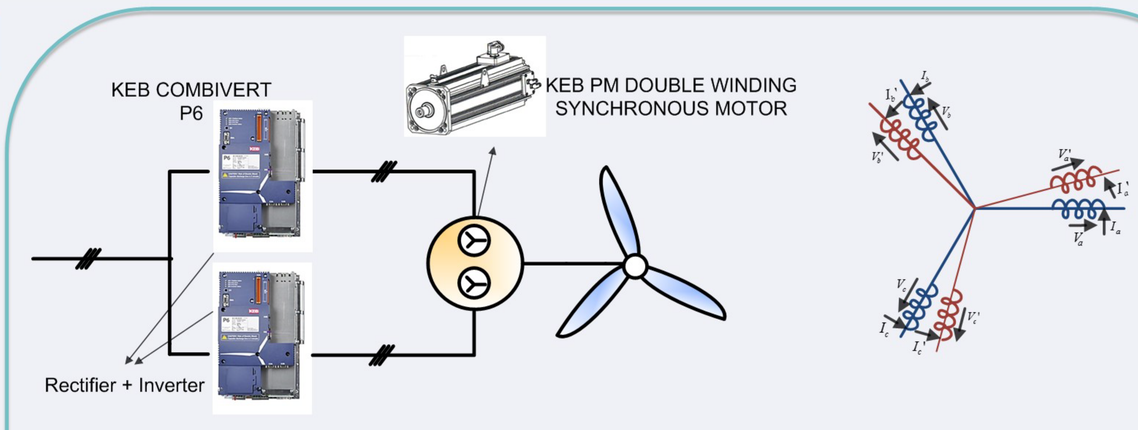
Abstract

Environmental concerns and shortage of fusil fuels are causing more and more renewable energy demand. Among renewable energy sources, wind power generation is becoming one of the most important kinds of reneable energy. In a common wind turbine, the extracted power from the wind is controlled by the pitch of the blades. This system has to manage the rotor speed and the aerodynamic braking of the turbine. Blade pitch control can provide a constant speed and power, holding them at their rated values. Furthermore, when the speed of the wind is excessively high, this system must guarantee that the aerodynamic and mechanical loads are not excessive for the mechanical parts of the turbine. In these conditions, the blades are pitched into the feathering position and the rotor is stopped. Moreover, when the control systems detect any fault on an element of the global system, the pitch control has to pitch the blades into the feathering position. Today's pitch systems are usually driven electrically or hydraulically. Thanks to the advancement of AC drives, as well as high efficiency motors, the use of electric technology in pitch applications is increasing. The use of this technology allows systems simpler and more efficient. In this work, ALSTOM POWER WIND in collaboration with IK4-IKERLAN propose and implement a double-winding Permanent Magnet Synchronous Machine (PMSM) system for wind turbine pitch systems. The system, based on KEB converters and motors, can operate individually or together, having each winding its associated converter increasing the safety and the availability of the wind turbine.

Double-winding Permanent Magnet Synchronous Machine

- **DW-PMSM** are conventional machines with 2 independent windings and separately fed by 2 independent converters.
- Lower phase current rating.
- Lower dc-link current and voltage ripples.
- Higher efficiency.
- Better fault tolerance capability. If a fault occurs, the system continues operating in faulty mode.
- For increasing the fault tolerance capability, the double winding must fulfill:
  - It must exist a physical separation between the phases, avoiding the propagation of a fault.
  - The machine has to present a large self-inductance, limiting the short-circuit current in the event of a shor-circuit fault.
  - A good combination of number of slots and number of poles must be chosen in order to maintain a low mutual inductance between phases. This avoids the faulty phases to affect the healthy ones



$$u_{d1} = R_s i_{d1} + \frac{d\Psi_{d1}}{dt} - \omega\Psi_{q1} = R_s i_{d1} + L_d \frac{di_{d1}}{dt} + M_d \frac{di_{d2}}{dt} - \omega L_q i_{q1} - \omega M_q i_{q2}$$

$$u_{q1} = R_s i_{q1} + \frac{d\Psi_{q1}}{dt} + \omega\Psi_{d1} = R_s i_{q1} + L_q \frac{di_{q1}}{dt} + M_q \frac{di_{q2}}{dt} + \omega L_d i_{d1} + \omega M_d i_{d2} + \omega\Psi_{pm}$$

$$u_{d2} = R_s i_{d2} + \frac{d\Psi_{d2}}{dt} - \omega\Psi_{q2} = R_s i_{d2} + L_d \frac{di_{d2}}{dt} + M_d \frac{di_{d1}}{dt} - \omega L_q i_{q2} - \omega M_q i_{q1}$$

$$u_{q2} = R_s i_{q2} + \frac{d\Psi_{q2}}{dt} + \omega\Psi_{d2} = R_s i_{q2} + L_q \frac{di_{q2}}{dt} + M_q \frac{di_{q1}}{dt} + \omega L_d i_{d2} + \omega M_d i_{d1} + \omega\Psi_{pm}$$

$$T = \frac{3}{2} p(\Psi_{d1} i_{q1} - \Psi_{q1} i_{d1} + \Psi_{d2} i_{q2} - \Psi_{q2} i_{d2})$$

$$= \frac{3}{2} p(\Psi_{pm}(i_{q1} + i_{q2}) + (L_d - L_q)(i_{d1} i_{q1} + i_{d2} i_{q2}) + (M_d - M_q)(i_{d1} i_{q2} + i_{d2} i_{q1}))$$

Double winding PMSM pitch system implementation

Normal Operation

- Both inverters work together in torque sharing mode.
- The first one acts as torque master and the other one acts as torque slave.
- The "torque master" sends its speed and torque values to the slave, which is in speed controlled operation and follows the master torque.
- Data exchange via safety communication.

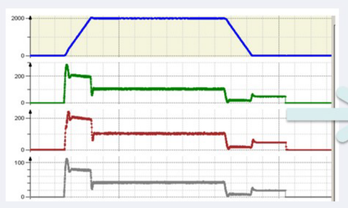
Small delay of the slave

green: master torque;
brown: slave torque;
yellow: master speed;
blue: slave speed

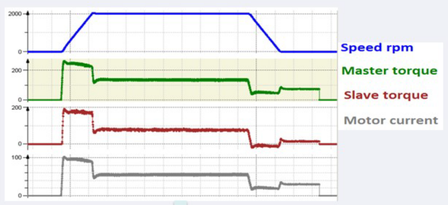
Faulty operation

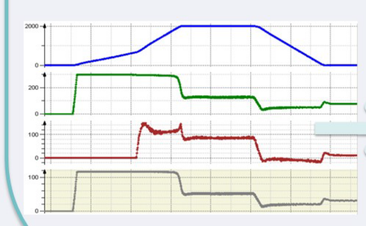
- PLd safety degree is obtained taking into account that 2oo3 motor blade will work correctly. With a DW-PMSM it is enough if 5oo6 motor systems work correctly.

→ Higher robustness



- Emergency run triggered by master control unit.
- Speed increased to 2000 rpm.
- Cross comunication working correctly.
- Slave continues in torque sharing mode: Same current and torque.





- Emergency run triggered by both control units.
- There is no torque synchronization by cross communications.
- Both windings do not create the same torque.
- This is reflected in the stator currents.

- Slave control unit triggers its own emergency run after the master unit has already started it.
- Neither torque synchronization nor cross-communication.
- Torque and currents different in windings.
- The windings work partially against each other, or one of them could be even regenerative.

Conclusions

The latest advancements in AC drives and motors are favoring an increase of the use of electric technology in pitch applications. Using a double winding motor enables increased safety, availability and performance, thanks to the implementation of two electronic converters to a double winding motor, which allows go to feather of the blade with a single or both converters. In case of failure in one of the converters or in one of the motor windings, it allows the turbine to operate in degraded mode. This system increases the performance of the machine thanks to the availability of more torque to accelerate and decelerate the blade.

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