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Design of motion controller for permanent magnet synchronous motor

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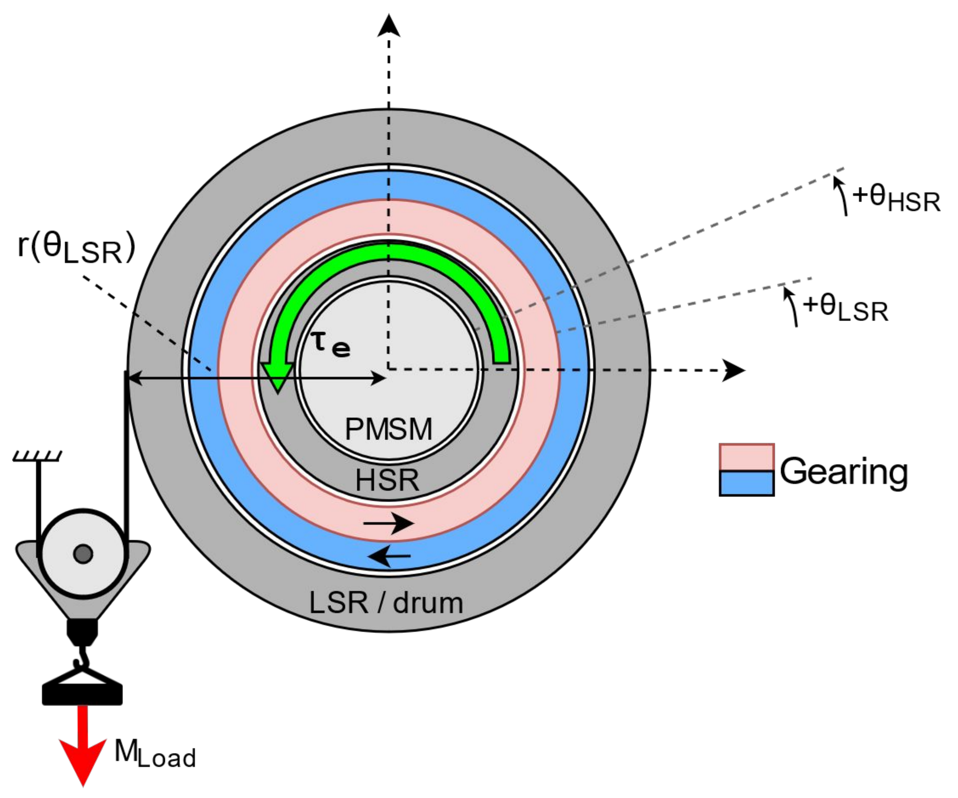
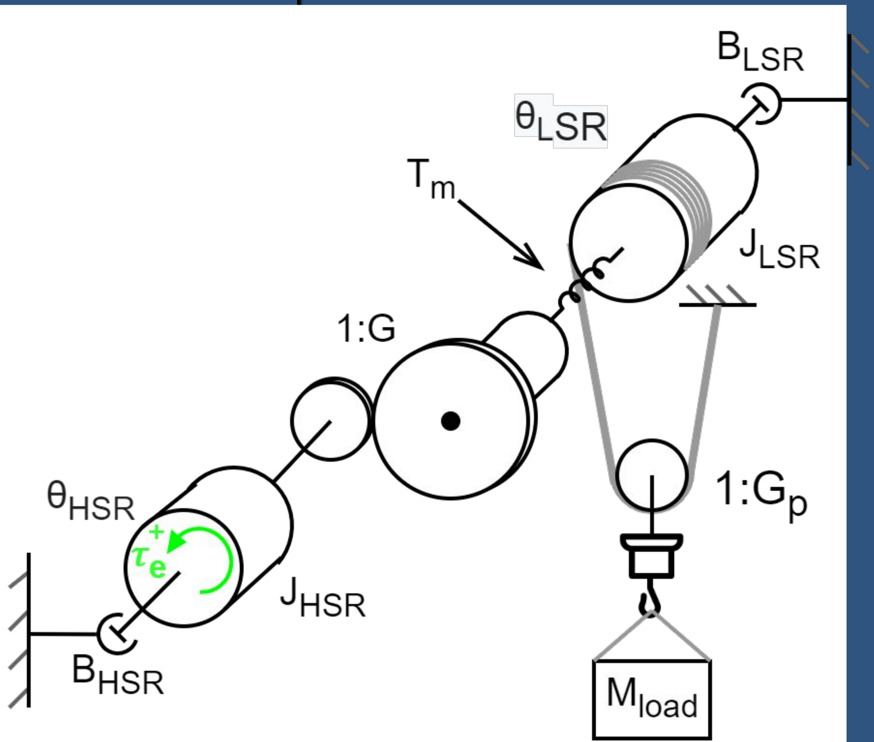
1. Introduction



The aim of this paper is to investigate the effect of the torsional spring effect that exists in a coaxial magnetic gear, in comparison to the same coaxial gear considered as a rigid system. The high-speed rotor (HSR) of the magnetic gear is the driving shaft, and is powered by a permanent magnet synchronous motor (PMSM). The low-speed rotor side of the gear (LSR) is the output shaft, and is connected to a winch drum, allowing the spooling of wire as part of a hoisting system. The wire is further put through a pulley at the hook of the hoisting system, providing another gearing ratio of two. The goal of using the PMSM and magnetic gear drive combination is to gain knowledge of how the motion of the system is affected when the torsional spring effect of the gear is included.

2. Model

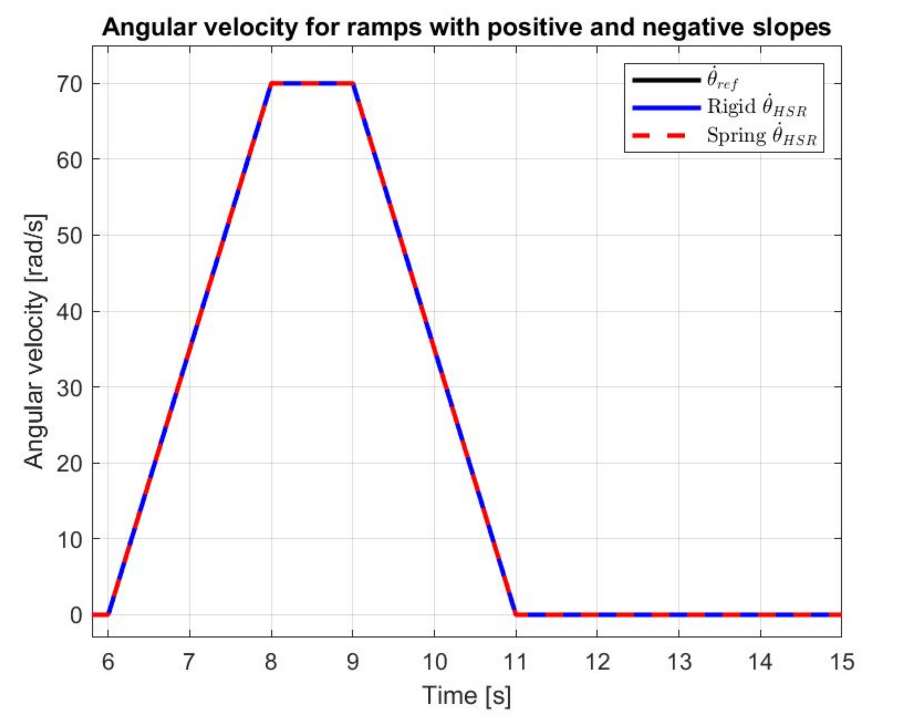


Mathematical models of the PMSM along with the two rotating bodies of the winch drive were made, in order to obtain a linear model for the controller design. The electrical model took offset in a three-phase AC circuit with a star connection. With Clarke and Park transforms the equations of the model were derived in the dq reference frame. These transformations are common for PMSM motors and also allows for convenient control of the system. The mechanical model was developed as both a rigid version and a version including the torsional spring effect from the magnetic gear. The rigid model took offset in a single equation of motion, relating the friction, inertias and load back to the HSR. The spring model took offset in two simultaneous equations of motion, neglecting the spring effect from the wire hoisting the load.

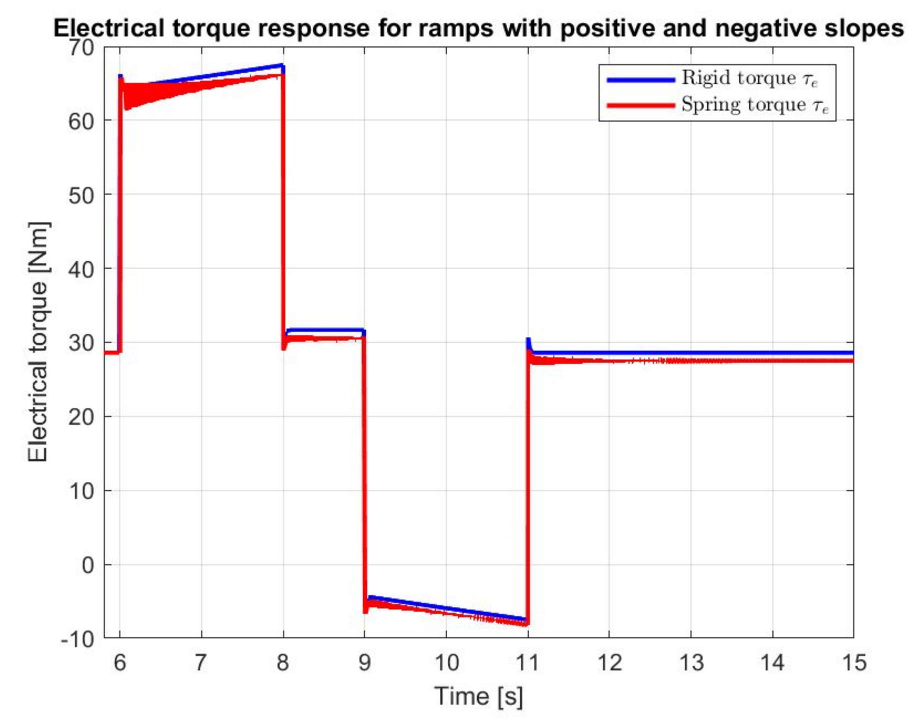
3. Controllers

PI controllers for the d- and q-axis of the current were designed using the pole-zero cancellation method, taking offset in the linear model of the rigid system. A third PI controller was designed for the outer mechanical speed loop of the cascade control system.
For torque control, the d-axis current controller had a fixed reference signal of zero while the q-axis controller was used to control the torque-producing current. The controllers designed from the rigid system were implemented in the nonlinear simulation models of both the rigid system and the spring system, to find out whether controller design on the basis of the simpler rigid model would be sufficient for controlling the spring system.

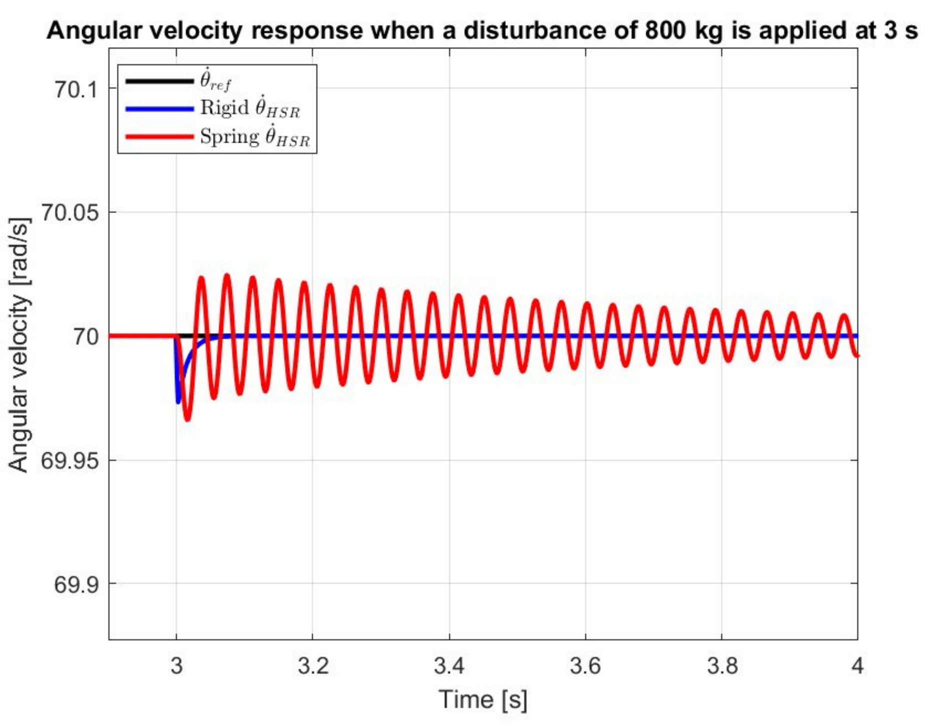
4. Simulation



The angular velocity image shows that the response of the models follows the described input and a difference between the models is not observed. The next figure to be studied is the response of electrical torque for the seen image.



The electrical response from the electrical torque is different for the rigid and spring models. Oscillations from the spring model can be observed and related to the torsional spring effect of the magnetic gear. These oscillations are greater when the acceleration of the HSR is changing.



When applying a load disturbance at a constant angular velocity, it is possible to see that the controller is able to compensate for this disturbance on both systems. In the rigid model, the disturbance is corrected without any overshoot. For the spring model, the settling time is longer and oscillations are observed.

5. Conclusions

From the comparison of the performed simulations for the rigid and the spring model, it can be concluded that the cascade controller designed for the rigid system was sufficiently controlling the spring system, within requirements set for steady state error, overshoot and settling time on the HSR angular velocity. The added spring effect had negligible effect on the controller performance in regards to settling time, overshoot and steady state error. However it was observed that the oscillations that occured from a sudden load step was not quickly reduced, but the oscillations was of a negligible magnitude in the simulations.

Acknowledgement

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