A PORTABLE IMPLEMENTATION OF A MODEL OF ELECTROMECHANICAL ACTUATORS USED IN MORE ELECTRIC AIRCRAFT DIMENSIONING TOOLS

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Abstract:
Modelling of the electric power systems of a More Electric Aircraft (MEA) is multidisciplinary and quite CPU demanding. This paper suggests a modelling approach of the electromechanical actuators implemented in a portable code constituting a reasonable compromise between required CPU-time and accuracy.

The approach is to divide the actuator model in three partitions, namely an current control rectifier, electromachine and gear model. By using only quasi-stationary electrical state variables [1] the variations within the electrical power cycles are neglected. The involved electromachines are modelled in terms of their efficiencies, moment of inertia, torque and back EMF constants. The rectifiers are described in terms of equivalent load dependent loss resistances corresponding to their efficiencies [2,3]. The gears are described in terms of efficiencies and gear ratios.

The model is designed in the modelling language Modelica with the objective that the model, i.e. the implementation of the model, should be flexible, extensible, portable to MATLAB and object oriented. The proposed modelling approach is considered to constitute a framework in future build-up of models of entire MEA aircrafts [4].

Keywords: electromechanical actuator, more electric aircraft, MEA, modelica, model, portable, flexible, object oriented

Introduction

In the design and optimization process of engineering systems one often finds the need of dividing the systems into several subsystems with known interfaces towards each other. Object oriented terminology used in the computer science is therefore very useful in such systems. One example of such complex and multidisciplinary engineering system is an aircraft (see Fig. 1).

In this paper the concerned subsystem is the power system in the first sublevel, the actuation system in the second sublevel and the current control rectifier, electromachine and gear in the third sublevel. Modelling this complex system is very CPU-demanding and multidisciplinary. The object oriented approach means that each object is described by its encapsulated behaviour and an interface for communication to other objects. This object oriented approach makes the model more flexible, portable and the involved objects more reusable. In order to reduce the CPU-time, i.e the amount of data, without losing the accuracy the electrical state variables are described in terms of rms quantities in the model. A compact behavioural description of the involved objects is used in this paper in order to reduce the amount of simulation data. The behaviour of the electromachines are described in terms of their efficiencies, moment of inertia, torque and back EMF constants. The behavioural description via efficiency is also used regarding the involved current control rectifiers and gears involved. This paper suggests an approach, where the model implementation can be reusable and portable which can be used in the optimization studies of the aircraft dimensioning tools.
Choice of the simulation environment

There are several simulation environments that could offer the object oriented features pointed out in this paper but the one chosen in this paper is the Dynamic Modelling Laboratory, Dymola [5]. This environment supports the open object oriented language Modelica among others. The Modelica language can be used for modelling of large, complex and heterogeneous physical systems [6]. General equations are used for modelling of the physical phenomena. The Modelica language supports several formalism, ordinary differential equations, ODE, differential-algebraic equations, DAE, Petri nets, finite state automata and bond graphs. The portability and reusability features of the Dymola is not restricted to modelica models. There is also an interface to SIMULINK and MATLAB. For example can a modelica model be “translated” to a SIMULINK block model.

Model implementation

The actuation subsystem model implemented in this paper comprises of three objects, current control rectifier, electromachine (see Fig. 2) and gear. The rectifier is modelled as an auto-transformer with a resistive loss for controlling the current level of the electromachine. The gear is modelled as an ideal gear with 95% efficiency. The resistance in the electromachine is modelled in form of efficiency look-up-table.

Fig. 2: The generic model of electromachine with the parameters, moment of inertia, loss resistance, torque and back-emf constant.

The physical behaviour of the involved objects are described in terms of mathematical equations. The connection points are also described in terms of mathematical equations for the involved flow and intensity variables.

Simulation example

The actuator is fed by a DC voltage source of 270 V with qn superposed AC voltage of 10 V amplitude. The actuator is on the mechanical side loaded by an inertia component of magnitude 36*10^-3 kgm², damper of 900 Nms/rad and a pulse load torque up to a limit of 100 Nm. The cycle of the pulse load is 100s where the last 10 s it goes down to zero. The angular velocity is compared to an exponential signal with the amplitude of 1 rad/s as feedback signal to the current rectifier. The current rectifier is assumed to have resistive loss equivalent to 12 Ω on the AC side and 13 Ω on the DC side. The electromachine parameter values are listed in table 1.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>t [Nm/A]</td>
<td>1.3</td>
</tr>
<tr>
<td>e [Vs/rad]</td>
<td>0.69</td>
</tr>
<tr>
<td>JEM [kgm²]</td>
<td>1.08*10^-3</td>
</tr>
</tbody>
</table>

Table 1. The parameter values for the electromachine

The model is simulated in Dymola at first and then translated in a MATLAB code and re-simulated in MATLAB for illustrating the portability.

Fig. 3: The torque provided by the electromachine, Dymola simulation.

Fig. 4: The current in the electromachine, Dymola simulation.

The Modelica semantic sets negative flow variable sign to sources and positive sign to loads.
The efficiency is low due to the low torque and angular velocity loading of the electromachine. The jumps are caused by the “switching off” the torque load (periodically).

**Conclusion**

The presented model approach is considered to constitute a framework in future build-up of models of entire MEA aircrafts. The object oriented implementation makes it possible to reuse and exchange the models between the different submodels and also portable to other environments like SIMULINK and MATLAB.

**Acknowledgement**

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**References**
