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Energy Consumption Modeling of a Turning Table and Standardized Integration into Virtual Commissioning

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Abstract

This paper describes the standardized integration of energy models into the virtual commissioning tool chain for a holistic energy consumption and peak power simulation of production cells used in the automotive industry. An energy model of a turning table as part of a demonstration cell is built in detail using modeling language Modelica. Further, an interface description for model connection to virtual commissioning is presented. Finally, simulation results are validated by measurements on a real demonstrator.

Keywords: Energy efficency; sustainable manufacturing; virtual comissioning; physics based modeling; functional mock-up interface (FMI).

1. Introduction

Rising energy prices and stronger regulations regarding to carbon dioxide (CO_2) emission challenge the industry to manufacture in a sustainable and efficient way. With the *Energy Efficiency Directive* [1] and the derived *National Action Plan (NEEAP) 2014 for the Federal Republic of Germany* [2] the European Union (EU) has set the aim of 20% primary energy savings until 2020. This leads to the national energy savings claims, which are manifested in

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Germany for example in the *Nation Action Plan Energy Efficiency* [3]. Because of this, the automotive industry also has to derive also energy saving targets to fulfill all the legislative requirements. One successful example to reach these targets is the European Union research project AREUS (Automation and Robotics for European Sustainable Manufacturing) [4]. One of the main aims of this project is to develop a new hardware and software for an energy efficient and sustainable production of the future [5–7].

Additional to energy efficiency, energy flexibility is a new challenge for the factories of the future. Germany has big growth rates in renewables, in particular wind power and photovoltaic systems. In 2015 Germany has an average rate of 31,6% of renewable energy related to whole energy consumption of the country [8]. The target value of renewables for the year 2050 is 80% [8]. For production plants this means that they have to handle a volatile energy supply system. Both of these challenges, efficiency and flexibility, in future directly impact the cost targets of a company. To achieve these targets related to energy consumption and volatile energy sources it is important that these criteria have to become a central part of digital planning of new automotive manufacturing plants. In the following, it is described how virtual commissioning (VC) gets enabled to integrate energy models of different mechatronic systems.

2. State of the art

Already Pellicciari et al. [9] described that increasing position accuracy and energy is a multicriterial optimization problem. A detailed mechatronic model of a positioning system was presented in his paper. Also Meike et al. [10] described an approach how to increase energy efficiency of multirobot systems by modeling the mechatronic system of industrial robots. Furthermore, a lot of other papers demonstrate the modeling of mechatronic components and derive a simulation and optimization of the energy consumption of production components [11,12].

The integration of mechatronic models into existing planning software is described by Bormanis [13]. He uses MATLAB Compiler™ to create a binary code out of this energy model of an industrial robot (six-axis). Also Süß et al. [14] describe an interface for exporting models from a modeling and simulation software into a common usable data format. The standard they use is called functional mock-up interface (FMI) [15]. One model that is converted via the standard is called functional mock-up unit (FMU) [15]. Moriz et al. [16] also described the use of FMI for the integration into a simulation of production systems.

3. Integration of mechatronic models to VC by FMI

To study the real behavior of the energy consumption of production cell, energy models has to be connected to the VC. Süß et al. [14] already describe how a standardized connection between VC and simulation models is possible (Figure 1). The extended VC with integrated energy simulation is named energy Virtual Commissioning (eVC).

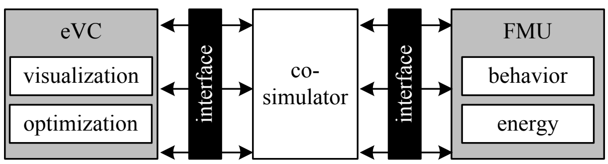

Figure 1: Connection between FMU and eVC for industrial robots simulation [14]

This approach uses FMI for the standardized exchange and integration of mechatronic models. FMI was invented in the *MODELISAR* research project, which is intended to be used for automotive research and development [17]. During the engineering process of cars there was the problem to merge simulation models from different suppliers and different simulation tools. Similar problems occur if different energy models of automated production cells from