DIGITÁLNÍ DVOJČE ENERGOBLOKU DOMORADICE

DIGITAL TWIN OF POWER BLOCK DOMORADICE

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Abstrakt

Životnost průmyslových jednotek je klíčovým parametrem v provozu i ve fázi jejich projektování. Digitální dvojče kombinuje obojí. Konstrukční modely založené na běžném standardu MKP simulací nemusí končit výrobou sestavy výkonového bloku, ale mohou dále fungovat v provozu a napomáhat tak k přesnější predikci životnosti reálného zařízení. Numerický model je již řadu let vhodný pro posouzení konkrétního stavu zatížení celého zařízení, ale technologie digitálního dvojčete umožňuje využít tyto informace v běžném provozu, kdy obsluha zařízení dostává přesnou hodnotu životnosti zařízení na základě historie skutečných podmínek zatížení a očekávaného budoucího provozu. Cílem tohoto výzkumu je vytvořit digitální dvojče pro monitorování, predikci a řízení životnosti turbín na základě metamodelů získaných ze softwaru optiSLang. Konstrukce metamodelů je založena na desítkách předpočítaných variant MKP výpočtů turbíny v softwaru Ansys. Software SVS Digital Twin poté komunikuje s PLC a je schopen číst data v reálném čase, zpracovávat je a následně přenášet zpět do PLC.

Abstract

The service life of industrial units is a crucial parameter in operation as well as in their design phase. A digital twin combines both. Design models based on the common standard of FEM simulations do not have to end in the production of a power block assembly but can continue to function in operation and thus help in more accurate prediction of the lifetime of real equipment. For many years, the numerical model has been suitable for assessing the specific load status of the entire equipment, but the digital twin technology makes it possible to use this information in normal operation when the operator of the equipment receives an accurate value of the lifetime of the equipment based on the history of actual load conditions and expected future operation. The aim of this research is to create a digital twin for monitoring, predicting, and controlling turbine lifetime based on metamodels obtained from the optiSLang software. The construction of the metamodels is based on dozens of precomputed variants of FEM calculations of the turbine in Ansys software. The SVS Digital Twin software then communicates with the PLC and can read the data in real-time, process it, and then transmit it back to the PLC.

Creation of the metamodels

FEM models

The calculation is divided into two steps - the calculation of the transient temperature problem and then the static problem, in which the temperature distribution found in the temperature problem will be input as the load. A separate model is created for both steps. The aim is to create a reduced model for different temperature transitions describing the physical processes in the turbine casing in terms of its strength, durability and deformation. Specifically, this involves checking for plastic deformations in the bolts, maximum life loss and then checking for deformations in the stator blade carriers.

In the model, selected nodes are placed approximately at the locations of the thermosensors on the real turbine. The temperatures at these nodes will be used as control parameters for the digital twin model - the measured temperatures and their rate of change on the real turbine will be compared with these calculated values.

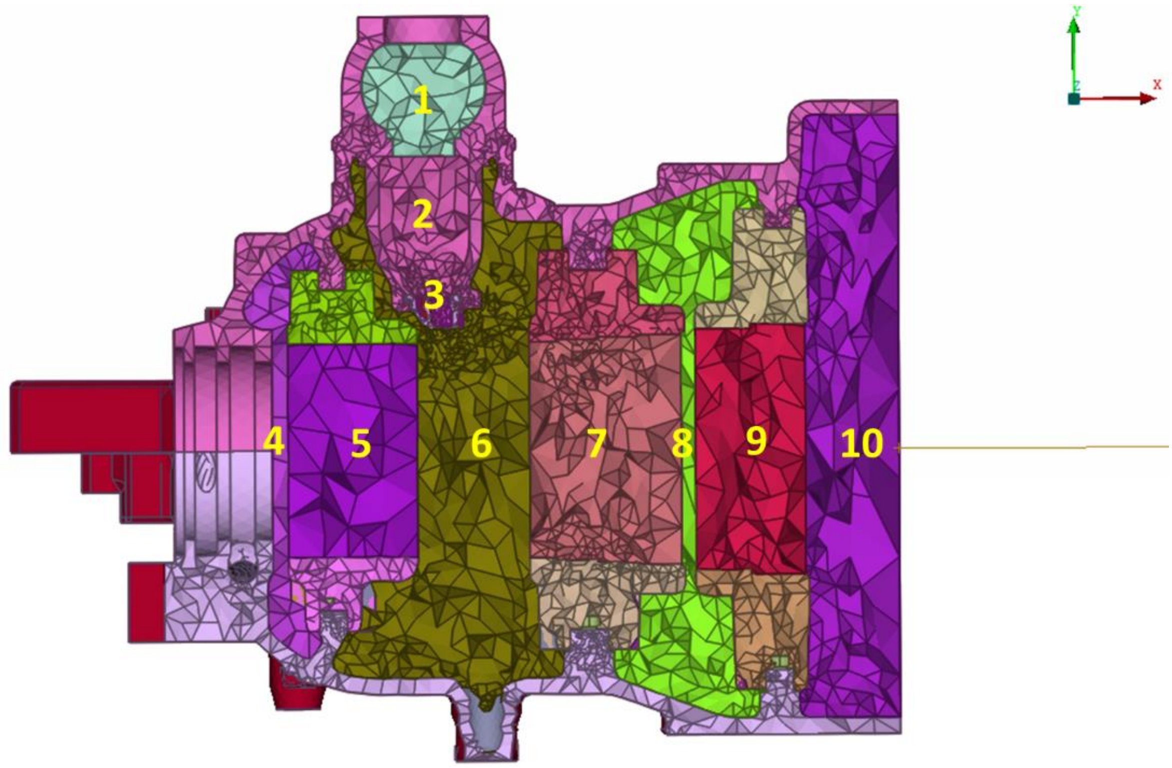

Fig. 1: Section through the turbine model

Functional mockup unit

The Functional Mock-up Interface is a free standard that defines a container and an interface to exchange dynamic models using a combination of XML files, binaries and C code zipped into a single file. It is intended to be used in computer simulations to develop complex cyber-physical systems. A component which implements the FMI is called a Functional Mockup Unit (FMU). An FMU is intended to be a portable, dynamic simulation model for exchange or co-simulation.

It consists of one zip-file with extension ".fmu" containing all necessary components:

- An XML-file that contains the definition of all variables of the FMU that are exposed to the environment in which the FMU shall be used.
- A set of C-functions is provided to execute model equations for the Model-Exchange case and to setup and run the slaves for the Co-Simulation case.
- Further data can be included in the FMU zip-file, especially a model icon (bitmap file), documentation files, maps and tables needed by the model, or all object libraries or DLLs that are utilized.

In our case, a dynamic model exchange system based on differential equations was created based on the metamodels, which can be exported to FMU format using Optislang.

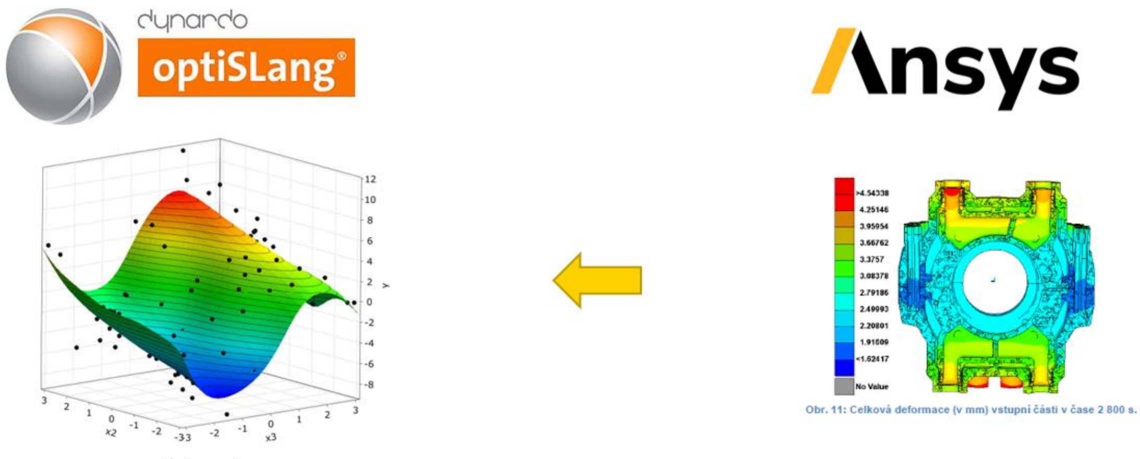

Fig. 2: Procedure for creating a metamodel for a digital twin using Ansys software

Digital twin

The digital twin of the turbine is located in the Domoradice power plant. Its core is SVS Digital Twin software. It is an interface created in SVS FEM, which ensures communication and data transfer between the FMU and the machine for which the digital twin was created. On the power unit plant side, it communicates with a programmable logic controller (PLC), which monitors the current state of the machine in real time using sensors and reacts to this state in some way, for example by reducing the machine speed. It can also be told how to react to this state by the operator directly in the control room, by a user with a smartphone or by a user with a smartwatch. It just depends on what technology the PLC has and how it is able to exchange data with the environment.

The communication of the digital twin with the PLC is done using the OPC Unified Architecture (OPC UA) protocol. It is an industrial M2M (machine-to-machine) communication standard. It is a technology based on commonly used communication standards such as TCP/IP, HTTP and SOAP.

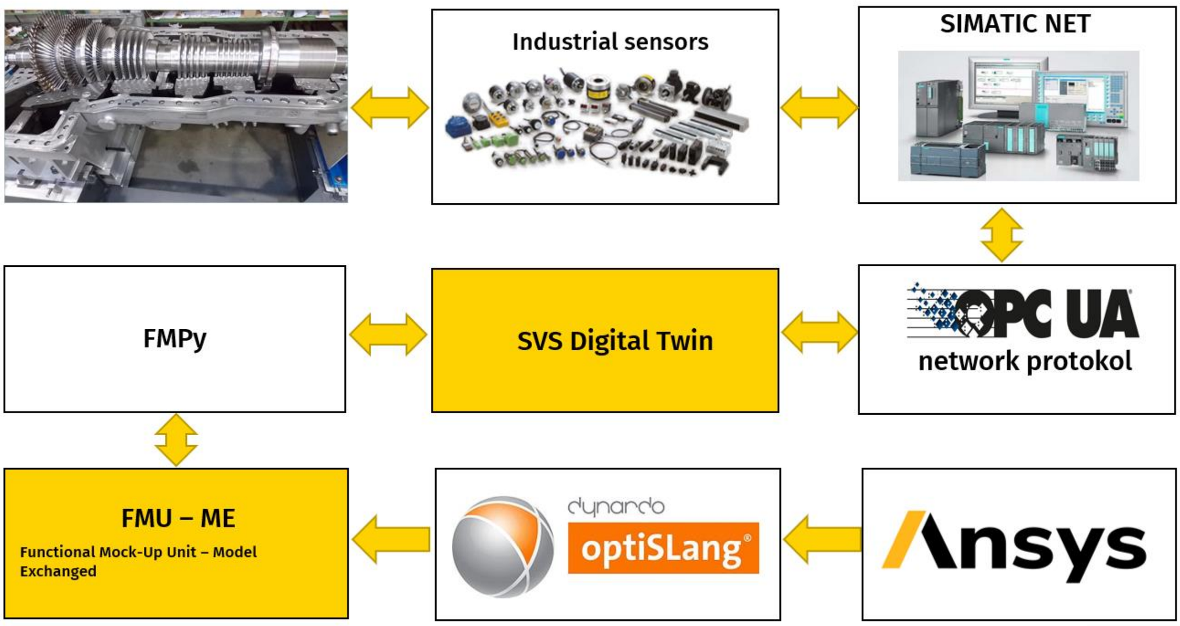

Fig. 3: Diagram of digital twin

When operating conditions change, the digital twin retrieves the current data from the PLC. Based on the generated FMU, it performs an evaluation and then sends the evaluated data back to the PLC via the OPC UA. the time step in which the evaluation occurs is in the order of seconds in common applications, such short calculation times are made possible by the use of FMU reduced metamodels from FEM simulations. The digital twin is implemented as a background service that can monitor the turbine throughout its whole life cycle.

Conclusion

A digital twin of the steam turbine located at the Domoradice power plant has been created. The digital twin can monitor and predict plastic deformations in the bolts, maximum life loss and deformations in the stator blade carriers of the turbine. To predict these values, it uses reduced metamodels created from FEM simulations in Ansys software.