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A Common Software Framework for Energy Data Based Monitoring and Controlling for Machine Power Peak Reduction and Workpiece Quality Improvements

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Abstract

A standardized and high frequent collection of energy data is a powerful tool to enhance industrial energy efficiency and has also proved to be most valuable in condition and process monitoring tasks in recent researches. For these monitoring and controlling functions in production sites a common software framework is essential. In this paper the development of such a software framework is presented. Further on two new approaches utilizing this software framework are introduced: Firstly the recognition and automatic reduction of power peaks between connected machine tools. Secondly the usage of energy data of machine tools for quality monitoring purposes.

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Keywords: Software Framework; Production Machines; Energy Controlling; Industry 4.0; Quality Monitoring; Condition Monitoring; Workpiece Monitoring

1. Introduction

2014 was the warmest year on record. Compared to the global average of the 20th century the temperature was 0.69 °C above [1].

The greenhouse gas emissions, which are one main factor of these global ecological trends, of 49.5 GtCO2 eq/yr are mainly driven by the industry with 28.6 % in 2010 [2].

The industry in Germany, which uses 30 % [3] of primary energy in 2011 and 46 % of electrical energy in 2013, must optimize the energy consumption with different strategies to stay competitive as well as to ensure that the ecological pollution stays in an acceptable range for humans, biodiversity and ecological systems.

There is not just the necessity to increase the efficiency in industrial processes and its components which leads to less energy and resource consumption: Renewable energy sources like wind energy or solar energy are highly volatile. Electric energy usage must be able to follow up a given profile or high load peaks must be prevented.

In the research project ETA-Factory challenges in energy efficiency for production machines, factory buildings and technical infrastructure are addressed [4]. For example a thermal network, which is established, can increase the energy efficiency using waste heat between machines as well as between machines and the building itself [5]. Individual optimization of subsystems (machines or building) reaches 30 % energy efficiency rates, whereas overall optimization leads to 40 % as presented in [4]. A mayor part of the energy savings are based on the connection of machines and devices.

According to [6] connected devices in the different fields of home consumer, transport and mobility, health and body, buildings and infrastructure, cities and industry will grow from 2 billion to 8 billion devices in 2020. This increase will change the market volume from 180 billion to 1 trillion $/yr and with the growth of connected devices in any domain, the opportunities of solving technical problems will grow. In its hightech strategy [7] the German government focusses on digitalization and energy efficiency in the industry. It is

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mentioned that Industry 4.0 is one enabler for linked energy systems to increase energy efficiency as shown in [8].

Connected devices are IT infrastructural linked objects like PLCs or sensors. Together with a common software framework they enable energy optimization potentials. These actual trends of connected devices create a chance to optimize the energy consumption establishing a common software framework.

In [9] a concept for analysing energy data is presented with low cost energy sensors. There is a high potential analysing energy data for recognizing energy waste in a factory as well as identifying bad states of processes.

Transparency of energy consumption is one key enabler for energy optimization [9]. Especially clustering the information for different operational periods increases the motivation for energy efficiency topics [10].

The software framework presented by [11] is of a conceptual high level infrastructure of information systems for energy based management. In this work a method, especially for connected machine tools for data acquisition and analysis is presented. Focusing on the different levels on energy usage like micro (data in microseconds) and macro (data clustered hours) presented in [12], here the micro level is focused.

Subsequently two approaches for the utilization of energy and process parameters based on the common software framework are demonstrated: power peak shifting and quality monitoring of workpieces.

Power peak shifting for short term is effecting costs for infrastructure as well as a more balanced electrical grid. The concept can provide:

- Optimization of energy consumption in a defined time interval and
- Online power peak reduction for connected machine tools.

The prospects of energy data (e.g. power demand) for quality monitoring during machining are analysed using simple signal processing methods based on an experimental series. It is shown that energy data is not only valuable for energy efficiency improvements but, providing the necessary software framework, for different condition monitoring purposes as well.

2. Software framework for energy monitoring and controlling of IT-connected machine tools

In the following a software framework is presented which is improved for automatic data aggregation to be used in a workflow system. Internal sensors of e.g. drives are used for data acquisition. Therewith no additional sensors are needed for monitoring and controlling purposes. The standard for data exchange is OPC UA due to its security, stability, scalability and supplier independency [13].

2.1. Framework and goals of GDS

The Generic Data Server (GDS) software framework described in [14] was a system for analyzing data and restricted to special cases. For use cases, which are described in this paper, it is further developed to a workflow based structure for enabling more flexibility. Now analysing, monitoring and controlling machines using the communication protocol OPC UA is possible. Besides the workflow the GDS consists of an analysis section which is a Web based HMI as well as a database system for long term data acquisition (Fig. 1).

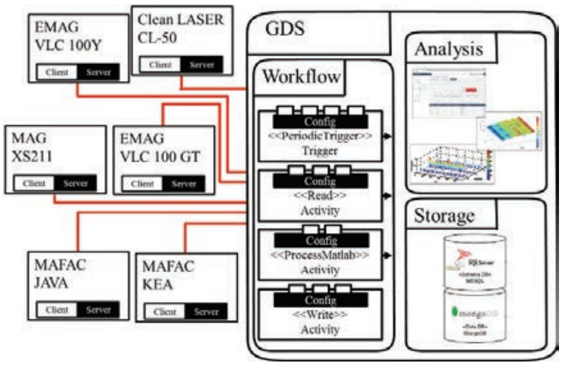

Fig. 1. Generic Data Server overview

Workflows are created through a configuration interface. Thereby a high flexibility is given to run tasks like

- reading data,
- processing data,
- storing data and
- writing commands to any OPC UA capable PLC.

A simple workflow shown in Fig. 2 has a periodic trigger which activates the workflow "Processing". With the following read activity data from an OPC UA server is read (like a temperature value or an energy counter from a PLC). User defined processing is possible using the "ProcessMatlab" activity which can run any Matlab created DLL. The data is transferred between each activity inside of the software with variables. Finally the processed data is stored in a database with a write activity.

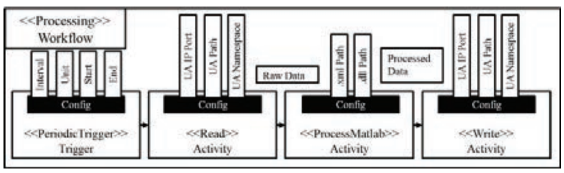

Fig. 2. Workflow structure of the Generic Data Server [15]

Limitations in the rate of communication are actually given through OPC UA with 10 Hz. Especially in the area of power