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Demand-oriented selection and combination of industrial bus systems for advanced energy management purposes

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Abstract

Industrial bus systems are the backbone of production control and management. Regardless of the utilised technology, industrial communication systems realise feedback loops from sensors and control values to actuators. Industrial communication is also the basis for an operative energy management system. Energy demands are metered and send to management and decision support tools to be analysed and evaluated. Present industrial bus technologies from production and building automation domains offer different functionalities to support an operative energy management. This paper aims to discuss the requirements of an advanced energy management system regarding the technical issues of appropriate data communication means. By describing the properties of various bus systems the advantages and disadvantages of each one is shown and the applicability for the described utilisation is considered. Finally, the possibilities to apply machine control mechanisms through the bus systems are analysed.

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Keywords: industrial communication; field bus; energy efficiency; energy monitoring; energy management

1. Introduction

In 2010 the industrial sector caused 28.9 % of final utilisation of coal, oil, natural gas and eletricity worldwide [1] and equivalent greenhouse gas emissions of 14.16 $GtCO_2eq/yr.$ [2]. Energy management plays a key role in reducing this industrial energy demand and greenhouse gas emissions of the industrial sector. To establish an effective energy management system, the continuous monitoring of demand behaviour of energy utilising entities and the knowledge of energy flows within a production environment is essential [3]. Energy management systems consist of various functions. Figure 1 shows a selection of these functions and a generic structure for data collection on field level. These functions can range from simple allocation and controlling issues with low requirements on update times, up to more superior control and data analytic issues with closed-loop feedback to machine's programmable logic controller (PLC) and high dynamics on sensor readings. A special challenge arises when energy management systems should have the ability to generate process information or knowledge for e.g. predictive maintenance purposes from the acquired data. For this purpose, higher data update frequencies are generally necessary. To comply with these needs, the communication infrastructure between elements of an energy management system, as shown in Fig. 1, must fulfil specific requirements. Against this background, this paper presents a literature overview regarding different classes of bus systems applicable for energy management purposes. A systematic approach to select and combine suitable bus systems to create a demand-oriented matching of energy management system's requirements and bus system's technical specifications is derived. The findings are discussed and applied in two scenarios within one case-study setup. The presented procedure enables manufacturing enterprises to select and combine suitable bus systems, dimensioned for their specific energy management use cases.

2. State of the art

2.1. Basic energy management functions

In the following sections energy management functions according to Fig. 1 are identified, characterised and analysed. In Chapter 4 the results of the literature review will be condensed within an evaluation matrix and matched with the available communication technologies presented in the Chapter 2.2.

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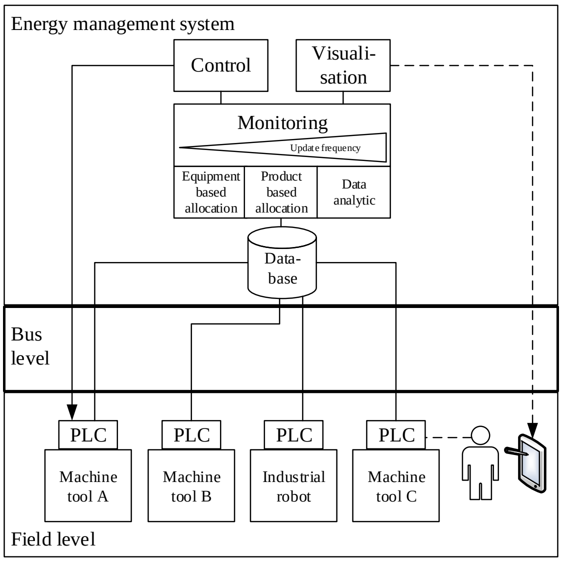

Fig. 1. Possible structure of an energy management system

Subsequently important key requirements are written in italics. The terms will be picked up again in the following review on bus systems.

2.1.1. Visualisation

Energy data acquisition and monitoring has been known for several decades and is standardised internationally in the ISO 50 001 [3]. First references for systematic characterisation of energy utilising entities can be found in the early 1980s [4]. In energy economy the provision of load profiles with an *update frequency* of 15 minutes is state of the art for many years. In the domain of production environments monitoring of energy data is not widely distributed, but essential to evaluate and improve energy efficiency of production processes [5]. For monitoring of cycle time demand specific consumption Mueller et al. recommend *update times* in the dimension of seconds. To make statements about energy efficient machine operation an *update time* in the dimension of minutes is requested [6]. Panten et al. state that for energy monitoring purposes in real-time high *update frequencies* are needed to recognise power peaks during tool changes [7]. To gain informations about tool conditions within a machine tool, Al-Sulaiman et al. used electrical power signals at an *update frequency* of 250 Hz [8]. For data mining purposes Denkena et al. suggests an update frequency of 500 Hz to capture applied forces on the tool of a milling machine. Resulting process data is evaluated and used to increase efficiency and flexibility in process planning [9]. For energetic evaluation of production processes, the measurement of a whole process becomes necessary. To be able to allocate dynamic energy demands to single events, at least an *update frequency* of ten samples within one steady state are recommended [5].

To realise machine based energy budgeting functions based on data monitoring and visualising, Stüger demands the *maximum data security and system reliability* as an important requirement [10].

In a medium-sized car manufacturing plant with a yearly output of 250 000 vehicles, more than 500 permanently installed *measurment points/bus participants* are necessary to allocate energy demands and resulting costs to a certain machine or cost center [6].

2.1.2. Control

Fig. 2 shows the generic communication pyramid within a factory and the seperation into machine near (PLC and sensors/actors) and production side or line wide (ERP/MES/SCADA) sections. In addition, the requirements regarding the update time and the data volume changing in vertical direction are depicted. The update time decreases with the transition from PLC to control level. On field level, real-time for sensor/actuator communication is needed [5]. Control of machines can be realised based on the ERP/MES/SCADA level or on machine level (PLC and sensors/actors) [11][12]. On sensor/actor level, as an example, the DMG EnergySave Box is available as a control unit to switch machine tools into an energy saving mode refer to Fig. 2 (1). When the energy demand of a machine tool drops below a predefined threshold for a defined period of time, the machine will be automatically switched to emergency stop condition and the light in the working chamber will be switched off. The control command is realised by a direct switching device at the machines emergency stop mechanism and the working chamber light. Therefore, the EnergySave Box is a closed, embedded system. Hence, *safety* issues are fulfilled [11]. Other solutions are implemented directly inside the PLC of a machine tool e.g. Heidenhain EnergyOpt refer to Fig. 2 (2). Standby and switch off times for components of a machine tool can be individually defined [13]. Obviously, controlling solutions usually are located at the lower end of the automation pyramid according to Fig. 2. Therefore, *interoperability* in vertical direction of the automation pyramid plays a less important role. On the level of production site, line wide solutions, such as the Siemens SIMATIC powerrate, offer the possibility to switch off consumers from a central process management system refer to Fig. 2 (3). Controlling issues are realised by serial fieldbus communication [12]. By this means, *real-time* and *safety* issues are respected.

2.2. Categories of buses and their technical requirements

According to Klasen et al., two main categories are differentiated [14]. The specifications of the various bus technologies (and protocols) are described according to the requirements demanded by the previously introduced energy management functionalities written in italics.

2.2.1. Serial field buses

Serial buses are commonly used for data connections in the lower layers of the automation pyramid. Typical use cases are interconnections between field devices and control units. This paper focuses on the most commonly used technologies as identified by Klasen et al. [14]. Accordingly, the most common field bus systems are CANopen, CC-link, CIP, INTERBUS and PROFIBUS. Generally, serial field buses operate in one or more possible *topological* forms such as line, star, ring and/or tree topology. Most of the buses follow a master/slave model, where only one bus participant can have the role of the master. The bus participant with this role is the only device that can initiate data