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The impact of digitalization on the future of control and operations

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ABSTRACT

The notion of Internet of Things (IoT), as well as related topics such as Cyber-Physical Systems, Industrie 4.0 and Smart Manufacturing are currently attracting a lot of attention within the process and manufacturing industries. Clearly, IoT offers many potential applications for automation, ranging from engineering installation of new plants to production management and more intelligent maintenance schemes including novel sensor technologies. The focus of this paper is, however, on the control and operations. Most likely IoT leads to new system architectures where open standards play a significant role. Through better connectivity, information will be much more easily available, which could result in that previously isolated functions will become more closely integrated. Here modeling at the right level of fidelity will be absolutely key. It can be expected that the importance of optimization will increase and this paper discusses some aspects related to the opportunities, challenges and changes triggered by IoT.

1. Introduction

The control and operations of process plants has undergone significant developments compared to the early analogue regulatory schemes. Computer based supervisory control was first tried already in the late 1950s. With the advent of the microprocessor the first distributed control systems (DCS) were introduced in the 1970s. This is sometimes referred to as the first digital revolution. Later, increased computational power as well as development of better optimization solvers have enabled advances also for the upper layers of the automation hierarchy (Zhang and Sargent, 1996).

However, a typical process industry company has separate departments for different functions such as plant operations, production planning, energy planning, supply chain optimization and maintenance management. Furthermore separate computer tools are traditionally deployed for these functions, which are often geographically distributed across a site or they can even be in different locations.

With the improved connectivity and dramatically increased access to computational power the so-called Internet of Things (IoT) shows promise of an increased integration of the control and operations in the process industry. The purpose of this paper is to discuss, more in detail, some of the currently on-going developments and to humbly try to predict some future changes that may occur as a result of this second digital revolution of industry. It will be shown that it is valuable to have access to supporting tools that ensure correct, agile and more efficient reactions to changes and that open the possibility for optimization also within a complex and frequently changing environment.

2. Business challenges for automation

Before focusing on technology it is important to consider that at the end of the day the aim is to obtain tangible economic benefits for the industry. Already 2005 during the work towards a Strategic Research Agenda for the EU technology platform for embedded systems – ARTEMIS – the first author together with a former ABB colleague, Nils Leffler, formulated two Grand Challenges for Automation:

- The sustainable 100% available plant
- To engineer systems 10 times of today's complexity with 10% of today's effort

The first challenge stresses that the highest priority for all process and manufacturing industry is that the production is in fact running. The 100% availability captures the vision that in the future there will be only planned maintenance stops. It can of course be debated whether this vision is realistic or even desirable, but as a

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vision it is hard to aim for anything less. In practice, one needs to find the right balance between maintenance cost and risk. Much of this relates rather to topics like condition monitoring and predictive maintenance, which are at the heart of the industrial digitalization but beyond the scope of this paper. Instead, what will be discussed below is embedded in the one word "sustainable", which then refers to topics like productivity, as well as, resource and energy efficiency.

The second challenge is primarily that of the automation suppliers. Regardless of the level of automation there needs to be continuous improvement in the time it takes to configure and commission new systems, solutions and products. We will come back to this challenge several times in the remainder of this paper.

The scope of the two Grand Challenges formulated 12 years ago is within a particular plant and its automation system. Both challenges are still relevant and the technologies of the industrial digitalization help to address them in several respects. However, along the second digital revolution in industry the scope for automation is increasing from single plants to networks of plants, or even value creation networks composed of value creation nodes of various types across an entire enterprise. In particular in the process industries, where several plants are interconnected by networks of utilities and intermediates, a more holistic automation approach might remove artificial constraints and unlock additional optimization potential.

Consequently, in 2016 a European Research and Innovation Agenda on Cyber-Physical Systems of Systems was proposed by three working groups (Engell and Sonntag, 2016). One core challenge with relevance to the nine considered technology sectors including the process industry is "distributed, reliable and efficient management of cyber-physical systems of systems". It is based on the observation that cyber-physical systems of systems cannot be managed and operated reliably and efficiently by centralized management and control, but require novel distributed management and control methodologies that can deal with partially autonomous systems with human interaction and frequently changing system structures. Particular research and innovation priorities from the field of process control and operations cover

- distributed robust system-wide optimization methods,
- system operation methods combining data-driven and model-driven approaches and
- integration of control, scheduling, planning and demand-side management for industrial production systems.

All of them are touched in the sequel of this paper.

3. Industrial digitalization

The last 10–15 years have seen a phenomenal development: the internet and later smart phone apps have changed almost every facet of our daily life. They have altered the way how we book travel, do our banking, watch TV, keep in contact with our friends etc. The drastic changes to the consumer market have, however, not yet fully reached the business to business market. Digitalization of industry began already in the 1970s when microprocessor controllers and distributed control systems were first introduced. In parallel the deployment of information technology (IT) in general and particularly the utilization of internet have increased especially from the 1990s, but the main functionalities and information have so far been separated from the control room by a firewall and the data flow has been primarily one-directional. What is now often referred to as "Digitalization" could also be called the second digital revolution. It will lead to a much closer integration of operational technology (OT) and IT. For a discussion of the economic potential of the Industrial Internet see (Evans and Annunziata, 2012).

Hence, similar to the way our daily life as private consumers has been transformed, the current industrialization digitalization will have a profound impact on every aspect of how a process or manufacturing industry conducts its business in the future. Examples of functions that will be impacted include how the companies handle their product development, customer contacts, collaboration with sub-suppliers etc. Many of the expected new digital functions are of course not related to control and operations which is the focus of this paper. In the following sections we will discuss more in detail the current and future implications of the industrial digitalization specifically on control and operations.

4. Current trends

The above introductory sections have already covered some upcoming trends and in this section some of these are further explored. The so called hypes or trends may not all be long-lived but they certainly also affect the expectations of the end users and may indirectly steer the developments of future operations and control. Also, at least for researchers it is always desired to challenge the current state-of-the-art and investigate the true potential of emerging technologies. Below some of the relevant trends are briefly discussed

- Internet of Things: As already discussed above, this is the enabler for cyber-physical systems, which is the core of for instance Industrie 4.0 (Germany) and Smart Manufacturing (US) activities. What it basically means is that any device can be connected to the internet allowing two-way communications across or between plants. This makes new data available also across operations and supports more horizontal applications with decentralized decision making. This fact easily creates unrealistic expectations through the countless opportunities of cross-collaborations between applications. A research question is to identify the main benefits from this collaboration potential. It is important that the engineering and information technology research communities collaborate on these to enable maximum flexibility, as it can result in a paradigm change within the process automation and its functional components.
- Automation Cloud enables software applications to be installed not physically in the plant but anywhere through either intra- or internet connection. This enables the use of much more powerful computing resources (e.g. parallel computing) and easier remote administration. It can also allow purchasing a solution as a service without investing in hardware, thus reducing the investment risk. Technically, even if it is possible to solve larger mathematical problems using the "cloud", still only a few algorithms exist that fully take advantage of this. Definitely, a research challenge is to identify how "unlimited" computing power may affect the life of a normal production facility and to define optimization algorithms that can fully benefit from this and create added value. Methods for systematically evaluating the true optimization potential of a processing plant and the related business models are still missing. Note that a cloud solution can also be hosted locally.
- Big Data technologies aim at analyzing large sets of non-structured data. This can enable new knowledge about the production identifying problems early or creating more accurate data-driven models. For instance, a scheduling function within operations can become more aware and knowledgeable about the underlying and surrounding processes – or the control strategy can be automatically adapted to various situations. It is, nevertheless, most important to have an idea of what one is looking for. The concept of machine learning can be an efficient way to allow