Digitalization of the Industrial Drivetrain to Optimize Energy Consumption and Efficiency

Matthias Manger and Jonas Harant

August 30, 2024

Digitalization of the industrial drivetrain to optimize energy consumption and efficiency

Jonas Harant and Matthias Manger

Siemens AG, Frauenauracher Str. 80, 91056 Erlangen, Germany

Abstract. With electric motor-driven systems expected to contribute to almost half of the world's total electricity consumption, the industrial drivetrain plays a crucial role in companies' digital transformation efforts. Two key use cases in this context are the detection of upcoming machine outages with the help of predictive maintenance and the optimization of the energy efficiency of the industrial drivetrain. By implementing sensor-based as well as sensor-less digital solutions for drivetrains and machines, which are addressing both use cases in industrial environments, operators are not only achieving a fast return on invest but also ensure continuous transparency and improvement of their equipment, resources, and processes. This paper presents two real-world examples from different industries to demonstrate the long-term benefits of digitalization for industrial drivetrains, including significant improvements in energy consumption with amortization in less than four months and an increased equipment lifetime of up to 15 %.

Keywords: Electric Motor-Driven Systems, Digital Drivetrain, Energy Efficiency

1 Introduction

The electrical drivetrain in the industrial sector is used for applications such as pumping, ventilating, compressing or mixing. It consists of several components, two of which are the electric motor and the frequency converter. Electric motors are used to turn electrical energy into torque and motion, while frequency converters convert an input frequency into an adjustable output frequency to control the speed of those electric motors. Electric motor-driven systems (EMDS) play a major role when it comes to energy consumption. Electric motors and the applications they drive are expected to consume 43% to 46% of the world's total energy. The largest contributor to this is the industrial sector, which accounts for 64% of the energy consumed by EMDS [1].

The adoption of digitalization in industrial drivetrains can therefore be one of the biggest levers for the reduction of total global energy consumption. As a result, many companies and governments have dedicated policies to reduce energy consumption of EMDS in industry. Switzerland, for example, has implemented its "Energy Strategy 2050" with the goal of reducing electricity consumption in the industrial sector by 35% by 2050 compared to 2010, with the reduction of energy consumption by EMDS as a central element [2]. For Siemens, one of the major industrial companies, the use of innovative technologies and energy-efficient drive systems in manufacturing are core to their net-zero carbon footprint goal by 2030 [3]. But not only is the reduction of the energy efficiency an important goal within industry, but also the reduction of unplanned machine failures and an improvement of machines efficiency. By leveraging real-world data coming from the drivetrain, significant improvements can be almost guaranteed. Predictive Maintenance has the potential to increase machine availability by 10 to 20% and at the same time reduce the costs for maintenance by 5 to 10% [4].

1.1 Digital Drivetrain Value Chain

Siemens Motion Control, a business unit within Siemens Digital Industries is a supplier of products, systems, solutions, and services in the motion control market. A team focused on the digitalization of the industrial drivetrain implemented the digital drivetrain value chain, describing the end-to-end process for the digitalization of electrical drivetrains, from simulating in the digital world, to optimizing the real machine (see Fig. 1). The customer use cases addressed range from improving energy efficiency to increasing machine availability and performance. For that, especially the two tasks of connecting and optimizing the industrial drivetrain are mandatory. At first, data must be collected from motors, frequency converters, and the application itself. This can be achieved using sensor nodes attached to a motor, a gearbox, or the application, or sensor-less when talking about devices such as frequency converters or motors that have interfaces for data acquisition and detailed component data already implemented. Once the information is captured from the drivetrain, the data must be analyzed and visualized to gain transparency, analyze the operational data and derive actions to optimize performance, energy efficiency, or reduce costs.

Digital Drivetrain, a business segment within Siemens Motion Control, addresses the entire drivetrain value chain by offering integrated solutions that take care of connectivity and data acquisition (sensor-based or sensor-less) with software-as-a-service offerings for optimization, both on-premise or cloud-based, with use cases such as predictive maintenance, fleet management, or energy optimization. The solution portfolio ranges from easy to use plug and play systems to high sophisticated expert condition monitoring systems and respective signal analytics software with condition monitoring libraries.

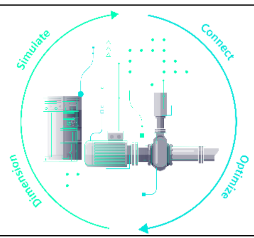

Fig. 1. Digital drivetrain value chain for the end-to-end digitalization of electrical drivetrains in industry

2 Digitalization of EMDS in industry

The following two examples demonstrate the practical application of the connect and optimize portfolio of the digital drivetrain value chain in real-world scenarios. These examples showcase how operators digitalization activities have successfully reduced energy consumption and improved efficiency and availability in different industrial settings.

2.1 Reducing energy consumption of factory infrastructure

The Siemens electric motor factory in Bad Neustadt is the leading Siemens factory for the production of main-, linear- and servo motors in induction and synchronous technology. Especially the topic of sustainable production is a focus area for the factory. During an assessment of the production infrastructure, an opportunity for improvement was identified in the energy efficiency of the cooling lubricant pumps. The pumps are responsible for supplying cooling lubricant to the machine tool systems of the production units. They operate continuously to ensure the circulation of coolant, which is essential for preventing the pipes from clogging.

To gain transparency about the pumps, the SINAMICS G120C frequency converters that drive the motors of the pumps were connected to an industrial PC (IPC), where Drive Connector SINAMICS and Drivetrain Analyzer Edge were installed for data acquisition and analysis of the drives parameters without the need of any additional sensors. As both applications were running directly on the IPC, no cloud connectivity was necessary, and thus everything was running in the factory itself on-premise. Continuous monitoring of real-time drive energy consumption data revealed that weekend energy consumption was approximately 90% higher than on average weekdays (see Figure 2), indicating that there was an error in the PLC code that was causing unnecessary energy waste.

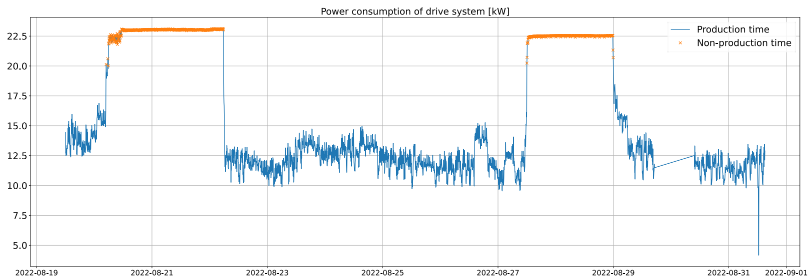

Fig. 2. Two peak plateaus (orange) highlighting weekend power consumption, which was around 90% higher than the weekday average

The pressure-controlled pumps were set to 4 bar during operation. On weekends, when the machine tools connected to the pumps were not operating, the cooling lubricant flowed past the machine tools, so there was no back pressure in the system. The pumps tried to compensate by increasing speed to bring the pressure back to 4 bar, which resulted in the drives running at maximum speed all weekend. The PLC code was adapted based on the insights gained from the drive data. Cyclic operation of the pumps was introduced during the weekend (see Fig. 3), reducing energy consumption, the costs for energy and potential wear and tear of the equipment within the plant. Cyclic operation, where the pumps are only turned on for fifteen minutes every two hours, is necessary to keep the coolant lubricant moving and prevent clogging and bacterial growth in the pipes.

$$ROI = \frac{Gain\ from\ Investment - Cost\ of\ Investment}{Cost\ of\ Investment} = \frac{9.500\ € - 2.900\ €}{2.900\ €} = 228\ \% \qquad (1)$$

Through the implementation of digitalization efforts focused on the industrial drivetrain, the factory was able to gain transparency into energy consumption, associated costs, and progress on key performance indicators (KPIs) for the energy efficiency of the monitored assets. The investment in hardware and software amounted to a total of 2,900 €. As a result of these efforts, the factory managed to save 43 MWh of electrical energy per year, corresponding to 9,500 € of saved energy annually.

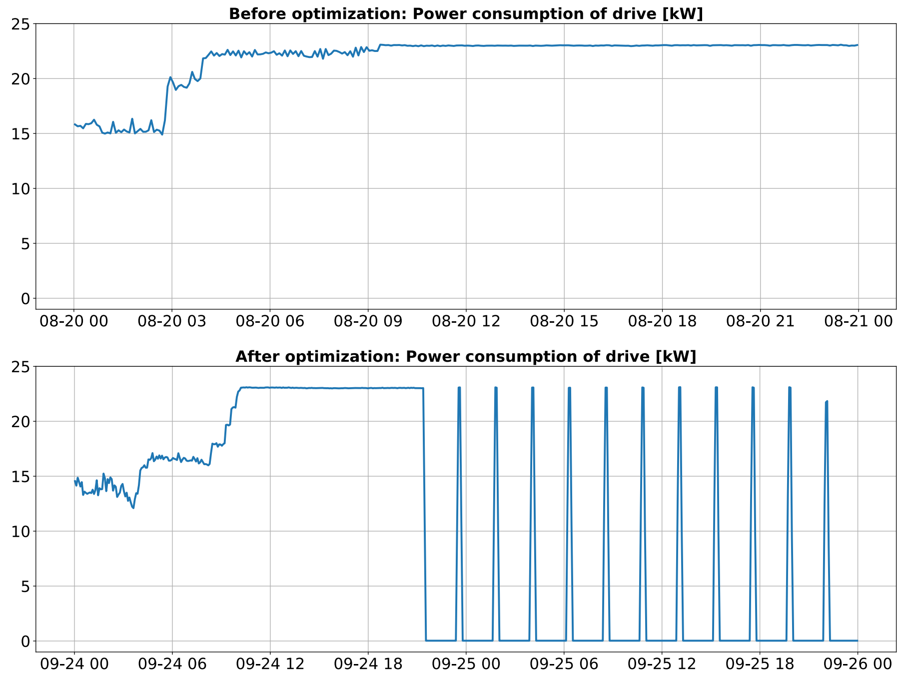

Fig. 3. Comparison of the power consumption of the drive in kW before and after switching to cyclic operation of the pumps

2.2 Digital transformation of public infrastructure

Returning purified wastewater to the environment is a complicated but necessary process that protects the natural environment and controls the potential spread of waterborne diseases. Scottish Water is a leading provider of water and wastewater services in Scotland. For them, especially the wastewater treatment process is highly energy intensive, making up 53% of total energy consumed and accounting for 71% of their carbon footprint [5].

With the help of digitalization solutions, their goal was to reduce costs, the risk of downtimes and decrease the environmental impact of their operations. Within a wastewater treatment plant, two types of EMDS are being used. Aerators, used for increasing dissolved oxygen levels in the water tanks, and screw pumps, used for dewatering sludge. Scottish Water equipped the motors driving the aerators with the plug and play cloud-based condition monitoring sensor node SIMOTICS CONNECT 400. The motor of the highly critical screw pump, as well as the gearbox and the screw pump itself, were monitored using sensors connected to the CMS1200 condition monitoring system to obtain high quality raw data from the application. The potential for operational optimization was identified primarily for the aerators. To reduce the energy consumption of the aerators, Scottish Water decided to drive the motor with a frequency converter, which kept the aerator motors running below their rated speed of 1,500 rpm. However, with the help of Drivetrain Analyzer Cloud, a cloud-based analytics application used to make sense of the data coming from the sensor modules, it became clear that by reducing the speed of the motors, the motors were operating closer to or at their resonance frequency. Vibration levels were up to five times higher than normal, resulting in increased wear that was slowly but surely damaging the motors and the applications themselves (see Fig. 4).

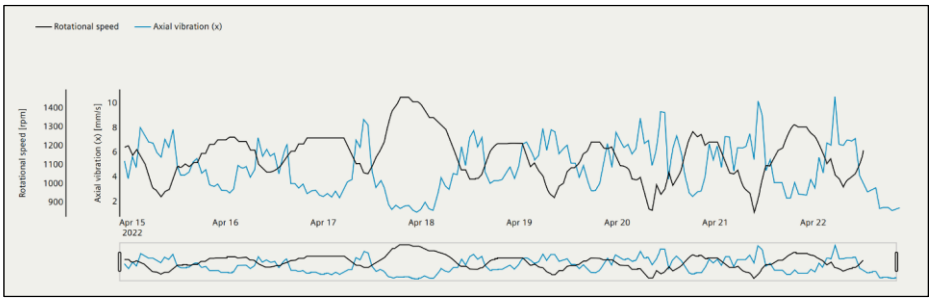

Fig. 4. Drivetrain Analyzer Cloud detected a system resonance with high vibration levels when the aerators were running at reduced speeds

Monitoring of vibration levels showed the negative effects of the reduced speed caused by the frequency converter. The reduced energy consumption resulted in higher vibration levels and decreased equipment lifetime. By returning the speed back to the specified speed of the motors driving the aerators (see Fig. 5), Scottish Water was now able to find an overall optimum operating point and optimize the total cost of the whole process, including energy cost, maintenance efforts, risk, and possibly earlier replacement. By using the information from the condition monitoring sensors, Scottish Water will easily be able to increase the overall life of the equipment by up to 15% and reduce the cost of responsive asset repairs by 10%, demonstrating that when considering the impact of digitalization efforts, it is important to consider not only the primary effects, such as energy consumption, but also the secondary effects, such as maintenance effort or equipment lifespan.

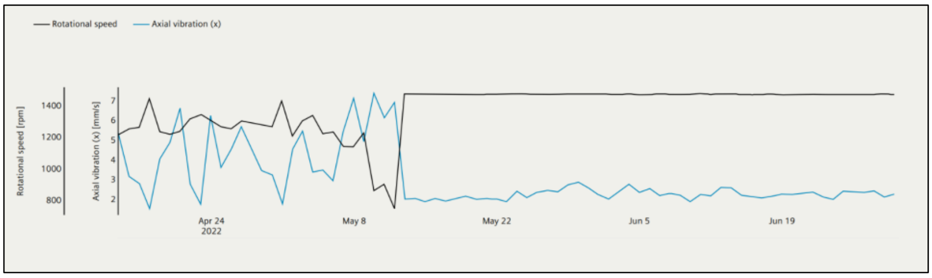

Fig. 5. The aerators are now being operated at 1,500 rpm to minimize vibration levels and thus the risk of unplanned outages.

3 Conclusion

This paper highlights the importance of digitalization efforts around EMDS, the primary consumer of electricity in industry. Two real-world examples from different industries were presented to showcase the significant impact of digitalization measures on reducing energy consumption, lowering maintenance costs, and eliminating the risk of downtime. By consistently collecting and analyzing data from EMDS, companies can gain transparency and make more informed decisions to reduce energy consumption and optimize efficiency of their drivetrains. The paper also emphasizes that digitalization can have a significant positive impact within just a few months, requiring a relatively small up-front investment and thus resulting in a high return on investment. As a result, digitalization is considered essential for almost every EMDS.

References

1. Waide, P., Brunner, C.: Energy-efficiency policy opportunities for electric motor-driven systems. International Energy Agency, 11 (2011).
2. Zuberi, M., Tijdink, A., Patel, M.: Techno-economic analysis of energy efficiency improvement in electric motor driven systems in Swiss industry. Applied Energy, 205 (2017).
3. Siemens AG, https://assets.new.siemens.com/siemens/assets/api/uuid:f738dada-509b-4ecc-9a2e-92279f0367e8/PR2015090345COEN.pdf, last accessed 2024/02/27.
4. Coleman, C., Damodaran, S., Chandramouli, M., Deuel, E.: Making maintenance smarter: Predictive maintenance and the digital supply network. Deloitte University Press (2017).
5. Scottish Water, https://www.scottishwater.co.uk/About-Us/News-and-Views/2022/06/170622-Scottish-Water-Intelligent-Assets-Helping-Improve-Service-and-Protect-Environment, last accessed 2024/02/27.