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A study on electric energy consumption of manufacturing companies in the German industry with the focus on electric drives

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Abstract

The German industry consumes almost 50 percent of the total electricity produced in Germany. Upon breaking down the industry in terms of electrical energy consumption, it is shown that more than 70 percent of electricity, required in the industry, is used to operate electric drives. Given the huge rise in energy prices, especially in Germany, coupled with the lack of information and data on electric motors, the need to make the power consumption of electric drives transparent became more important than ever. This paper concentrates on the investigation of the electricity consumption of electric drives in the manufacturing plants. The focus lies on the various industrial applications of electric drives along with the identification of the main electric power consumers in the German industry.

In order to create transparency regarding the energy consumption, a study was carried out in the second quartile of 2014. A number of randomly selected German manufacturing companies were sent an online questionnaire. After eliminating the incomplete answers, 210 answers were used as the database.

The study on the real distribution of electric power consumption in the German manufacturing industry is presented for the first time in this paper. The study shows that most of electric power consumption can be allocated to a few applications in the industry. The dominant applications are compressed air systems, pumping systems and air conditioning systems. Other significant motor applications are cooling systems and machine tool. This paper rounds off by presenting the main study results as well as future research potential examined during this investigation.

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Keywords: Electric drives; Sustainable manufacturing; Energy effciency; Energy consumption

1. Introduction

Since the start of the industrialization the economies of the world have put their emphasis on making production efficient, reliable and cheaper. Automation played a great role in achieving this goal. Industries now depend greatly on the automated production because through automation it is possible to produce more standardized products faster with higher quality. Automation itself depends on the continuous availability of energy. In the past decade the energy price doubled making the prices of almost everything to increase [1]. Currently the energy prices in Germany in comparison to the other European countries, USA and China are relatively high. Germany is currently going through an energy transition by putting emphasis on the renewable energies and shutting down the nuclear power plants. This transition would cause a gap between the

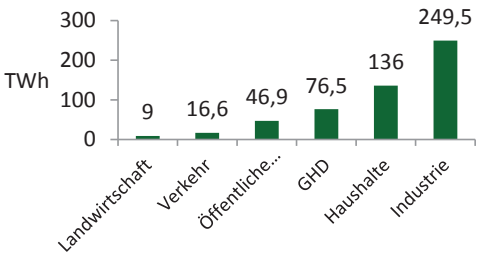

Fig. 1. Electrical energy consumption in Germany

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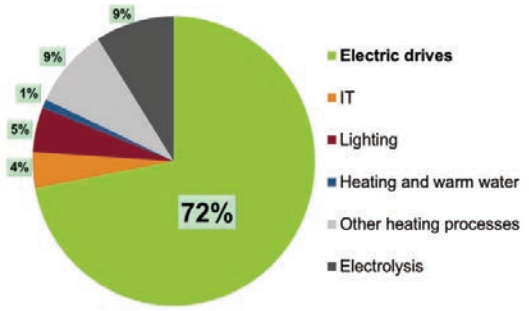

Fig. 2. Electrical energy consumption in the German industry

supply and demand of energy.

This gap can be filled by taking measures like importing energy, increasing the energy production through fossil fuels and increasing the energy share of renewable energy resources. Another very important approach that can help fill the demand and supply gap is the efficient use of energy.

Fig. 1 shows that the German industry consumes almost 50 percent of the total electricity produced in Germany. Upon breaking down the industry in terms of electrical energy consumption, it is shown in Fig. 2 that more than 70 percent of electricity, required in the industry, is used to operate electric drives [2].

It is very important to make this big portion transparent in order to focus on the relevant applications for optimization. Currently there is very little information available on the electricity consumption of industrial applications, which makes energy management difficult.

Given the huge rise in energy prices, especially in Germany, coupled with the lack of information and data on electric motors, the need to make the power consumption of electric drives transparent became more important than ever. However the major consumers of electricity are not clearly known. Therefore the biggest challenge for the industry is to figure out and pinpoint the applications and systems which require enormous amount of energy. The objective is to use the Pareto 80-20 rule and optimize the most relevant drive systems first.

2. Methodology

As shown in Fig. 3, the data required for the estimation of the electrical energy consumption of industrial plants is principally collected through interviews with experts from industry and a questionnaire which was sent to various companies from all the major branches in Germany. Out of all the sent questionnaires 210 complete answers were received. The answers were then evaluated. Additionally more data was gathered through our own calculations and through specific parameters from other research contributions.

With regards to the research contributions, in the first step the power consumption of electric drives in the German industry is considered. Several different scientists argue that the structures within an industry sector in Europe are very similar and thus deviations can be disregarded. Hence in case of lack of information on the German industry, European industry can be considered for further research [3]. Furthermore the sectors trade, commerce and services could be taken into account for the required research data. Although this is a different sector, therefore it should be decided whether conclusions from this sector can be drawn on the industry.

Moreover, this study focused only on electric motors with a power output of more than 0.75 kW for the investigation. Electric motors with a power range of up to 0.75 kW are mainly used in the household instead of industry.

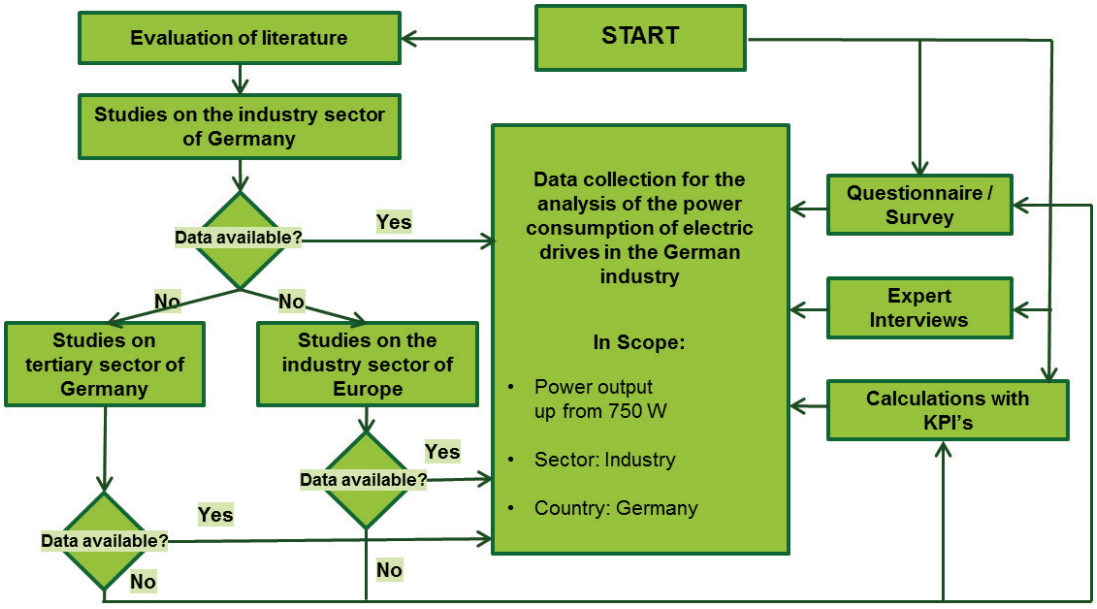

Fig. 3. Data Collection Process

3. Energy consumption in German Industry

To make the energy consumption transparent the first step was to figure out the consumption of electricity in different industry sectors.

Fig. 4 shows the precentral consumption of electric energy by the drive systems in ratio to the total electrical energy consumption of a given industry sector.

3.1. Energy efficiency of electric drives

Currently in commercial, industrial and institutional facilities in Germany, there are about 35 Million electric motors in operation predominantly in the range of 0.75 to 375 kW [4]. Approximately 85 % of the electric drives in use have a power output from 0.75 to 7.5 kW [5]. Despite this high portion, electric motors in this power range are not the main power consumers in the industry. The large motors are responsible for the high industrial electricity consumption. Three-phase asynchronous motors with squirrel cage rotors correspond to more than two thirds of all produced electric motors in Germany. The reason is their simple and rugged design [6]. Few of the installed motors is Germany had an efficiency class IE2 or higher. However, due to the new regulation of the European Commission in 2009, in the near future IE2 and IE3 electric drives will dominate the market.

Variable speed drives are mainly used in the mechanical engineering and food industry. It is predicted that for about half of all the electric drives a speed control is economically beneficial. Thereby using high efficiency motors can reduce the energy consumption up to approximately 3% whereas using a frequency inverter can reduce energy consumption of the motors by approximately 15% [7].

3.2. Energy Consumption by electric drives

It is shown in Fig 5 that the compressed air systems, pumps and air conditioning are the dominant applications in regards to energy consumption by the electric drive applications. Pumps show especially in the chemical industry and the paper industry a very high power consumption. The immense power consumption in the paper industry can be attributed to the enormous demand of water in paper manufacturing and the high number of pulp pumps. The energy consumption of fans can be divided into systems for air conveyance as well as for cooling, drying and extraction in the industrial processes.

Furthermore, compressed air systems, refrigeration systems as well as the spindle drive and the axle drive systems of machine tools consume a large amount of energy. The approximately 62.000 compressed air systems, in Germany, are used in various industry sectors [8]. The branches that have huge compressed air demand are the manufacturers of rubber and plastic products, glass and ceramics, processing of mineral products, mechanical and automotive engineering. Common areas of applications are drying, spraying (painting), blowing, positioning and transporting the work items. Moreover, in two-third of all compressed air systems an electric motor with a power output of up to 110 kW is installed and in the rest of the cases the power range of the installed motors is between 110 kW and 300 kW. The group of the compressed air systems up to 110 kW is responsible for about three-quarters of the electricity consumption [9].

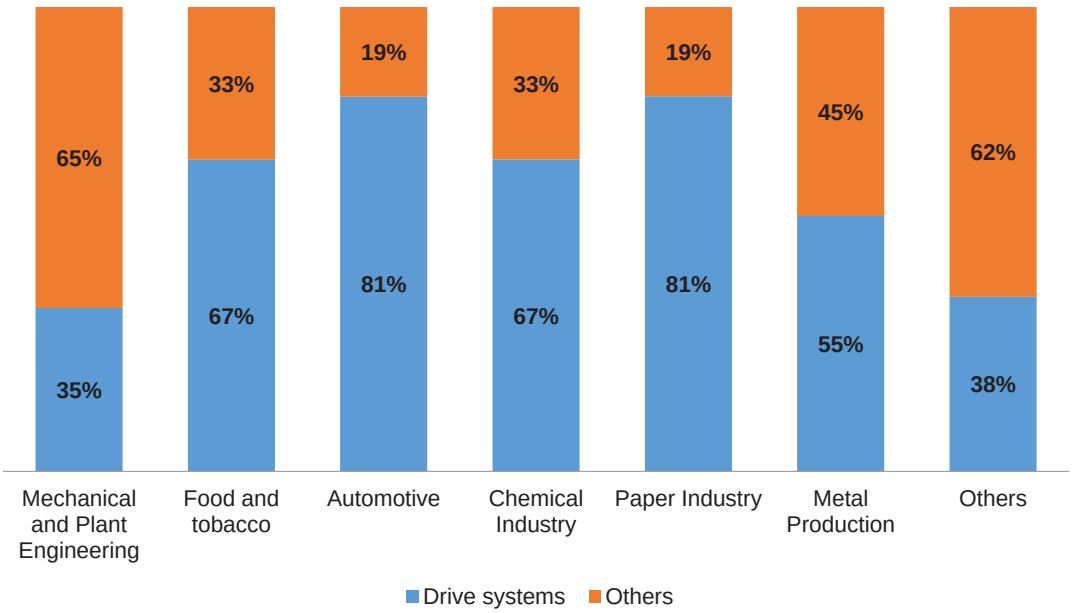

Fig. 4. Ratio of electricity consumption of drive systems to total electrical energy consumption

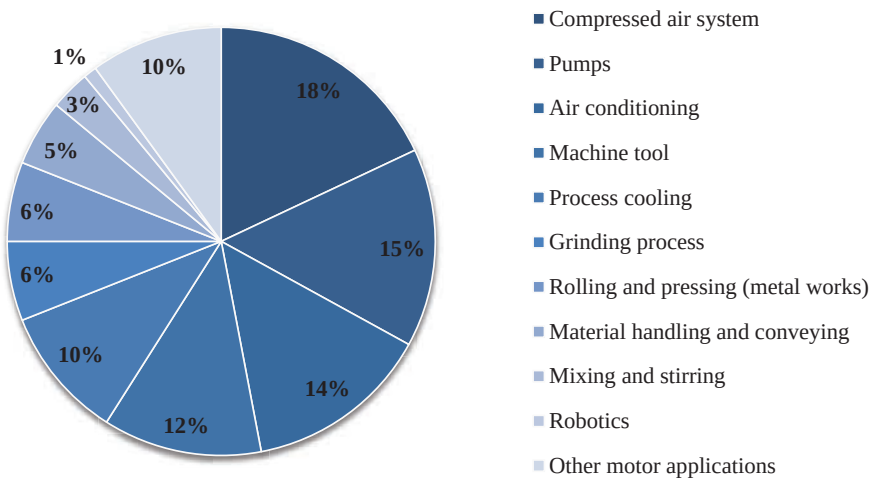

Fig. 5. Electrical energy consumption of drive systems

In addition high-pressure compressors for providing "Cryorefrigeration" to produce different basic chemicals such as ammonia, chlorine and oxygen alone make up a major part of the total power consumption in the chemical industry; therefor this proportion is significant for the whole German industry [9]. Refrigeration facilities exist in numerous industrial sectors. An area of refrigeration technology with growing relevance is to provide air-conditioning to offices and production rooms. Another area of refrigeration technology is to provide cooling for different manufacturing processes and storage of goods. The electricity consumption for refrigeration applications is strongly influenced in various industries. While in some sectors little or no refrigeration is used. Overall, in Germany over 120 million refrigeration systems are in operation, of which the vast majority is driven electrically [10]. Approximately 660.000 are used in the industry whereas for the air-conditioning of buildings about 2.3 million systems are in use [11].

Overall, the industry in comparison to all other consumption types observes by almost 50 % the highest share of installed refrigerating capacity, followed by public institutions and hospitals. In the food industry, mainly smaller facility sizes are installed, while in the chemical sector fewer facilities with a higher capacity are used. For industrial processes in the chemical sector, large refrigeration systems with a power output above 1 MW are often installed. The "Compression cooling process" is the most important process in the air-conditioning and refrigeration technology and in more than 90 % of the cases, a compression refrigeration system is used [12].

Typical industries, in which machine tools are used, are the automotive, mechanical engineering and metal processing. About 40 % of the produced machine tools in Germany are used in the automotive sector. The spindle drive and the axle drive systems of machine tools correspond to about 33 % of the total power consumption of a machine tool. Applications such as the milling of round logs cement and lime as well as rolling and pressing in the field of metal production compose about 5 to 6 % of energy proportion, which can be justified by the relatively few processes. However, in the whole industry these process-specific applications consume considerable proportion of energy.

Conveyor systems have a small proportion of the total electricity consumption within electric motors. This is based on the fact that approximately 80 % of the used electric drives in conveyor systems contain an output of power of up to 1 kW. The mixing and stirring technologies which are mainly used in the chemical industry consume a small amount of energy as compared to some of the other systems mentioned above. Industrial robots are vastly used in the manufacturing industry. According to some estimates up to 50% of the workload is executed by the robots in the automotive sector. Nevertheless, according to the study shown above the absolute electrical energy consumption of robots adds up to approximately 1% of the total electrical energy consumption of the Germany industry.

4. Conclusion

The analysis shows that the most electric power consumption by the electric drives in the industry can be allocated to a few applications. The dominant applications are pumping systems, compressed air systems and air conditioning systems. Other significant motor applications are cooling systems and machine tool.

By concentrating on the applications named above and analyzing these systems in detail, a good portion of energy wastage could be reduced. It is also very important for the industry to know the details about their main energy consumers, so that they may improve their carbon footprint in addition to reducing their energy costs. Furthermore the manufacturing compa-

nies may enhance their market competitiveness by becoming more efficient and green.

This paper has provided the necessary information for the companies to take the first step towards sustainable and energy efficient production.

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