**Lappeenranta University of Technology**
School of Business and Management
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# INDUSTRY SPECIFIC LIFECYCLE SERVICES FOR PROCESS CRITICAL MOTORS

**Master's Thesis 2016**

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**ABSTRACT**

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**Subject of the thesis:** Industry specific lifecycle services for process critical motors

**Year:** 2016 **Place:** Vantaa

Master's Thesis.
Lappeenranta University of Technology
School of Business and Management
Industrial Engineering and Management

83 pages, 8 figures, 9 tables and 2 appendix

Examiners: Senior Lecturer Jorma Papinniemi
Professor Tuomo Uotila

**Keywords:** Industrial service business, lifecycle services, effectiveness, availability, maintenance

This Master's Thesis examines industrial service business and studies how Global Technical Support Center Finland, part of ABB Oy, can develop its lifecycle services based on availability related customer needs. Focus is in three most business critical industry segments OGP (Oil, Gas and Petrochemical), Power and Metals.

The research was conducted as a qualitative case study, including literature review and empirical part. The literature review explores industrial service business, product lifecycle services and related customer needs, product effectiveness and maintenance. This study contains also characteristics of constructive research. Primary material was gathered through internal and external interviews. Both theme and semi-structured interviews were performed.

This research has shown that customers have different needs depending of the industry segment where they operate. Most remarkable differences are related to maintenance schedules. The main outcomes of the study are the industry specific lifecycle service models that combine company recommendations with customer specific needs. Other development needs were related to proactivity, condition based monitoring, information sharing and lifecycle estimations.

**TIIVISTELMÄ**

**Tekijä:** Anna Ettanen

**Työn nimi:** Industry specific lifecycle services for process critical motors

**Vuosi:** 2016 **Paikka:** Vantaa

Diplomityö.
Lappeenrannan teknillinen yliopisto
School of Business and Management
Tuotantotalous

83 sivua, 8 kuvaa, 9 taulukkoa ja 2 liitettä

Tarkastajat: Tutkija-lehtori Jorma Papinniemi
Professori Tuomo Uotila

Hakusanat: Teollinen palveluliiketoiminta, elinkaaripalvelut, tehokkuus, käytettävyys, kunnossapito

Tämä diplomityö tarkastelee teollista palveluliiketoimintaa ja tutkii, miten ABB Oy:hyn kuuluva Global Technical Support Center Finland voisi kehittää elinkaaripalvelujaan, käytettävyyteen liittyvien asiakastarpeiden pohjalta. Tutkimuksessa keskitytään kolmeen liiketoiminnan kannalta kriittisimpään teollisuussegmenttiin, jotka ovat OGP (Oil, Gas and Petrochemical), voimantuotanto ja metallintuotanto.

Tutkimus toteutettiin laadullisena tapaustutkimuksena. Kirjallisuusosiossa keskitytään teolliseen palvelu-liiketoimintaan, elinkaaripalveluihin sekä niihin liittyviin asiakastarpeisiin, käytettävyyteen sekä kunnossapitoon. Empiirisen osuuden materiaali kerättiin pääosin sisäisten ja ulkoisten, puolistrukturoitujen haastattelujen ja teemahaastattelujen avulla.

Tutkimuksessa havaittiin, että asiakkailla on erilaisia tarpeita riippuen teollisuussegmentistä, jolla he toimivat. Suurimmat erot liittyvät huoltoaikatauluihin. Tutkimuksen päätuotos ovat teollisuuskohtaiset elinkaaripalvelumallit, joissa yhdistyy yrityksen suositukset ja asiakastarve. Muut kehityskohteet liittyivät proaktiivisuuteen, mittaavaan kunnossapitoon, tiedon jakamiseen ja elinkaariarvioihin.

**FOREWORD**

This Master's Thesis is made to Global Technical Support Center Finland. I want to thank Ilpo Värelä and Sami Karttunen for providing me this interesting project and for guiding me to right direction. As well, I want to thank many of my other colleagues for the support during my whole studies. Many thanks to Senior Lecturer Jorma Papinniemi for guidance during this project.

I am grateful for the support that I got from my sisters and friends during this project and school. Especially I want to thank my parents and friend Hanna for encouraging me to continue in the moments when it was challenging.

Finally, I want to thank Matteo for reminding me that there are so many other important things in life and for taking my thoughts away of studies when I needed it most.

Vantaa, March 12th, 2016

Anna Ettanen

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## LIST OF ABBREVATIONS

ABB - Asea Brown Boveri Inc

BU - Business Unit

Exp - Explosion proof

GTSC - Global Technical Support Center

OEM - Original equipment manufacturer

OGP - Oil, Gas and Petrochemicals

PG - Product Group

VSD - Variable speed drive

# 1 INTRODUCTION

The purpose of this Master's Thesis is to examine industrial service business and study how company can develop its lifecycle services based on customer needs. In this chapter the background of the theoretical part is discussed, then research aim and limitations are defined and finally the structure of the thesis is presented.

## 1.1 Thesis background

Economic numbers show that service business and after-sales markets are growing and the potential has been recognized by companies in different industry segments (Bundschuh & Dezvane 2005; Cohen at al. 2007). A few reasons behind this trend can be identified. Deregulation and increased global competition force manufacturers to find new business possibilities. New possibilities were find by adding services in core business and by utilizing constantly growing installed base. (Davies 2004; Fang et al 2008; Henkel et al. 2004.)

Companies need to offer right services at right service level. Services must meet the customer needs. This forces the companies to understand the environment where the customers operate, and recognize their specific needs. These needs have to be segmented and understood. (Bundschuh & Dezvane 2005; Markeset & Kumar 2003.) Lifecycle services aim to help customers to focus on their core competences by improving product availability during its whole lifecycle (Henkel et al. 2004; Ulaga & Reinartz 2011).

This case study is made for Global Technical Support Center Finland (GTSC FI), a part of the global motor and generator manufacturer Asea Brown Boveri Inc (ABB). GTSC operates in after-sales markets and offers lifecycle services such as maintenances, repairs and spare parts and replacement machines. Case company will be introduced in the chapter 4.

The subject of this Master's Thesis is a very well-timed since it is related to the case company's strategy. It is part of the process to develop product and industry specific lifecycle management and to increase resources to ensure superior customer process uptime.

## 1.2 Research aim and limitations

The target of this Master's Thesis was to study how a case company can develop their lifecycle services based on customer needs and find out is there a need for industry specific lifecycle service models.

The main research question is:
*How to develop industrial lifecycle services based on customer needs?*
This question will be observed with these sub-questions:
*What are industrial service business and lifecycle services?*
*What needs customers in different industry segments do have?*
*What kind of lifecycle service models company will have?*

In this research, focus is in business-to-business markets. Company is acting all around the world but this research is made only for the use of Global Technical Support Center Finland (GTSC FI). Only three most business critical industry segments are observed. They are OGP, Power and Metals industries. Only process critical synchronous motors and diesel generators, in their usage lifecycle phase, are recognized. Focus is in availability related customer needs.

Matters related to the lifecycle information management are outside of this research. Focus is not either in planning new lifecycle service products.

### 1.3 Thesis structure

This research consists of theoretical and empirical parts. First in the theory, the characteristics of industrial service business and lifecycle services will be described. Then, service business related customer needs will be discussed. Finally, terms related to the product effectiveness and issues related to the maintenance will be described in general state.

In the empirical part, case company and its lifecycle services are first introduced. Then, characteristics of the chosen industry segments are described and customer specific service needs will be introduced and compared. Finally, in the discussion part, customer specific needs are analyzed from the base of literature review and recommendation for the industry specific lifecycle service models are given.

# 2 RESEARCH CONTEXT AND LITERATURE REVIEW

The most relevant, issue related literature is presented in this chapter. First, the characteristics of the industrial service business and product lifecycle services are defined. Then the lifecycle service related customer needs are discussed and terms related to product effectiveness are explained. Finally, at the end of the chapter, the issues related to maintenance are presented in general state.

## 2.1 Industrial Service Business

Product manufacturers have been suggested by most of the management literature to integrate services in to their core production activities (Oliva & Kallenberg 2008). Nowadays service products are big part of the business, in many manufacturing companies. The potential of after-sales markets has been recognized by manufacturers in different industries. (Bundschuh & Dezvane 2005.) Also economic numbers show that after-sales service markets are growing and becoming even larger than product markets in some industries (Cohen et al. 2007).

For example, according to study made by German Insititute for Economic Research, product related services account over 18% of the total turnover of the German discrete part manufacturing industry. Percentage is even higher in some other countries. (Aurich et al. 2006.)

There are three different stages that can be described when designing a product service system. First stage refers to the traditional manufacturers with focus on providing physical products to the customers. In next stage, manufacturer extends its business to services and in last stage, manufacturer provides highly individualized solutions to its customers. Product core is manufactured at a specific point in time, while corresponding services are realized throughout the product lifecycle according to demands of customers. (Aurich et al. 2006.)

Several reasons behind the transition toward services can be identified. Service product thinking has increased since the beginning of the 1990s. Deregulation and market globalization have resulted in increased competition and transparency. This period can be seen as the beginning of a massive transition from manufacturing companies to performance providers. (Henkel et al. 2004.) Intense global competition forces manufacturers to shift to service offerings (Fang et al. 2008). According to Davies (2004), stagnating product demand and the strong East Asian competition in high-volume manufacturing, in the beginning of the 1990’s, pushed companies to find new business possibilities from the services. On the other hand, constantly growing installed base has created new business needs for services. (Davies 2004.)

Service business can benefit companies and their customers several ways. Many companies have added services to their offering by means of better competitiveness and performance. (Fang et al. 2008.) By offering technical services, company achieve chance to differentiate their products from the similar rival products (Aurich et al. 2006). Services are intangible in their nature thus less imitable than physical products and providing more sustainable competitive advantage. Focusing on services also provide opportunities to generate revenue from the existing installed base. (Oliva & Kallenberg 2008.) With services, industrial customers can achieve higher productivity by means of higher equipment uptimes and longer equipment life time (Aurich et al. 2006).

As a consequence for the benefits, some challenges can be also identified. Even potential of the after-sales service markets has been proven, many companies are still hesitating. One reason is that services are more difficult to manage than manufacturing of products. For example, customer repairs related demands are difficult to predict. (Cohen et al. 2007.) Most manufacturers have a separate service department that is responsible for delivering services such as suppling expert assistance and spare parts. Too often these departments are uncomfortable with the intense service expectations of their customers. (Markeset & Kumar 2003.)

Relationship between service department and customer stands until the end of the machine’s life time. Product support strategy should be aligned with customer’s needs. It is necessary to analyze customer’s maintenance organization, location, level of competence and culture.

Customer's operational environment, operation and maintenance goals and strategies need to be understood, to assure optimal performance and customer satisfaction. (Markeset & Kumar 2003.)

## 2.2 Product Lifecycle Services

Management of the whole lifecycle and related services has become an important factor in industry (Sääksvuori & Immonen 2004). Recent literature on business strategy emphasizes that manufacturers have started to build on their manufacturing base and shift to provide services that are related to the whole lifecycle of the product (Davies 2004).

Companies that have taken the step to the after-sales service market, have find new business opportunities and they are interested to offer wider range of value added services to their customers. Target is to cover the whole product lifecycle which can vary from the years to even more than 30 years. (Sääksvuori & Immonen 2004.)

Here below are typical lifetime targets for few power electronic applications (Wang et al. 2014):

- *Aircraft* 24 years (100,000 hours of flight operation)
- *Automotive* 15 years (10,000 operating hours, 300,000 km)
- *Industry motor drives* 5–20 years (60,000 hours at full load)

- *Railway* 20–30 years (10 hours of operation per day)
- *Wind turbines* 20 years (24 hours of operation per day)
- *Photovoltaic plants* 5–30 years (12 hours per day)

When designing a product service system, two different lifecycle perspectives can be drawn. From the view of customer, product lifecycle consists of product purchasing, usage and disposal. (Aurich et al. 2006.) From the view of manufacturer, lifecycle can be divided into four stages. These stages are system design, production operations, field operations and retirement. (Hatch & Badinelli 1999.) The product core must be optimized by this last lifecycle perspective (Aurich et al. 2006).

Product design determines the configuration and the reliability of the product and components and the goal is to build a product that performs all functions successfully throughout entire lifecycle. Performance requirements that depend upon reliability are not specified explicitly by most of the customers. (Hatch & Badinelli 1999.) The main target of the product lifecycle services is to ensure best possible reliability for the product during its whole lifecycle (Ulaga & Reinartz 2011).

After production, system is used by the customers and maintenance and support has a major role. This stage determines the competitiveness of the product in the market. (Markeset & Kumar 2003.) Support needs depend on parameters such as reliability and maintainability. Spare parts, maintenance and warranty optimization must be considered at the time of design and without a proper lifecycle approach it is not possible. (Lad & Kulkarni 2008.)

The scope of the support has broadened over the years and it includes such aspects as installation, commissioning, repair services, maintenance, spare part supply, modifications, warranty schemes and training. Product support can be classified as tangible or intangible support as well as planned and unplanned support. Tangible support includes exchange of physical parts and intangible support refers to non-physical support such as training and online support. Planned support is related to preventive maintenance and installation. Therefore unplanned support is related to corrective maintenance activities which are often inconvenient, costly and time consuming for all parties involved. (Markeset & Kumar 2003.)

The target is to consider customer’s needs but at the same time find optimum balance between realization time, quality and cost. The needs are highly specific since there are multiple possibilities for using a specific product depending on the corresponding business environment of the customer. (Aurich et al. 2006.) For example environmental conditions such as temperature, humidity, dust, maintenance and operational personnel training have considerable influence on the product reliability (Markeset & Kumar 2003).

By exploiting customization potentials of product and service, ability to fulfill highly individual customer demands increases (Aurich et al. 2006). Many service providers have started to offer total performance guarantee for their products, which means that they are taking the full responsibility for the operation, maintenance and support of the system (Markeset & Kumar 2003).

## 2.3 Customer needs in service business

Many companies have erroneous assumption that customers care only about price but in reality it is proven that companies can fulfill most of the customer requirements only by focusing to response times, parts coverage, after-hours availability and add-on services (Bundschuh & Dezvane 2005).

There are critical success factors that are common to all service providers. These include responsiveness to customer request, understanding of customer needs, reliability, technology and people. (Henkel et al. 2004.) Customer satisfaction is decided by the total value received and by the quality of the interaction and relationship experience, throughout the lifecycle of the product (Markeset & Kumar 2003). By creating value to the customers, service providers will increase their capability and their resource base to identifying opportunities (Henkel et al. 2004).

Service business is a powerful tool to increase customer retention and to generate new revenues. Customer understanding, customer integration and ability to create measurable economic benefits for service customers is one of the success factors for service providers. (Henkel et al. 2004.)

Understanding of customer's needs throughout the customer lifecycle and choosing of the right areas to play in, is highly important for service provider (Henkel et al. 2004). Companies must provide right services at right service level and understand customer needs (Bundschuh & Dezvane 2005). Companies have to understand how value is created in through the eyes of the customers and it is important to gain detailed understanding of the activities that customer performs in using and operating product during its lifecycle (Davies 2004).

Service offering must be suitable for the customer needs and customized to the certain point where it can be still easily managed. Customer service needs must be segmented and understood. (Bundschuh & Dezvane 2005.) Close dialog with customer allows the company to identify customer's business needs and develop the capabilities to offer services that are linked to the customer's priorities (Davies 2004).

Customers can be roughly divided to three different groups according to their needs. Risk avoiders want to avoid big bills but care less about other issues. Basic-needs customers want standard level of service including basic inspections and prescheduled maintenance. Hand-holders require higher service levels with quick and reliable response times and they are ready to pay for privilege. (Bundschuh & Dezvane 2005.)

Service products offer opportunities to the customer to improve reliability, efficiency and availability and thus possibility to focus on their core competences (Henkel et al. 2004). Customers highly appreciate reliability and low costs. Companies need to deliver products with documented and predictable quality, reliability, supportability and maintainability. (Markeset & Kumar 2003.)

It is almost impossible to design product without a need for maintenance hence products need to be designed for effective and efficient maintenance and support (Markeset & Kumar 2003). Some customers expect a threshold level of inspections and maintenance while some of them are ready to invest for more frequent or additional services such as remote monitoring (Bundschuh & Dezvane 2005).

## 2.4 Product effectiveness

According to Pecht (2009) the ultimate goal for any product or system is that it performs intended functions as cost-effectively and well as possible. Effectiveness can be defined as the ability of a product to meet an operational demand when operated under specific conditions. Product is effective if it carries out the intended function well. (Pecht 2009.) Service support has become important factor to enhance product effectiveness and prevent unexpected downtime. Right level of spare parts in site and right maintenance level can increase availability of product by minimization of the product downtime for repair and service. (Ghodrati & Kumar 2005.)

For many long life time products, the highest costs come from the operating, supporting and maintaining. Many decisions that are made in design phase will affect the whole life time of the product. (Pecht 2009.) Industrial products have become more complex which makes their availability more critical. Lack of incomplete support cause unexpected downtimes which leads to unexpected losses. (Ghodrati & Kumar 2005.)

Product effectiveness is influenced by how product is used, how it is maintained and by its design and production processes. Product can be used continuous or in cyclic operation. Products that operate continuously are maintained after failure occurs and any failures reduce effectiveness. Cyclically operated products are maintained when operation is not critical. Potential failures can be prevented with a planned preventive maintenance program. (Pecht 2009.)

Failures in design and delivery processes can lead to failures in product. However also operational environment and how the product is used affect to failures. The underlying causes of failures can be attributed to physical flaws such as corrosion and overload, error in work processes such as maintenance and operation and to errors in user perspectives and attitudes. (Markeset & Kumar 2003.)

There are several components of product effectiveness (Pecht 2009). They are represented in figure 1.

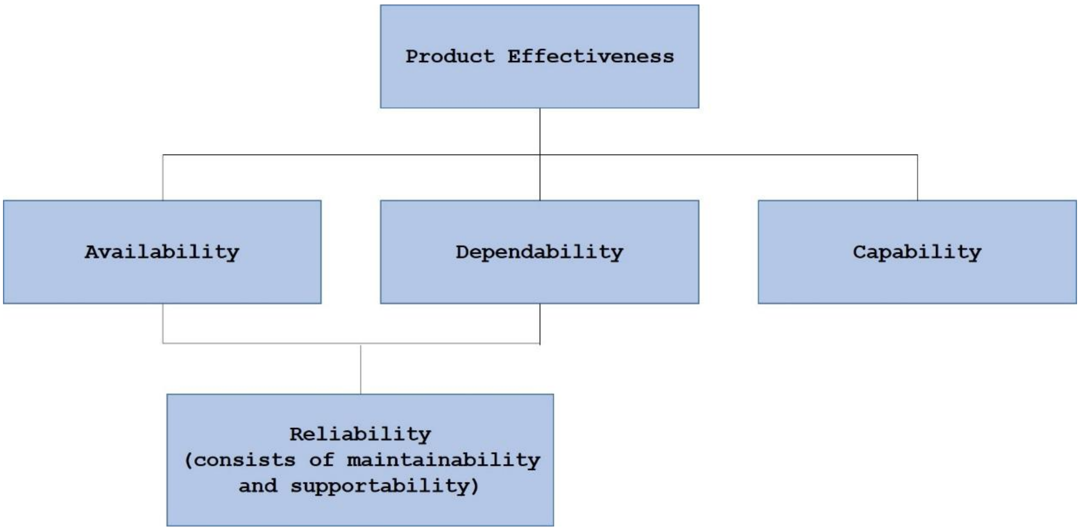


***Figure 1. Components of product effectiveness***

These components are described in the following chapters. The focus in this Master's Thesis is in availability and reliability.

### 2.4.1 Capability

Capability describes how well a product accomplishes the task to which it is assigned. It is a state-dependent measure. Normally capability is zero if product is not operating. However, that is not always the case. Pecht (2009) gave an example with a tank. A tank may not be able to fire but enemies who sees tank are not likely aware of its state and tank might still accomplish its protective mission. The units of measuring the capability depend on the product and on tasks that it have. It can be related directly to product output, an ordinal scale or probabilities. (Pecht 2009.)

### *2.4.2 Dependability*

Dependability can be defined as a measure of the product’s condition during the performance of its function. Most of the products can be in different states during their operations. Dependability measures the likelihood for the states. For example product with 10 components has 1024 possible states. Dependability concept is often used to quantify effectiveness. (Pecht 2009.)

Dependability encompasses required attributes of a product assessed by reliability and maintainability or safety in order to manage with the chain of fault-error-failure threats of an operational product by combining factors related to fault prevention, fault tolerance and fault forecasting (Morel et al. 2009).

From the analytical view dependability refers to how the product transitions from one state to another. For example failure will transit product from one state to another less capable state. If repair is possible during its operation transition back to the normal state will be possible. On the other hand if failure causes product breakdown, there will be no useful output until repair is done. (Pecht 2009.)

### 2.4.3 Availability

Availability is a broad term and it express the ratio of delivered to expected service. Reduced number of failures and reduced time of repair leads to increasing availability. (Birolini 2014.) The operational availability of the product can be defined as probability that product is operating satisfactorily at any point in time when used under stated conditions. In the definition total time considered includes operating time, active repair time, administrative time and logistic time. (Pecht 2009.)

Availability can be expressed as:

$$A = \frac{(MTBF)}{(MTBF + MTTR)}$$

, where MTBF is the parameter mean time between failures that means the expected time to failure and MTTR is mean time to repair that shows how much time it takes to repair the component after it has failed. High availability requires high MTBF and low MTTR. The higher the number A is, the higher is the availability of the component. (Pecht 2009.)

### 2.4.4 Reliability

Reliability can be defined as measure of the product’s ability to avoid failure. Low reliability may result in lost performance, compromised safety and the need for restorative actions such as repair and maintenance. On the other hand high reliability will lead to longer operating times. (Pecht 2009.)

From the qualitative view reliability can be defined as the ability of the product to remain functional. Quantitatively it can be defined as the probability that no operational interruptions will show up during a specific time interval. However failures are allowed for redundant parts that can be repaired without operational interruptions. (Birolini 2014.)

Reliability consists of four key elements. There is always a chance for failure so reliability is a probability. Secondly reliability is defined on intended function. It means that product requirements is the criteria against which reliability is measured. Thirdly reliability applies to specific time period so it has a specified chance that it will operate without failure before a final time. Lastly reliability is restricted to operation under stated conditions and both normal and abnormal operating environment must be addressed during design and testing. (Morel et al. 2009.)

The higher the reliability of the equipment is, the lower is the probability of a break down which can lead to downtime. To achieve higher reliability, we need to have more robust components and include redundancies in design. It is costly and it needs to be balanced against the cost factor to achieve optimal result. (Larsen & Markeset 2007.)

### *2.4.5 Maintainability*

Reliability can be increased by increasing maintenance (Birolini 2014). Maintainability is one of the main factors in achieving higher operational effectiveness which leads to increased customer satisfaction (Knezevic 2009).

Birolini (2014) defines maintainability as a characteristic of an item under given conditions for use, to be retained in, or restored to, a specific state in which it can perform a required function, when maintenance is performed under given conditions and using given procedures and resources (Birolini 2014). Maintainability could be described as the characteristic of product design and installation that determined the requirements for maintenance expenditures to accomplish operational objectives in the user’s operational environment (Morel et al. 2009).

Maintainability refers to the easiness of the operations to repair or modify a product to prevent and correct faults and to improve performance. It is the ability to reach a component when performing the required maintenance task. (Morel et al. 2009.) The objective of maintainability is to minimize maintenance time and labor hours considering design characteristics such as accessibility and standardization. Maintainability can be measured in MTTR. (Birolini 2014.) Importance of maintainability is growing because of the increasing efforts to reduce maintenance costs during product lifecycle (Knezevic 2009).

The general objective is to maximize availability and uptime of the equipment through making it easily maintainable. The main idea behind the maintainability is to ensure equipment design that provides the equipment the attributes needed for it to be serviced and repaired efficiently. (Birolini 2014.)

### *2.4.6 Supportability*

The term supportability refers to the characteristics of the equipment design and installation that enable effective and efficient maintenance and support through the products lifecycle. It can be measured in MDT (Mean Down Time). (Pecht 2009.) Supportability can be defined as ability of the system to support mission objectives (Smith & Knezevic 1996).

Supportability has an important role nowadays in lifecycle considerations of a product. Supportability functions should be considered during the design state. (Kumar & Knezevic 1998.) Both, amount of necessary support and the way how it can be delivered, should be considered. Supportability can have considerable influence on both effectiveness and cost aspects of the product. Too often product managers overlook the importance of support and its associated revenues. Supportability requires a full understanding of customer support needs. (Goffin 2000.)

Supportability is strongly affected by such considerations as spare parts, tools, personnel and capital investment equipment (Smith & Knezevic 1996). All support issues should be considered, not just maintenance and repair (Goffin 2000). One of the most important factor related to supportability is the spare parts. It is generally noted that availability and location of spare parts has the biggest impact on the supportability. (Smith & Knezevic 1996.)

## 2.5 Maintenance

Maintenance defines the actions to be performed for product to retain or restore it on a specific state (Birolini 2014). Maintenance can be classified in different ways. In its simplest state it can be just divided to planned and unplanned maintenance. General way to classify maintenance is to divide it to reactive maintenance, preventive maintenance and condition-based maintenance also known as predictive maintenance. (Alsyouf 2007.)

Reactive maintenance actions are taken only when failure occurs. Related cost are usually high but it can be considered cost-effective in some specific cases. (Alsyouf 2007.) The target of the preventive maintenance is to detect and repair hidden failures (Birolini 2014). It can be defined as maintenance that is carried out with pre-determined intervals and it intends to reduce the probability of failure of product. Pre-determined intervals can be time-based or use-based. Condition based maintenance began in aircraft industry and became important in all industries as a consequence to more automated and complex products. It is carried out according to need as indicated by monitoring. (Alsyouf 2007.)

Maintenance strategy establishment requires technical understanding of the machine and functions and resource types needs to be examined. Often an interactive approach is required to be able to deal with maintenance problems in unpredictable environments. (Markeset & Kumar 2003.) The key component of the proactive maintenance strategy is the ability to integrate maintenance with the rest of the company’s activities. For example understanding of long-term sales and operations planning is needed when planning of the long-term shutdowns for repairs. (Laszkiewicz 2003.)

Lack of right metrics and poor understanding of the issues lead often to underestimation of the maintenance effects. Often there is no transparency to the losses related to the unnecessary downtime or later deliveries and no tangible returns attached to maintenance’s role in avoiding downtime or making on-time deliveries. Companies could gain competitive advantage by focusing their maintenance strategy to reducing expenses, improving uptime and optimizing production processes. (Laszkiewicz 2003.)

According to the query that was made for Maintenance Technology readers, 40 percent of the efforts is spent on reactive maintenance tasks meanwhile ideal state would be 12 percent. At the same time, 15 percent of the time is spent on predictive maintenance activities even 35 percent would be an ideal state. This difference is related to the changing role of maintenance. 20 years ago the primary goal of maintenance was to prevent losses and it was required to provide the basic need at minimum cost. Nowadays companies are researching all possible ways to ensure productiveness at the right time and to keep the plant in full production. (Laszkiewicz 2003.)

Examination of the environmental conditions and the maintenance history of the equipment help predict the life time of the each component. Common equipment failures can be recognized by reliability measurements. Root causes can be often determined based on that information and it can lead to increased operator and equipment efficiency and assist companies to adopt proactive and predictive maintenance activities. (Laszkiewicz 2003.) Collecting data about the product’s technical health during the operation phase can benefit manufacturers in many ways. It can be used to develop a new generation of products or to change the design to remove or reduce any critical weaknesses in design. Data can be used also to make prognoses about future maintenance and support needs and to predict the life time of the machine. (Markeset & Kumar 2003.)

Automated sensor-based diagnostics systems can signal product ill-health. Remote and real-time assessment of performance requires integration of various technologies. Internet and advanced communication technology can be used to facilitate assessment of product performance, maintenance and support system. (Markeset & Kumar 2003.)

# 3 RESEARCH METHODS

In this Master’s Thesis both theoretical and experimental research methods were used. This research was conducted as an extensive case study. Case study can be defined as an empirical research that examine existing phenomenon in the real life situation, in its own environment (Hirsjärvi et al. 2010). It allows the investigator to gain the holistic and meaningful characteristics of real-time events. Unique strength is the ability to deal with a full variety of evidence such as documents, artifacts, interviews, and observations. (Yin 2009.)

In this research, qualitative methods were used. Qualitative research can be roughly defined as “based on non-numeric material”. Common features for qualitative research are appropriate target group, human being as information source, information collection in real life situations and research problem shaping during the research process. Qualitative material refers to the material that is in text format and that has been collected by such ways than interviews or observing. In qualitative research, research plan may change during the research process. (Hirsjärvi et al. 2010.)

This research includes also characteristics of constructive research. A constructive research approach aims to improve existing practices. It is problem solving in a real-life organizational setting through the construction. There are crucial steps in the constructive research approach such as obtaining of a general and comprehensive understanding of the topic and innovating and constructing a theoretically grounded solution idea. (Lindholm 2008.)

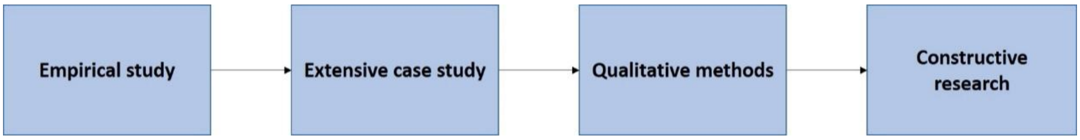


***Figure 2. The research approach***

Research material can be divided in two groups according the information collector. These groups are primary material and secondary material. Primary material has been collected by researcher and secondary material has been collected by someone else. (Hirsjärvi et al. 2010.)

### 3.1 Primary material

Primary material in this research is gathered through interviews. Both theme and semi-structured interviews have been performed. Interviews were made inside the company and outside for the original equipment manufacturer (OEM) and end-customers.

Theme interview is a semi-structured method that is based on pre-described themes. There are no direct questions and they don’t follow any specific order. (Hirsjärvi et al. 2010.) Main target is to allow interviewees tell freely of certain issues (Eskola & Suoranta 2008). In semi structured interview, there are certain questions but answer choices do not exist, thus interviewee answers with own words (Ruusuvuori & Tiittula 2009).

An interview is common method in both qualitative and quantitative research. Interview has always a certain target. Interviewers ask questions and want answers because of the interest for information. (Ruusuvuori & Tiittula 2009).

### *3.1.1 Internal interviews*

Most of the internal interviews were conducted face-to-face and they lasted from 50 to 90 minutes. Totally nine internal interviews were conducted from which one was made as email query with a help of chattool, six were made face-to-face as semi-structured interviews and two were made face-to-face as theme interviews.

The interviewees inside the company held the following positions Sales manager, Area sales manager, Product market manager, Marketing and Sales manager and Global product manager. All interviewees have long experience from the chosen segments, customers and products. Part of them were observing the issue from the design view and other part from the service business view. All interviewees, except one in abroad, are working in Finland.

The target of the internal interviews was to collect existing knowledge that is spread all over the company and that is partly in intangible form. Two theme interviews were conducted to gain overall picture of the current lifecycle services and related issues in GTSC. Rest of the internal interviews were conducted to get good picture of the industry segments and to perceive how good understanding company has of its customer needs.

### *3.1.2 External interviews*

All external interviews were conducted face-to-face and they lasted from 40 minutes to 100 minutes. Totally six external interviews were conducted and all of them were semi-structured interviews. Five of the interviews were conducted in the customer’s office and one in the GTSC office.

All interviewees are working in the large, global companies. Two interviews were made for the end customers in OGP industry segment, three interviews were made for the end customers in Metals industry and one interview was made for the OEM customer in Power segment. Interviewees held positions of Maintenance engineer, Supervisor, Development engineer and Team leader.

Slight view difference can be seen between replies from the OEM and end customers. However this was conscious decision since GTSC is in close co-operation with OEM customer in question. Customer was able to give a larger view of the whole Power industry segment.

The target of the external interviews was to gain good picture of how motors and generators are used, in which kind of environment they are used, evaluate the criticality of the processes where motors and generators are operating, understand what kind of maintenance strategies companies have and what lifecycle service related expectations customers do have.

### 3.2 Secondary material

Also secondary material was used in this research to support primary material. It was mainly used to draw a clearer picture of the research problem and related issues. It also helped to form interview questions and gave pre knowledge of the issue.

Internal and external marketing material and power point presentations were used to give overall picture of the current lifecycle service offering and industry specific characteristics. Material also helped to understand the structure and the characteristics of the motors and generators. ABB Intranet was used to find information of the case company and customer’s internet sites helped to understand their processes and plants.

GTSC has made one previous Bachelor’s Thesis related to the lifecycle services. It was made by Henna Kivelä. In that study, named Designing a Maintenance Package for Diesel Generators, concentration was in diesel generators and focus was mainly in the content of the spare part packages. This research was explored and it gave background information of subject.

# 4 CASE STUDY APPROACH AND RESULTS

In this chapter, first the case company and its lifecycle model and lifecycle services are introduced. Then characteristics of the chosen industry segments are described and finally the customer specific service needs will be introduced and compared.

## 4.1 Case company

Asea Brown Boveri Inc., ABB, was established in 1988. It is one of the world's largest companies in power and automation technologies with operations in around 100 countries. Company has over 145 000 employees and the headquarter is in Zurich, Switzerland. ABB is organized into four divisions based on customers and industries. These divisions are Electrification Products, Discrete Automation and Motion, Process Automation and Power Grids. Divisions are divided to the Business Units (BUs) and again Business Units are divided to the Product Groups (PGs). GTSC FI operate under PG Service.

The structure of ABB from the view of GTSC FI is described in figure 3.

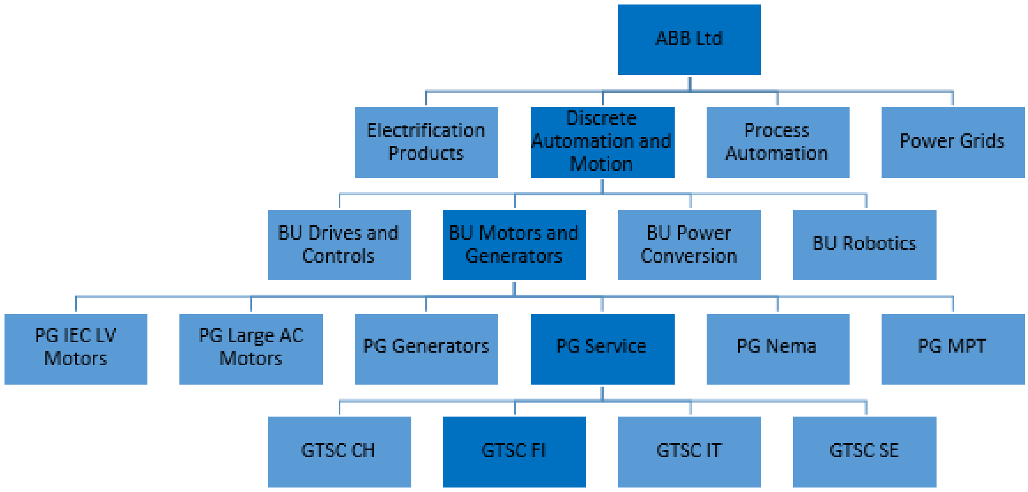


***Figure 3. ABB Group organization chart***

PG Service is responsible of the service business that is related to the products manufactured by the other PGs under the same business unit. PG Service of Motors and Generators consists of Global Supply Units and various Local Sales Units. Global Technical Support Centers are Global Supply Units and they are located in Finland, Italy, Sweden and Switzerland. Global Technical Support Centers offer lifecycle services mainly for the ABB made machines. GTSC FI is responsible of handling cases mostly related to the Strömberg and ABB made machines that have been manufactured and delivered from the Helsinki factory.

## 4.2 Lifecycle model

According to lifecycle model, that is currently used in case company, product lifecycle is divided into four phases. These phases are active, classic, limited and obsolete. The length of each product lifecycle phase is related to the product and it is correlated with the design lifetime of the product. Services available are related to the age of the machine. The older the machine, the more limited are the services available.

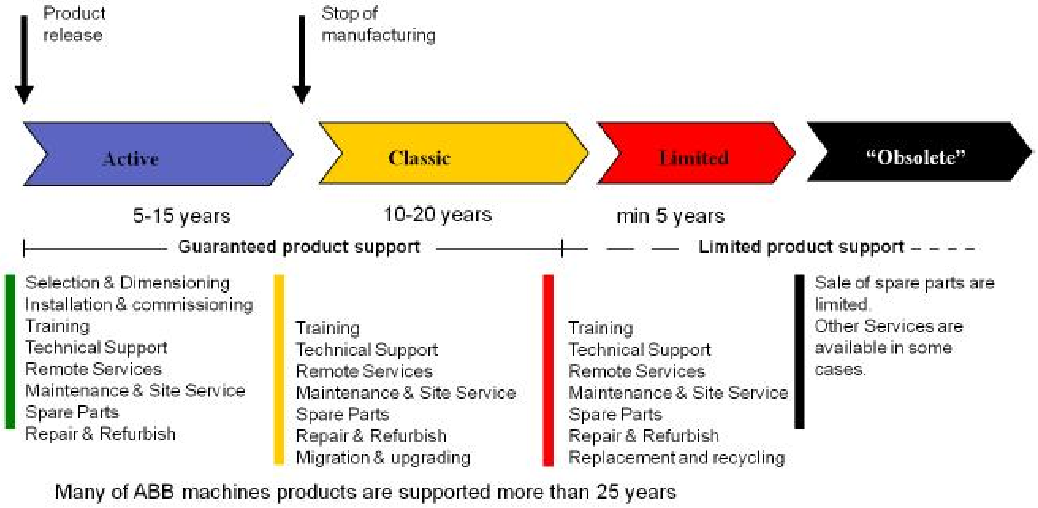


***Figure 4. ABB lifecycle phases***

Active products are in volume production and full service support is available. Support for replacing limited or obsolete products is available. Classic products are no longer in volume production but replica spare machines are still available. Full service support is available in this phase.

Limited products are not in volume production and service support is limited. Repair services and spare parts can be offered as long as materials exist. Technical support, maintenance and site services are offered still. It is recommended that customers will replace the product with a new one. Obsolete products are the oldest machines. They are not manufactured anymore. Service support is very limited or not available. It is strongly recommended that customers will replace the product with new one.

### 4.3 Lifecycle services

Offered lifecycle services include services for the whole product lifecycle. Main services of the GTSC FI are listed here below:

- Installation and commissioning
- Spares and consumables
- Maintenance
    - Preventive maintenance
    - Predictive maintenance
- Lifecycle assessment
- On-site condition monitoring
- Remote condition monitoring
- Repairs
    - On-site and workshop
    - Remote troubleshooting
    - Technical support
- Advanced services
    - Energy efficiency
    - System performance
    - Other solutions
- Extensions, upgrades and retrofits
- Replacements
- Training
- Service agreements
- Services tailored to specific industry

There are two type of spare part packages available. Operational spare part packages are meant for commissioning and initial years of operation. Recommended spare part packages are extended versions of operational packages and they are meant to cover anticipated spare parts needs over the life time of the product. Capital spare parts are major components or parts of machine and meant for critical applications where all downtime need to be minimized.

Target of preventive maintenance is to avoid failures and cut the risk of unscheduled downtime. There are available preventive maintenance kits that aim to cut maintenance times. Kits consist of genuine spare parts that are installed during specific maintenance.

Preventive maintenance program consist of four levels; L1-L4. Intervals depends on machine type and application. Levels 1 and 2 consist of visual inspection including review of operating parameters like voltage, current, load, temperature, cooling conditions and vibration. Protection, trip and alarm logs needs to be checked. Filters, oil, brushes and other consumables if needed are changed. Difference between L1 and L2 maintenance is that L2 includes also measurement of insulation resistance of the stator.

Maintenance levels 3 and 4 should be carried out by ABB authorized personnel. L3 maintenance includes all steps that are included to the L1 and L2 maintenance but also inspection of bearings, cleaning of coolers and detailed rotor inspection should be carried out. L4 maintenance consist of same things that L3 but also measurement of insulation resistance of the stator needs to be done. Machine will be opened for rotor removal if applicable and detailed inspection of free standing rotor and stator as well diagnostic measurements will be done.

***Table 1. Preventive maintenance program***

| Maintenance programs | L1 | L2 | L3 | L4 |
|---|---|---|---|---|
| Intervals | Per each machine type. Defined in user manual | | | |
| | 0.5-1 year | 1-2 year | 3-5 year | 8-12 year |
| Expected work time | 4-8 hours | 8-16 hours | 5 days | 10 days |
| Manpower needed | 1 service engineer | 1 service engineer | 2 service engineers + 1 local technicians | 2 service engineers + 2 local technicians |

There is an ABB LEAP solution for lifecycle assessment. It produces an actual lifetime estimate. Results can be integrated directly into a maintenance plan. There are also solutions for on-site condition monitoring. They processes for example vibration and electrical data. These solutions aim to identify defects as early as possible and prevent potential failures and enhance reliability.

There are different repair services available. Repairs can be performed on-site or in workshops. Advantage of on-site repair is that there is no need to ship damaged equipment and it is possible to save time. Engineers analyze the root cause or the problem, determine corrective actions and carry our repair work. However in complex repairs, rebuilds and overhauls it may be necessary to carry out repair in workshop. Workshops are available over the world.

## 4.4 Industry segments

Three industry segments were chosen to this research according to their business criticality. Characteristics of these three industry segments are collected by internal interviews and they are described industry by industry in this chapter.

### *4.4.1 OGP*

Previously term COG referring to chemical, oil and gas has been used. Nowadays term OGP, referring to oil, gas and petrochemicals, has replaced it.

OGP segment is often divided to upstream, midstream and downstream. Upstream refers to all facilities for production and stabilization of oil and gas. Midstream is broadly defined as gas treatment, shipping and storage. Downstream refers to oil and gas refining. All these sub segments have their own processes which depends whether oil or gas is processed.

Synchronous motors, compressor motors from their type within OGP refineries, operate in different kind of processes. However they are mainly used in LPDE processes or in hydrocracking processes. Motors drive compressors.

In LPDE processes there are usually three synchronous motors. First one is related to primary booster compressor where compressor increases the pressure of ethylene gas between 200-300 bars. Next step in process is the hyper compressor where pressure will be increased until 2000-3000 bars. Third step, in which synchronous motor is involved, is extruding which is also the last step in the LDPE production process.

OGP sites are located all over the world and often in remote locations. There are many old facilities in Europe and USA. Access to the sites are often limited because of the safety issues. Most of the processes in the OGP industries are complex. Processes are exposed to the harshest environmental conditions and they put a high demand on the process equipment.

OGP refineries are mainly in hazardous areas and all motors need to fill exp requirements which means that gas drifting inside the motor is completely prevented. OGP related motors are always designed for specific plant and according to the specification including operational conditions, provided by the customer. Motors are mainly placed inside the buildings and they are usually water cooled.

Ambient temperature range between -40°C and 55°C. Pre-purging and pressurization device gets air from the vent pipe and pre-warming is needed if this air is too cold. Ambient humidity in OGP refineries can raise up to 100 percent, however it usually stands between 50-90 percent. Humidity may affect corrosion inside and outside the motor for unpainted areas. Likewise possible gases in the air may damage paint coating and lead to corrosion.

Contamination is usually not a problem in OGP refineries. Motors fill exp requirements and are so well protected that dirt can’t drift inside the motor. In the areas where sand storms exist, sand might damage the coat painting of the motor. Mechanical strain is not a problem generally for motors in OGP refineries. When piston engine moves, load moment varies per circle and load vary in axle. Motor is not shaking but it faces stress. Short circuits in the power grid may stress motor but this is considered already in design phase.

In OGP industry process, value and downtime cost are extremely high. Shutdowns are often planned years before and everything need to be done as a single shot, although not for the whole site at the same time. There is really limited time window to perform installations, maintenance and repairs.

### *4.4.2 Power*

Diesel power plants produce electricity. The main components in the plant, related to generator, are diesel engine, generator and foundations, bearings and auxiliary devices. A diesel generator operates as a part of diesel power plant. Diesel engine drives the shaft of the generator. There are different variations of the diesel power plants. Firstly diesel power plants are used for producing electricity as a basic load. Secondly they are used only for balancing load peaks and thirdly they are used as reserve plants.

Power plants are often located in challenging environments where national power grid doesn’t exist, for example in jungle, in desert or in the mountains. Generators are also often operating on the marine usages. All these environments set different requirements for the generators. The most common factors that need to be taken into consideration are ambient temperature, ambient humidity, contamination, altitude and mechanical strain.

Ambient temperature range between different plants is high. Highest temperatures can be near to 60°C meanwhile lowest temperatures can go below -40°C. Temperature is an important factor when estimating generators life time. Often ambient temperature is measured outside the plant. However more important is to know temperature inside the plant and especially the temperature of the air that is used for the cooling of generator. For example, the positioning of the fans affect to that temperature.

When generator is operating, humidity is not affecting since the temperature of the coil stays around 100°C degrees. However humidity may affect to the life time of the generator when it is not operating or it is stored. For example heating resistors should be on when generator is not operating because humidity will decrease insulation resistance value.

Most of the land based generators are air cooled. Contamination can have serious effect if it blocks air filters. This will lead to raised temperatures and cut generator’s estimated life time. In the plants that are located in desert, sand might drift inside to the generator. In altitudes more than 1000 meters, generator’s cooling efficiency decreases because of the decreased aerial pressure. Altitude requirements are considered already in design phase.

Diesel generator has to stand lot of mechanical strain because rotating machine cause high amount of the natural vibration. Especially starts and stops cause lot of stress to the generator and they are nowadays common in so called flexible usages. In flexible usages different type of energy sources are used and for example when output from the wind generator decreases, diesel generator is starting to operate. There are different ways to place generators and the highest vibration arises when diesel motor and generator are placed on common foundation.

### ***4.4.3 Metals***

Rolling mills process steel slabs. Steel slabs are processed thinner and lighter depending of the final usage. The rolling mill operate like giant mangles, rolling slabs into plate or sheet. After rolling into different thicknesses, different grades of steel can be quenched, hardened, tempered and after-treated.

Synchronous motors, mostly used as VSD motors within rolling mill processes, operate in many different kind of processes. There are many different applications that can be classified different ways. For example hot and cold rolling, ferrous and non-ferrous rolling, slabs and coils. In hot rolling process, steel slabs are heated in furnaces. Then, softened slabs are rolled and thickness is reduced. Cold rolling process is used when wanted sheet thickness is less than can be obtained by hot rolling.

Operational conditions don’t affect remarkably to estimated life time of the motor, in metal processes because motors are placed inside the mills and they are mainly water cooled. Often motors are also separated with wall from the rolling processes. Ambient temperature range between 0°C and 50°C but during stoppages temperature might go below 0°C degrees and heaters are needed to keep oil temperature up.

Suitable ambient humidity is needed to ensure that slide rings and brushes operate well. If their operating is weakened, brushes will dry and that will cause carbon dust. Normally in rolling mills ambient humidity is in decent level.

Contamination in rolling mills is often high because process itself produce dirt. Often motors are separated with wall from the other processes but there are also open mills where motors are exposed to dirt. Contamination can drift inside the motor during the years but it is mainly not causing problems. There is air scoop in the motor that let air to go inside the motor and cool brushes. These air filters need to be cleaned often.

Mechanical strain is not usually a problem for motors in rolling mills but damages of rolls cause strain to motors. For example, if roll breaks off, motor will face really high axial shock. Motor should withstand this shock load.

## 4.5 Customer specific service needs

In this chapter, customer specific needs are presented from the view of usage, criticality and maintenance and inspections. In the last part, other related needs are discussed. Information is collected by external interviews.

### *4.5.1 Usage*

OGP refinery should operate 98% of the time. There are continuous projects to improve availability. Motor should operate continuously from one to five years depending of the process and refinery. Interviewees in this case don’t remember the situation that failure in motor would had stopped the production in the refinery.

Motors in OGP refineries are used continuously. They need to operate until planned stoppages. However there are time to time failure situations that stop processes. If redundancy exist, motors are used in shifts according to their operating hours.

Within Power industry operating rate of the plant should be as high as possible. Generator should operate without a break as long as the plant operates, in some cases even until 18000 hours continuously. Generators are optimized to full power and in power plants they are also operating really near to it.

Generators operate with cyclic load and continuously, depending of the usage and plant. Usages can vary from power plants and ships to nuclear plants. In the power plants generators usually operate continuously depending of the need of electricity. There is often various generator sets in the power plant and power producing can be divided and planned according to the amount of operating generators. In some plants, few of the generators can be stopped for the night when need for electricity is lower.

Cycles can vary in high level. On the ship main generators operate when ship is moving and until it arrives to the harbor. In the harbor, auxiliary generators are turned on. In the nuclear plants, generators are intendent to operate only in the case of emergency and they may not be used ever, except test run for couple of hours in the year.

Sometimes, the original planned usage of the generator can change also according to the changes in the operating environment. For example, in Brazil, there is a plant that was originally designed as a load peak plant for the hydroelectric power plant but because of the low rain rate in Brazil, it is used continuously nowadays.

In Metals industry there are certain availability targets for every process line. For example in the hot rolling mills, target is that mill is in use 75% of the time. In rolling mills load vary between 20-130% when speaking about the nominal power.

Motors are mainly operating with cyclic load. In the cold rolling mill, cycles vary from 10 minutes to 30 minutes, depending on the process. Stoppages that are related to these processes, are coil change every 60 minutes and roll change every 10 to 60 minutes. In the hot rolling process, cycles are really short. Length of the cycle depends of the quality and the speed. In one of the customer's processes, load cycles are usually two minutes. That is followed by three minutes idling and again two minutes operation. That continues for an amount of repetitions.

***Table 2. Usages in industry segments***

| USAGE | | | | |
|---|---|---|---|---|
| Industry | Continuous | Cyclic load | Duration | Comments |
| OGP | X | | | |
| Power | X | X | | Cyclic load in marine and emergency usages |
| Metals | | X | 2-30 min | |

### *4.5.2 Criticality*

In the range from 1 to 5, in which 5 is the highest, interviewees in OGP industry evaluated that criticality of the motor is between 4 and 5, when observing from the view of the whole refinery. However, criticality depends of the processes and structure of the process lines. For example, if one of the motors, in primary or secondary usage, would get broken, the whole operation could stop, depending of the redundancy. In other processes, there might be couple of hours gap until problems arise.

There are many urgent components in the power plant and generator is one of them. Interviewee evaluated that criticality of the generator is 5 when observing from the view of the whole plant. However, criticality depends of the structure and usage of the plant. If there is only one generator set, criticality is really high. In the plant consisting of several sets, criticality is a bit lower, even if the target is to keep them all operating at the same time.

Interviewees in Metals industry evaluated that criticality of the motor, in rolling usage, is 5, from the view of the whole rolling mill. Motor should operate all the time. Failures should be fixed as soon as possible. One customer had problems with motor and repair took three days. Production was organized in a different way and the worst catastrophe was prevented. However that was the maximum time for this kind of arrangement.

In OGP industry unplanned stoppages should be prevented. There are immediately extremely high costs. Maximum time for motor downtime is eight hours. After that there will be serious problems. The whole process would be down and gas production should be limited. Customer that has redundancy, could continue but with lower production and with bigger risks. Longer downtime can lead to high economic losses. Losses can be even 1 million per day and during shorter stoppages approximately 100000 euros per day. These losses consist of production losses and penalties.

In the Power industry, broken generator needs to be fixed as soon as possible. However customer is often ready to evaluate for example between different shipping choices, based on economic factors. There are always economic losses related to failures. There are direct losses if electricity production is stopped and it is not possible to produce electricity to the grid. In some cases, it is needed to purchase electricity from the other source, to be able to fill the contract requirements. There might be also penalties for the plant, if reliability percent per year is not achieved. Losses can be approximately 10000 euros per a day.

In Metals industry losses can be near to 10000 euros per hour because failure have influence to other processes usually. Repair work can be difficult to execute since motor positioning is challenging. There might be also costs if production need to be organized different way.

***Table 3. Criticality in industry segments***

| CRITICALITY | | | |
|---|---|---|---|
| Industry | Evaluation | MTTR | Losses per day |
| OGP | 4-5 | 8 hours | 1 000 000 EUR |
| Power | 5 | 7 days | 10 000 EUR |
| Metals | 5 | 3 days | 250 000 EUR |

In OGP industry, other interviewed customer has three motors in the same line so if one motor gets broken, it is possible to switch on the third one. However there will be lower production for a moment and switching on motor takes a bit of time. Other customer has no redundancy. Both customers do not have spare motors or capital spares. Other customer has evaluated that redundancy is enough, third motor is seen as a ready to use spare motor.

In Power segment there are sites where safety regulations require to have spare motor available. These kind of usages are for example hospital and ship usages. Customers do purchasing decisions according to their knowledge and knowhow of the criticality. For example, gold mine in Australia has evaluated that production losses would be so high that it must have a spare generator.

In Metals industry, all customers have process lines were failure could stop the whole process because there is no redundancy. However all customers have also possibilities to change production lines in certain processes so that one motor can be skipped and they can continue with limited production. In that kind of situation, it is not possible to produce all product types. One customer has three lines of which only certain line can be out of use. Two of the customers have spare motors and one not. Spare motors are not identic and not suitable for all motors but with small modification, it is possible to replace most of the motors.

One customer in Metals industry doesn’t have capital spares. Other two customers have spare rotors. One of them was needed when there was a rotor failure. With spare rotor it was possible to bring broken rotors one by one to the workshop. Other customer has spare rotor that it not identic to the existing one so it would not be possible to drive motor full speed with spare rotor.

In OGP industry, other customer has lot of spare parts on site. When motor was purchased, spare part kit was included. It consist of consumable spares such as bearings and heaters. Some of the spare parts are left over from the installation phase. Spare parts are usually purchased according to ABB recommendations and criticality evaluations made by the customer. Other customer doesn’t have many spare parts on site but it is possible to borrow them from their other refinery. Some of the spare parts could be modified from the other parts on site. Purchased spare parts are usually electrical components that are easy to change. Spare parts are mainly needed for modification work of the old machines.

In Power segment, decision of spare parts is usually made based on ABB recommendations and economic factors. There are sometimes situations that spare parts need to be purchased because there is a failure in the generator and customer is in a hurry.

In Metals industry, there are spare parts on site. They are mainly consumable parts, such as bearings and carbon brushes. It is not possible to borrow spares form the other mills. Spares are selected according to ABB recommendations and according to own knowhow. There are also spares that are needed when changing the rotor. According to interviewee failures that are related to motors are very rare but it is good to have spares available just in case.

***Table 4. Spare motor and spare part availability***

| SPARE PARTS | | | | |
|---|---|---|---|---|
| Industry | Redundancy | Spare motor | Capital spares | Spare parts |
| OGP | 1 yes and 1 no | No | No | Yes |
| Power | Yes and no | Rare | Rare | Yes |
| Metals | 2 yes and 1 no | 2 yes and 1 no | 2 Yes and 1 no | Yes |

There are many reasons why customers don’t buy spare motors and spare parts. If redundancy exists, some customers feel that spare motors are not needed. Often the reason is in price that customer think to be too high. Often decisions are made based on criticality evaluations and failure history.

Some of the customers don’t have space to store spare motors. If it is not possible to store spares near to the site, there will be gap before motor is in use again. In some marine usages there are difficulties to decide the place where to store spare motor since ships are moving.

According to interviewee from the Power industry, customers trust the OEM and ABB equipment and don’t buy often spare generators and capital spares. They think that large companies are able to deliver new equipment with short delivery times. General attitude is that generators do not get broken and if they would, spares would be easily available.

| Not to buy: | To buy: |
|---|---|
| • High price<br>• High redundancy<br>• Low criticality<br>• Limited stocking options | • Low price<br>• Low redundancy<br>• High criticality<br>• Good stocking options |

***Figure 4. Purchase decision concerning spare parts***

Failures may cause stoppages in production, production losses or lower production. Failures in power plant leads to stoppages in electricity production and may break also motor that is in the same set. Failure in rolling mill stops production for a moment and leads to production losses. There are always increased risks when process differs from the normal. For example risk of fire increases. Changes in the process always cause problems. In some cases company may ultimately lose the customer.

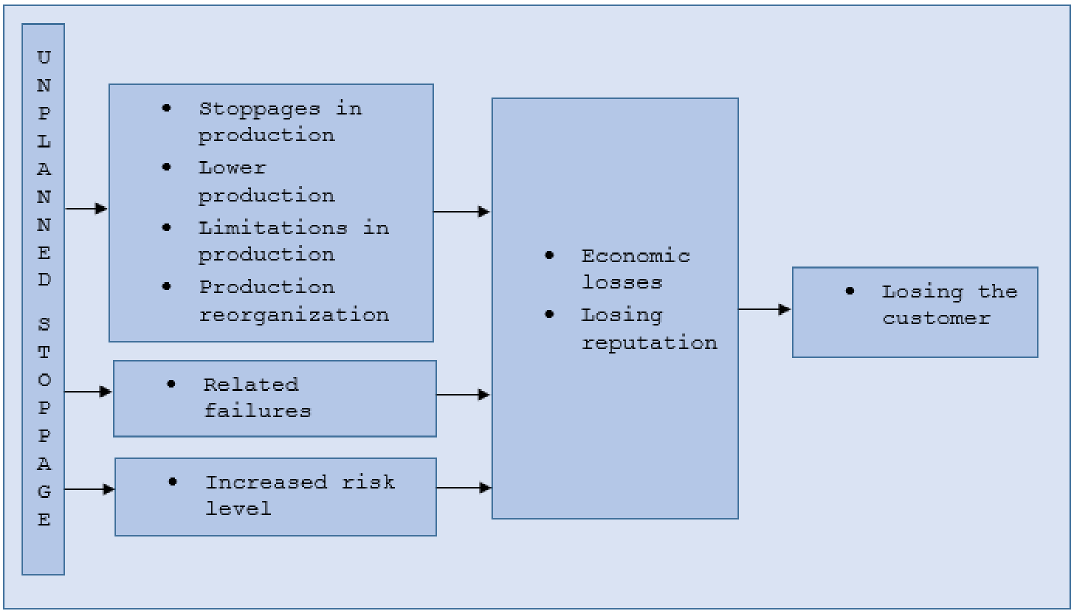


***Figure 5. Possible consequences of unplanned stoppages***

### *4.5.3 Maintenance and inspection*

In OGP industry, there is a difference in the maintenance schedules between two refineries. Cycles for the larger maintenance stoppages are 2 years and 5 years. They are usually in the spring or fall. Stoppages take approximately one month. Schedule for stoppages is planned yearly and schedule is planned process by process. There are slightly differences in shut down schedules depending of the process. Catalyst is changed every one to two years but that break is not meant for motor maintenance.

According to interviewees there are never unplanned stoppages for the whole refinery. Other customer has several shorter unplanned breaks during the year. Other customer told that there are failures in the processes but not even yearly.

In Power industry, maintenance schedules follow the maintenance schedule of the diesel motor. Intervals are usually displayed in hours. Interval is approximately 8000 hours. However smaller maintenance work occur weekly.

In Metals industry, in the hot rolling, there is one larger maintenance stoppage in a year. In the cold rolling mill there are two larger stoppages a year. They last approximately 14 days. Maintenance stoppage last approximately two to three weeks depending of the maintenance needs. There are also shorter planned stoppages, for example eight hours break, every two weeks and two to three days break, twice a year. It is possible to do some small maintenance tasks during these short breaks.

Maintenance for motor during the stoppage can last one day less than complete stoppage because time is needed to attach rolls on their places and rolls need to be test driven. Sometimes, it is needed to use motor during stoppages so maintenance for motor can’t be done. In both mills, there are unplanned breaks often. For example in the coil line there are breaks once a week, in plate line once every two weeks.

***Table 5. Maintenance schedules in industry segments***

| MAINTENANCE SCHEDULE | | | | |
|---|---|---|---|---|
| Industry | Larger stoppages | Duration | Shorter stoppages | Unplanned stoppages |
| OGP | Every 2-5 year | 4 weeks | Several in a year | Several in a year |
| Power | 1 per year | Varies | Weekly | Weekly |
| Metals | 1-2 per year | 2 weeks | Weekly | Weekly |

There are many things that need to be considered when planning the maintenance stoppages. For example in OGP industry it is needed to consider also maintenance stoppages in the nuclear plant. In Power industry, such things as possible length of stoppage, scope of the maintenance, spare part availability, site conditions and needed resources such as tools and capable personnel need to be considered.

In Metals industry, stoppages should be scheduled to the period when there is a low season in the market. Stoppages are usually in early fall or in the end or beginning of the year. Maintenance plan need to be done from the view of the whole mill and also maintenance schedules of the other plants in same area need to be considered since resources are limited.

There are also many other things to be considered when planning the larger stoppages. For example different equipment variations, what task can be done by own employees and what task need to be done by external resources, what are the most critical parts of the processes, how to divide resources such as tools and people between different process lines and what task is taking the longest time. Also weather conditions should be considered since for example water washes can’t be done when the temperature is below freezing. Maintenance plans need to be done as early as possible. Also practical experience is used to plan the stoppages.

| Internal | External |
|---|---|
| • Complete plant and processes<br>• Most critical processes<br>• Work task that takes most of the time<br>• Maximum duration<br>• Scope of the stoppage<br>• Resources<br>• Tools | • Stoppages in other plants in same area<br>• Weather conditions<br>• Situation in the markets<br>• Resources<br>• Tools |

***Figure 6. Things to be considered when planning stoppages***

There are many reasons behind unplanned stoppages. In OGP industry, there are breaks that are caused by gas leaks or failures in cylinders. There are also automation failures in the processes but not even yearly. Interviewee told that there have been problems to restart motor after the stoppage in the refinery. That can lengthen the planned stoppage. Usually these kinds of problems have been fixed in one day.

In Power industry, unplanned stoppages are often consequences of skipped maintenances. One reason to skip maintenance is the lack of knowhow and competence. Other reasons are user mistakes and customer’s will to optimize spare parts. There are customers that are ready to run generator without maintenance until the end of life time.

In Metals industry, reasons behind the unplanned stoppages are related to product manufacturing and broken equipment. Most of short breaks have no influence for the production but they leave mark to the process. These cases are analyzed and they should be minimized. There has been situations where motor failure was the reason to unplanned stoppage but these are rare.

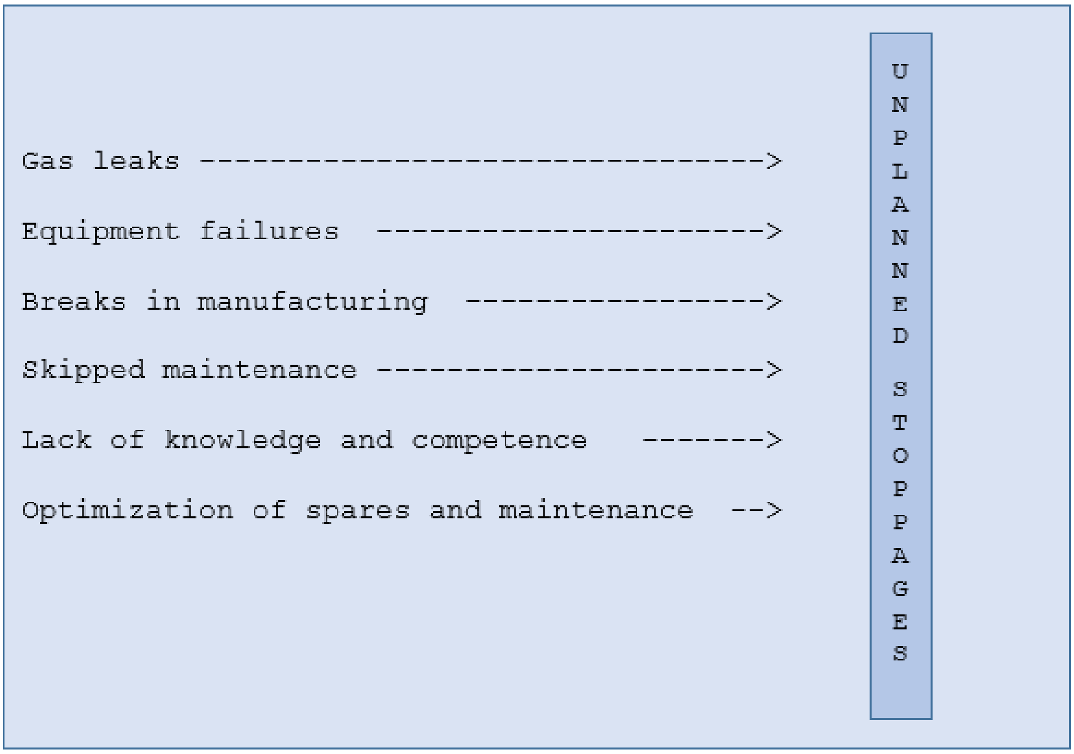


***Figure 8. Reasons behind unplanned stoppages***

In all these interviewed industry segments, smaller inspections and maintenance are usually made by customer’s own maintenance people and larger maintenance is made by external resources.

In Metals industry, some of the smaller maintenance such as carbon brush maintenance can be also made by external resources. Larger inspections are usually done during short breaks, just before large stoppage so that needed changes can be scheduled to large stoppage. If short break is well planned, it might be possible to do maintenance for the bearing lubrication and carbon inspections.

Many of the interviewees told that there is continuous monitoring for the bearings and stator temperatures. In OGP industry, maintenance is often done on site but it might require for example opening of the roof which takes a bit of time.

Maintenance recommendations are given by ABB and some of the interviewees told that are following them. However even recommendation are considered, customers make their decisions according to their own view of the issue. Often they decrease the amount of maintenance but there are also customers who have done more maintenance that recommended by ABB.

### *4.5.4 Other needs*

Customers were mainly satisfied to GTSC lifecycle services. Many interviewees told that there is flexible cooperation between GTSC and customers. However there are also things to develop. They are related to such issues as price, spare part and spare motors availability, delivery times and service availability. Issues to be developed are listed below:

- Lower price
- Shorter delivery times for spares and spare motors, also for ex-motors
- More pro-activeness
    - Knowledge of installed base
    - Lifecycle estimations
    - Maintenance schedules
    - More information about needed actions
- Prioritization of urgent cases
- Productization of the maintenance
    - How to quote maintenance to global customers in different kind of sites?
    - Including estimation for the length of maintenance, costs and way to be invoiced
    - General instructions
- Workshop availability
    - Minimized delivery times
    - Minimized cost
    - If some work is not possible to do in workshop, could ABB have subcontractors to do specific work?
- Spare parts availability for older motors and generators

- If spares are not available there should be technical support that help to find different kind of solution

***Table 6. Customer specific needs***

| CUSTOMER SPECIFIC NEEDS | | | | | |
|---|---|---|---|---|---|
| | Availability | Delivery time | Price | Pro-activiness | Productiozation |
| Spare parts | X | X | X | X | |
| Capital spares | X | X | X | | |
| Spare motors | X | X | X | | |
| Maintenance | | | X | X | X |
| Technical support | X | | | | |
| Workshop | X | X | | | |

Interviewee from the Metals industry told that ABB LEAP and MACHSense don't fit well to measurements in rolling mill usages. Some of the customers consider measurements expensive and have evaluated that failures are so rare that these kind of investments are not economic. However customers are mainly interested of predictive maintenance issues and lifecycle estimations. Interviewees have many own condition measuring systems and tools. However they told that it is sometimes interesting and good to have external opinion to issues.

Many customers have different kind of maintenance contracts with ABB. Some are interest to have them only case by case and some prefer more comprehensive contracts. Maintenance contract need to be planned in close cooperation with ABB and customer, to satisfy both parties. An ideal situation would be to prevent failures by planning maintenance according to measurements.

# 5 DISCUSSION AND RECOMMENDATIONS

The results of qualitative study are discussed in this chapter. First, customer specific needs are analyzed from the base of literature review and finally, recommendation for the industry specific lifecycle service models are given.

## 5.1 Lifecycle services in case company

Lifecycle service model that is currently used in GTSC is in very general level. Lifecycle service recommendations are same for all customers in all industry segments. According to Markeset & Kumar (2003) product support strategy should be alignment with customer’s needs. In this Master’s Thesis, industry specific lifecycle service models that take into account customer specific needs, were created.

According to Ulaga & Reinartz (2011) the main target of the product lifecycle services is to ensure best possible reliability for the product, during its whole lifecycle. In this case study focus was in availability related customer needs and it can be stated that customers are nowadays making lot of efforts to increase effectiveness related issues such as availability and reliability.

Close dialog with customer allow company to identify customer business needs and develop the capabilities to offer services that are linked to the customer’s priorities (Davies 2004). It seems that employees in different tasks in case company have lot of information of customer's needs but this information is not collected and shared in an organized way. Generally it can be stated that company has good understanding of customer needs but this knowledge should be utilized more to support GTSC operations.

**5.2 Operating environment and usage**

Customer's operational environment, operation and maintenance goals and strategies need to be understood to assure optimal performance and customer satisfaction (Markeset & Kumar 2003). According to this case study, it seems that customers in different industry segments have very different operating environment, usages for the motors or generators and attitudes towards maintenance. There are also differences inside the same industry segment, especially in issues related to the maintenance strategies. However it is possible to find industry specific needs. According to Aurich et al (2006) the demands are highly specific since there are multiple possibilities for using a specific product depending on the corresponding business environment of the customer.

In the rolling mills, circumstances are often dirty and process itself causes heat and dirt. In OGP refineries there are mainly motors that fill ex requirements. Safety regulations are high in refineries. In power plants ventilation and temperatures have important roles.

Motor or generator usages vary according the industry and its processes. Product can be used continuous or in cyclic operation (Pecht, M. 2009). In refineries, motor is in continuous operation hence in rolling mills motor is operating in cycles and it can be driven with really heavy load for moments. Usages for generators vary from the continuously use to duties with cyclic load, depending of the plant or site. These issues are mostly considered in design phase but may increase the need for the maintenance.

### 5.3 Maintenance

The most recognizable difference between these three industry segments is in maintenance schedules. In the rolling mill there is planned stoppage yearly. There are also many shorter breaks in the processes. During these breaks it is possible to do some small maintenance tasks for the motors. In the power plants, schedules for the stoppages vary. Maintenance for the generator is planned according the maintenance schedule of the diesel motor since it has been evaluated that motors need more maintenance than generator.

OGP refinery should operate continuously at least for 2 years, some refineries even for 5 years. This sets challenges to maintenance schedules. Maintenances should be planned so that it is possible to operate motor for long period without breaks. Maintenance tasks that are made during the stoppages, need to be chosen by considering that target.

Understanding of long-term sales and operation planning is needed when planning of the long-term stoppages for repairs

(Laszkiewicz 2003). Situation in the market and overall processes of the plant need to be evaluated when deciding the suitable moment for the stoppage. Also weather conditions need to be considered. It seems that stoppages are mainly executed during fall and spring. This should be recognized by GTSC.

## 5.4 Redundancy and spare parts

In the most critical processes, repair time should be minimized. According to Ghodrati & Kumar (2005) right level of spare parts in site increase availability of product by minimization of the product downtime for repair and service. When evaluating spare part need, process criticality should be considered. Spare motors and some smaller parts have long delivery times and in case of failure, repair can take lot of time. All customers within this research have consumable spares available but availability of spare motors and capital spares depend on customer.

Some customers have redundancy in their processes. Redundancy is important because it decrease production losses in case of failure. In some cases, redundancy can be seen as spare motor that is available for use. However if there is no redundancy it is highly recommended to have spare motor available. Spare part availability need to be considered when planning the lifecycle service models and recommendations should be given to the customers.

### 5.5 Life time estimations

Some of the customers hope more pro-activeness from the GTSC. They wanted GTSC to provide lifecycle estimation including recommended maintenance and spare part. That requires GTSC to have exact information of installed base and more understanding of customer processes, operating environment and the maintenance history. According to Laszkiewicz (2003) examination of the environmental conditions and the maintenance history of the equipment help predict the life time of the each component.

Many customers are ready to invest in additional services such as remote monitoring (Bundschuh & Dezvane 2005). According to interviewees, monitoring tools are common nowadays. All customers have some kind of measuring for the motors. Case company could utilize measuring information when evaluating life times for the motors but that require continuous measuring. Customer may not always want to give all data to the external company. However it seems that interest for predictive maintenance is increasing.

### 5.6 Losses

Lack of incomplete support cause unexpected downtimes which leads to unexpected losses (Ghodrati & Kumar 2005). Within industry segments that were observed, there are differences in losses that are caused by unplanned downtime. In OGP refineries and rolling mills, failure can lead to really high losses already in one day. However redundancy and production reorganization can help to minimize losses. In

Power segment, losses are usually smaller than in other two segments. However there are usages where failure situations can’t exist and spare motors or redundancy is required by the security regulation.

According to Larsen & Markeset (2007) to achieve higher reliability, there is need to design in redundancies. It is costly and it needs to be balanced against the cost factor to achieve optimal result. (Larsen & Markeset 2007.) Recommendations for spare motors and parts need to be done by considering possible losses from the failure.

## 5.7 Industry specific lifecycle service models

Current lifecycle service model used by GTSC is made from the view of the company and it is the recommendation which kind of maintenance intervals there should be, to ensure best possible availability for the motor or generator. However model doesn't pay attention to the customer’s different needs in different industry segments. In this research new, industry segmented lifecycle models were formed. In these models, existing recommendations are combined with customer needs. All maintenance levels from L1 to L4 require to stop the motor, L1 for a shorter moment and L4 for a longer period.

Maintenance schedules in OGP refineries are challenging. It is not possible to execute maintenance according to GTSC’s current recommendations. Motors need to operate without a break from 2 to 5 years. Motors are used continuously and requirements concerning operating environment are mainly considered already in design phase. When comparing this new industry specific model to the existing model, the biggest difference is in L3 and L4 maintenance intervals which now follows the customer schedules. It might be challenging to execute L1 and L2 maintenance as it is recommended in this new model but they should be scheduled within some small break such as catalyst change work. Since these new maintenance intervals are longer than general recommendations, it is highly recommended to execute LEAP measurements within all maintenances. Possible losses from the unexpected downtime in refineries are extremely high so spare motors are highly recommended in this industry segment.

***Table 7. Lifecycle service model for OGP industry***

| OGP | | | | |
|---|---|---|---|---|
| Maintenance programs | L1 | L2 | L3 | L4 |
| Intervals | 1 year | 2 year | 5 year | 15 year |
| Expected work time | 4-8 hours | 8-16 hours | 5 days | 10 days |
| Manpower needed | 1 service engineer | 1 service engineer | 2 service engineers + 1 local technicians | 2 service engineers + 2 local technicians |

In the model for Power industry, intervals are informed in hours unlike in the models for other two industries. Since it is common in Power industry segment to inform usage times in hours, it is convenient to use similar way in this model. Diesel motors need more maintenance than diesel generators thus generator’s maintenance schedules follow motor’s maintenance schedules.

***Table 8. Lifecycle service model for Power industry***

| POWER | | | | |
|---|---|---|---|---|
| Maintenance programs | L1 | L2 | L3 | L4 |
| Intervals | 8000h | 16000h | 32000h | 80000h |
| Expected work time | 4-8 hours | 8-16 hours | 5 days | 10 days |
| Manpower needed | 1 service engineer | 1 service engineer | 2 service engineers + 1 local technicians | 2 service engineers + 2 local technicians |

In Metals industry, motors operate with cyclic load and operating environment can be challenging which makes it important not to have too long maintenance intervals. The model for Metals industry is mainly corresponding with current service model. Maintenance schedules in the rolling mills allow maintenance as it is recommended in current lifecycle service model hence there is no need to change existing model.

Possible losses from the unexpected downtime in rolling mills are very high so spare motors are highly recommended in this industry segment.

***Table 9. Lifecycle service model for Metals industry***

| METALS | | | | |
|---|---|---|---|---|
| Maintenance programs | L1 | L2 | L3 | L4 |
| Intervals | 1 year | 1-2 year | 3-5 year | 8-12 year |
| Expected work time | 4-8 hours | 8-16 hours | 5 days | 10 days |
| Manpower needed | 1 service engineer | 1 service engineer | 2 service engineers + 1 local technicians | 2 service engineers + 2 local technicians |

As it can be seen, it is justifiable to replace current lifecycle service model with industry specific models. It is not needed to change the content of these maintenance levels. These models can be used by the customer as a recommendation how to make maintenance to their motors or generators and as well to help the sales managers in their work.

# 6 CONCLUSIONS

In this chapter, first, the main findings of this Master's Thesis will be presented. Secondly, an assessment of the limitations will be discussed and finally future implications of the study will be provided.

## 6.1 Summary of key findings

This Master's Thesis concentrated on studying how company can develop their lifecycle services based on availability related customer needs, in certain industry segments.

Based on customer interviews it can be stated that customers are fairly satisfied with GTSC lifecycle services. However there are certainly things to develop. It seems that ABB has good understanding of customer needs and operational environment in customer site but this knowledge and information should be shared better inside the company.

Customers request more proactivity from the GTSC. They want more information of installed base and of the actions that should be made for the motor or generator. It seems that customers are willing to make maintenance contracts with GTSC and some of them already have them. End customers request specific maintenance contracts and in the other hand OEM customer hope more productized maintenance services.

Customers were also interested to get more specific life time estimations and to move towards predictive maintenance actions. Condition based monitoring systems should be developed to be suitable in all industry segments. At the moment they are not suitable for rolling mill usages and there are some limitations related to Exp motors in OGP field.

This Master’s Thesis showed that it is possible to find industry specific differences in customer needs therefore there is need for the industry specific lifecycle service models. Currently used model doesn’t take customer needs into account.

Usages and operating environment between chosen industry segments vary considerably. These needs are mainly considered in design phase. However depending of the usage, motor or generator face different kind of stress and that can impact the estimated lifecycle of the motor or generator.

The most remarkable difference between chosen industry segments is in maintenance schedules. OGP refinery may need to run for five years without a break, while there is a maintenance break in the rolling mill yearly and some maintenance actions can be made also during the shorter breaks. All this challenge GTSC to offer services in suitable level at the right time.

Failure related losses vary in great level between chosen industry segments. Biggest economic losses may occur in OGP processes where they can rise even to 1 million in a day. Criticality can be compensated with right level of spare parts. It seems that customers are most prepared for failures in the Metals industry segment. On the other hand there are differences inside the same industry segments when observing the existence of the redundancy, spare motors, capital spares and spare parts. It is obvious that redundancy and spare parts can minimize losses that may follow failure. This is something that should be highlighted in the conversation between GTSC and customer.

In the end of the research, industry specific lifecycle service models were created. These models combine GTSC recommendation with customer needs. They can be utilized by both GTSC and the customer.

Model that was formed for Metals industry, mainly correspond with the existing model. Operating environment is challenging and maintenance schedule allow maintenance according to current recommendations. Model that was formed for Power segment, follow the schedule of the diesel motor maintenance and recommendations are given in hours. The most significant difference can be seen in OGP industry segment. Maintenance schedules in refineries do not allow maintenance to follow ABB recommendations. Since maintenance intervals are longer it is highly recommended to make LEAP measurements within all maintenances.

## 6.2 Limitations of the study

This Master's Thesis was conducted as qualitative single case study which set certain limitations. Results are difficult to generalize outside this specific department or company since they are directly depending of the certain products in certain customer's operating environments.

In this Master's Thesis industry specific needs were presented but it is noteworthy to highlight that there are also differences inside the same industry segments. All customers that were interviewed in this study are working in large, global companies where operating environment may vary radically compared to smaller companies. Therefore it need to be stated that created models might not be suitable for all the customers inside the same industry segments.

Qualitative data include always the risk of bias. Data is mostly collected by interviews and there are always challenges to separate facts from the opinions.

## 6.3 Future research topics

From the base of this research couple of suggestions for future research can be made.

Three most business critical industry segments were chosen to this research to which the specific lifecycle models were formed. It would be interesting to research later on how these specific models potentially improve cooperation between case company and customer. Decisions to create specific models for other industry segments could be made based on that research.

While doing this research it has been shown that people within the case company have lot of knowledge of customer needs and specific industry segments. However this information is too often in intangible form and not shared inside the company. It would be important to research how this intangible knowledge could be transformed in tangible form and how this and earlier data could be collected, saved and shared so that it would be usable for all the people needing it.

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# APPENDICES

## Appendix 1. Internal interview (in Finnish)

PROSESSI:

1. Missä laitoksen prosessien vaiheissa moottorimme/generaattorimme ovat mukana?

2. Mikä on moottorin/generaattorin tehtävä eri vaiheissa?

KÄYTTÖOLOSUHTEET:

3. Asettaako käyttöympäristö erikoisvaatimuksia moottoreille/generaattoreille?

4. Millaisia ympäristön lämpötiloja eri laitoksissa voi olla?

5. Entä kosteuspitoisuuksia?

6. Voiko laitoksissa oleva lika vaikuttaa moottorin/generaattorin toimintaan? Miten?

7. Kohdistuuko prosesseissa huomattavaa mekaanista liikettä moottorille/generaattorille?

KÄYTTÖTAPA:

8. Miten moottoria/generaattoria käytetään osana prosessia eli ajetaanko sitä sykleissä vai jatkuvasti?

9. Jos moottoria/generaattoria käytetään sykleissä niin minkä pituisia syklit suunnilleen ovat, millä teholla ja kuinka usein moottoria/generaattoria ajetaan?

10. Jos moottoria/generaattoria käytetään jatkuvasti, niin millä teholla moottoria/generaattoria ajetaan ja kuinka usein käytössä on suunniteltuja katkoja?

KRIITTISYYS:

11. Onko kriittisillä moottoreilla/generaattoreilla normaalisti redundanssia?

12. Onko laitoksilla varakoneita?

13. Kuinka kriittisessä asemassa moottorit/generaattorit ovat koko laitoksen prosessin kannalta tarkasteltuna?

**Appendix 1 (cont’d)**

KORJAUSAIKA:

14. Osaatko antaa yleisellä tasolla arviota kuinka nopeasti koneen tulisi olla uudestaan käytössä virhetilanteen sattuessa?

15. Kuinka kauan kone saa olla alhaalla?

16. Mitä seurauksia koneen alhaalla olosta seuraa?

17. Osaatko antaa arviota yleisellä tasolla kuinka paljon virheenkorjauksesta aiheutuu kustannuksia?

18. Mistä kustannukset muodostuvat?

HUOLTOVÄLI:

19. Mitä pitäisi huomioida huoltovälejä mietittäessä?

20. Miten moottorin/generaattorin huoltoväli on riippuvainen muun laitoksen huolloista?

21. Yleinen arviosi siitä, millainen suhtautuminen huoltoihin ja niiden tärkeyteen on?

TARKASTUSVÄLI:

22. Miten usein tarkastuksia tehdään?

23. Millaisia tarkastuksia tehdään?

24. Kenen toimesta tarkastuksia tehdään?

25. Ovatko asiakkaat kiinnostuneita investoimaan esimerkiksi ABB LEAP ja MACHsense mittauksiin?

## Appendix 2: External interview (in Finnish)

KÄYTTÖOLOSUHTEET:

1. Asettavatko laitoksen käyttöolosuhteet (lika, kosteus, lämpötila, mekaaninen rasitus) erikoisvaatimuksia moottoreille/generaattoreille? Millaisia?

2. Aiheuttavatko laitoksen käyttöolosuhteet moottorin/generaattorin käyttöön liittyviä ongelmia?

3. Yritetäänkö käyttöolosuhteiden vaikutuksia minimoida laitoksessa? Miten?

KÄYTTÖ:

4. Millaisia käytettävyystavoitteita laitoksella on?

5. Kuinka pitkään tahtimoottorin/generaattorin tulisi toimia tauotta?

6. Käytetäänkö tahtimoottoria/generaattoria sykleissä vai jatkuvasti?

7. Jos käyttö on jatkuvaa, katkeaako se normaalisti vain vikatilanteessa tai suunnitellun alasajon yhteydessä?

8. Jos tahtimoottoria/generaattoria käytetään sykleissä, minkä pituisia syklit ovat?

9. Millaisella teholla tahtimoottoria käytetään?

KRIITTISYYS

10. Asteikolla 1-5, kuinka tärkeässä osassa tahtimoottori/generaattori on koko laitoksen toiminnan kannalta tarkasteltuna?

11. Johtaako tahtimoottorin/generaattorin rikkoutuminen tuotannon pysäytyksiin tai tuotannon alenemiseen?

12. Onko tahtimoottorilla/generaattorilla redundanssia?

13. Onko tahtimoottoreille/generaattoreille varakoneita?

14. Jos ei, mitä esteitä varakoneen hankinnalle on?

15. Onko tahtimoottoreille/generaattoreille kapitaaliosia, kuten vararoottoria tai varastaattoria?

**Appendix 2 (cont’d)**

16. Jos ei, mitä esteitä kapitaaliosien hankinnalle on?

17. Onko moottoreille/generaattoreille varaosia sitella?

18. Millä perusteella varaosat valitaan sitelle?

19. Kuinka tyypillisesti varaosatarve johtuu koneen alhaalla olosta ja kuinka usein siitä, että täydennetään varastoja?

20. Kauanko tahtimoottori/generaattori saa olla suunnittelematta alhaalla (vikaantumisen yhteydessä)?

21. Mihin laitoksen prosesseihin vikaantuminen vaikuttaa?

22. Millaisia suoria ja mahdollisesti epäsuoria taloudellisia menetyksiä vikaantumisesta seuraa?

HUOLLOT JA TARKASTUKSET

23. Kuinka usein laitoksessa / prosesseissa on suunniteltuja huoltoseisakkeja?

24. Kuinka usein laitoksessa / prosesseissa on ei-suunniteltuja seisakkeja? Millaisia syitä niihin on?

25. Kuinka usein tahtimoottorin/generaattorin ja käyttölaitteen toiminnassa esiintyy suunnittelemattomia seisakkeja? Millaisia syitä niihin on?

26. Kenen toimesta huollot ja tarkastukset tehdään tahtimoottoreille/generaattoreille?

27. Kuinka usein huoltoja ja tarkastuksia tehdään tahtimoottoreille/generaattoreille?

28. Mitä tekijöitä tulee huomioida laitoksen huolto-ohjelmaa suunniteltaessa?

29. Entä tahtimoottorin/generaattorin?

30. Kuinka kauan tahtimoottorin/generaattorin huolto saa kestää suunnitellun huoltoseisakin yhteydessä?

**Appendix 2 (cont'd)**

MUUTA

31. Oletteko tyytyväisiä ABB:n elinkaaripalveluihin?

32. Miltä osin ABB voisi kehittää elinkaaripalvelujen tarjontaa?

33. Olisitteko kiinnostuneita tekemään huoltosopimuksia ABB:n kanssa? Millaisia?

34. Olisitteko kiinnostuneita tekemään muita elinkaaripalveluihin liittyviä sopimuksia ABB:n kanssa? Millaisia?

35. Ovatko ABB:n tarjoamat mittausmenetelmät ABB LEAP ja MACHsense teille tuttuja?

*ABB LEAP: Life Expectancy Analysis Program, analyysillä saadaan tietoa staattorikäämityksen kunnosta ja sen jäljellä olevasta eliniästä. Näiden perusteella staattorikäämitykselle voidaan laatia todelliseen kuntoon* perustuva, optimoitu kunnossapitosuunnitelma.

*ABB MACHsense: valvoo keskeytyksettä kunnosta kertovia tunnuslukuja, jotka kertovat sähkömoottorin tai generaattorin pääkomponenttien tiloista (roottorikäämitys, laakerointi, asennus) sekä erilaisista lämpenemisilmiöistä.*

36. Olisitteko kiinnostuneita näistä mittaustekniikoista?