Industrial Involvement in Ancillary Services

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Power networks are undergoing major transitions that create new challenges in maintaining a reliable supply and operational safety. Provision of ancillary services from untapped industry sources has been considered as a possible solution. This study highlights the importance of increased industrial involvement and introduces Ancillary Service Provision Methods which facilitate the utilisation of industrial resources in the provision of ancillary services.

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System Responsibility

All equipment in the power system itself and connected systems are adapted and optimized to the given levels within the critical parameters of the supplied electricity. In order to create a safe, stable and reliable operation of the system, these parameters must be maintained within a predefined range. The exact definition of the preferred range and desired properties vary according to their location in the grid. The desired properties and ranges in the transmission and distribution systems can be summarized in the concepts of Power System Stability[1] and Power Quality[2].

The procedure of maintaining the desired values of the electricity parameters and ensuring system reliability can be summarized in the concept of system responsibility. This is a general responsibility shared by all power system operators regardless of voltage level. To fulfil this responsibility the power system operators can use the following assets: a robust power grid, correct planning of production and ultimately the use of ancillary services[1].

Ancillary Services

Ancillary services can be described as the set of services and functions necessary to support the secure and reliable operation of the power system[3]. The power system operators can use ancillary services provided by a third party themselves or implement technical solutions such as grid assets and components connected to the grid[4].

Traditional Providers

Traditionally these services have been provided by centralized large scale electricity production, and then mainly by generators[3]. In Sweden for example more than 90% of the automatic frequency regulation currently is provided by hydropower[5]. However, some of the ancillary services also require network devices[3].

A Power System in Change

The power system and especially the balancing procedure in the EU and the Nordic countries is currently undergoing a major change, with the main drivers being: climate policies, European integration, and technological development.

An example of the effects from climate policies comes from the current political decisions within the environmental area in Sweden. The Swedish government has, in addition to the 17 sustainable development goals in “Agenda 2030” from the European Union, created 16 environment quality goals. One of these goals, particularly connected to the power system, is “limited climate impact”. This goal is then further defined in the political climate framework in the form of a set of stage goals[6]. The stage goal for 2045 state that Sweden should have net zero emissions of greenhouse gases, and subsequently net negative emissions[7]. In addition to this, a majority of the parties in the Swedish parliament have agreed on a common plan to reach a 100% renewable electricity production by the year 2040[8].

Due to rapid cost reductions for wind and solar production, these technologies are likely to represent the majority of new installed power production. From these two technologies, wind is the energy source that demands the lowest electricity price to incite new construction and therefore become the power source that is expected to increase the most[9]. In scenarios created by Svenska kraftnät, the production from wind is expected to increase from 27 TWh in 2020 to between 82 and 102 TWh in 2040[9].

The European Commission has released a series of regulations called the Clean Energy for all Europeans package. The aim of the package is to increase competition and consumers’ choices for buying clean electricity at reasonable prices. One step in the development of the European markets is an increased integration of the power markets between different member countries. The regulations in the package concern a wide range of areas in the power sector. And an area where bigger changes are expected in the coming years is within power balancing and ancillary services[10].

The recent technological advancements within the areas of IT, digitalization and Big Data enable more automation of the balancing markets. This increased automation in turn enables smaller bid sizes and shorter time intervals in the market solutions. These changes ultimately enable players with smaller assets to participate in the balancing markets and in the provision of ancillary services[11].

Introduced Challenges

The changes taking place in the power system bring the benefits of an increased decarbonization, a fairer power market and possibilities of a more efficient system operation. On the other hand these changes also introduce challenges that have not been faced before.

Due to the stochastic variations in wind production and diurnal variations from solar, concerns are expressed about the operation of the future power system. These concerns are partly related to frequency stability, a part of the Power System Stability that has shown a destabilising trend in the Nordic system. The amount of minutes with frequencies outside of the normal operation interval almost doubled between 2003–2017[11].

Another challenge is introduced by the expected decommissioning of nuclear power. In Sweden all remaining reactors are expected to be decommissioned after a service life of 60 years. Which means a successive decrease of nuclear power from 2035 to 2050. Scenarios created by the Swedish Energy Agency also predict that new investments in nuclear power production during this time would be unprofitable and are therefore deemed unlikely[12]. The decrease of nuclear power in the production mix considerably decreases the amount of inertia in the system, which is an important asset in the effort of creating a stable frequency. Another important benefit of the nuclear power generators is the ability of voltage regulation. In Sweden this has been a very important feature because of the geographical position and the high availability[1].

These new challenges mean that new resources capable of providing ancillary services are essential.

New Providers

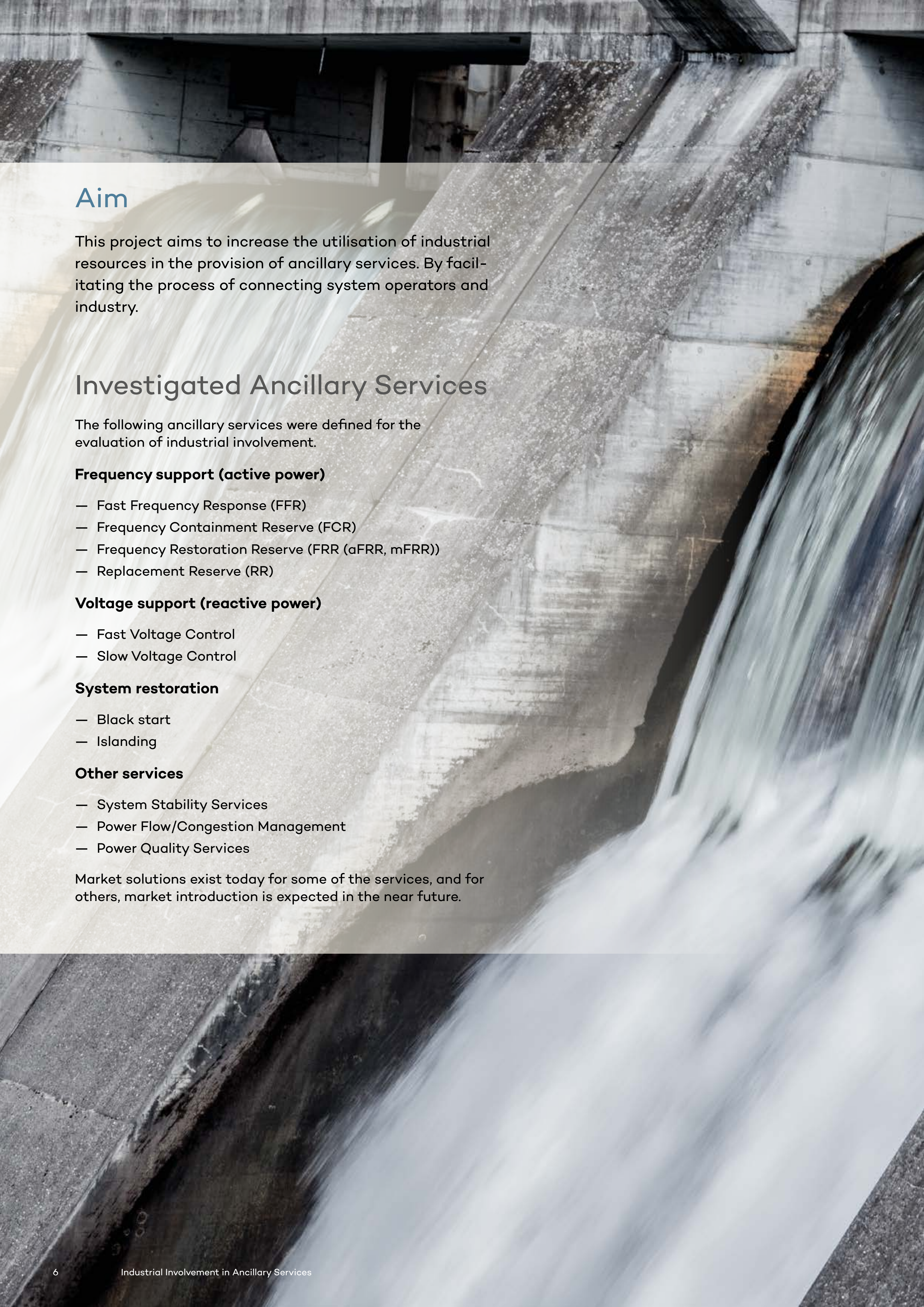
The Swedish Energy Market Inspectorate (Ei) contends that a greater involvement of the consumer side of the market in provision of ancillary services is essential for a continuous efficient operation of the power system[13]. A large part of the electricity consumption is derived from industrial applications, and the share of consumption from industry is expected to increase. In Sweden industry currently consumes 37% of the country's electricity and this number is expected to climb to 49% by 2050[14].

It is evident that consumers will be important for provision of ancillary services and that industry is a large stakeholder in the consumer segment. However, it has also been demonstrated that the technical potential as well as the economical potential of ancillary service provision from industry is vast.

For example, studies have shown that the mechanical pulp and paper industry in Finland alone could provide up to 20% of the yearly requirement for regulating power at a price for regulating power corresponding to 1,6–2 times the days average spot price[15].

Even though there is an enormous potential for industry to provide ancillary services, the participation remains low. This concern has been addressed in several studies and a commonly stated reason is the lack of knowledge. Both from the power system operators' side, to know what the technical possibilities in industry are and from the industry side, to know what the needs in the power market are[16].

"Another challenge is introduced by the expected decommissioning of nuclear power."



Aim

This project aims to increase the utilisation of industrial resources in the provision of ancillary services. By facilitating the process of connecting system operators and industry.

Investigated Ancillary Services

The following ancillary services were defined for the evaluation of industrial involvement.

Frequency support (active power)

— Fast Frequency Response (FFR)
— Frequency Containment Reserve (FCR)
— Frequency Restoration Reserve (FRR (aFRR, mFRR))
— Replacement Reserve (RR)

Voltage support (reactive power)

— Fast Voltage Control
— Slow Voltage Control

System restoration

— Black start
— Islanding

Other services

— System Stability Services
— Power Flow/Congestion Management
— Power Quality Services

Market solutions exist today for some of the services, and for others, market introduction is expected in the near future.

Ancillary Service Provision Methods

The first step of facilitating the connection and increasing the understanding between system operators and industry, is the introduction of a method called Ancillary Service Provision Methods (ASPM). The basic idea is that industries should be able to identify processes and equipment that they possess and can use without having to consider market demands or requirements. A schematic representation of the method is displayed in Figure 1.

Figure 1. Structure of the applicable Ancillary Service Provision Methods in industry

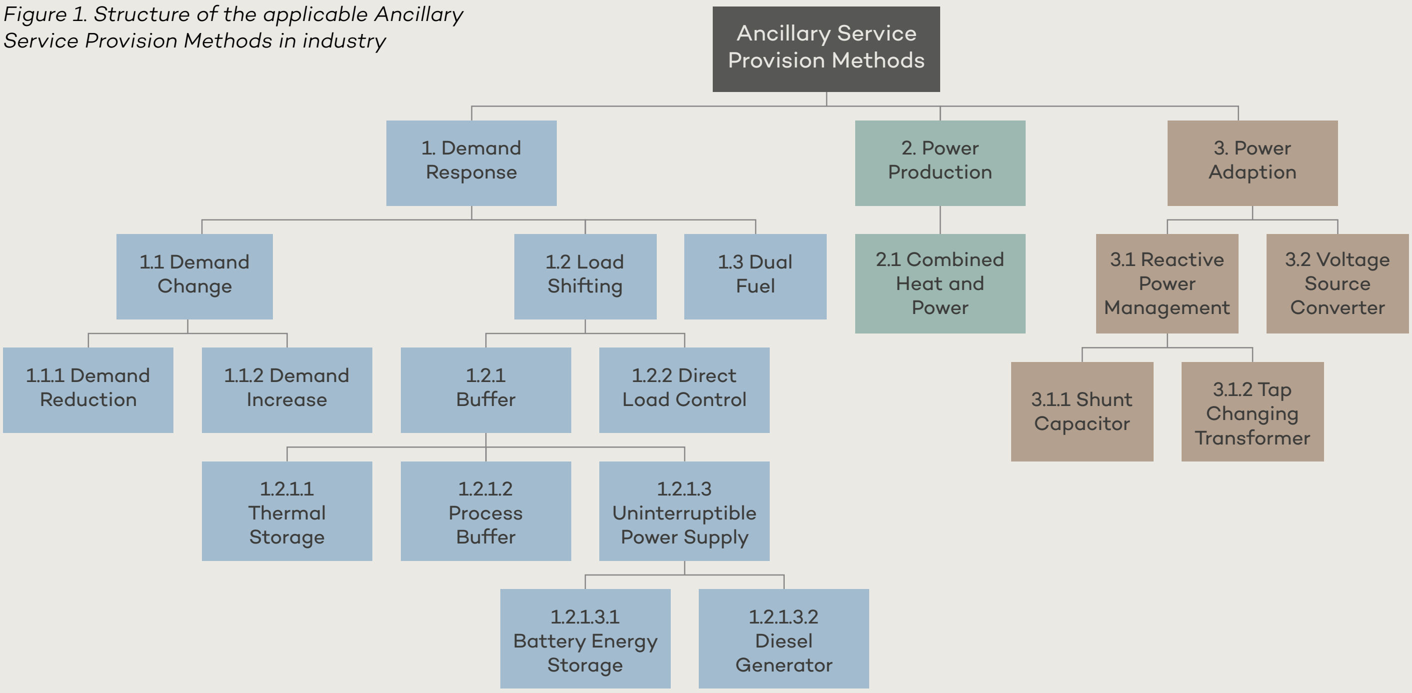


Figure 1 describes the different ASPM that have been defined in the study. The ASPM are proven methods that are able to provide or are currently being used to provide ancillary services. There are even more methods available for provision of the services. However, a restriction has been made to only include ASPM that can be realised by the use of existing or planned equipment and processes that contribute to the product or service produced in industry.

The ASPM are divided into three main categories: Demand Response, Power Production and Power Adaption. Demand Response refers to actions taken by power consumers to adjust their demand according to network needs. The Demand Response category is then further divided into subcategories as illustrated in Figure 1.

Power production is the category that historically has been the main contributor to the balancing of the electricity system and provider of ancillary services. Because of the restriction to only include methods that are vital for the process, only Combined Heat and Power is included as possible ASPM.

The third main category, Power Adaption refers to equipment that is used to adapt the power supply to the specific demands and defined parameters needed for correct functioning of the production units and the process. With the main parameters being frequency and voltage.

As mentioned above, the introduction of ASPM is an attempt to overcome the identified barriers for utilisation of the full potential of industrial processes in ancillary service provision.

Method Evaluation

The method has been evaluated through a series of interviews in autumn 2019 with industries active in Western Sweden. The selection of industries consisted mainly of electricity intensive segments including pulp and paper, steel and metal, chemical, and refineries. Furthermore, segments with large potential for electrification, including cement and harbours, were interviewed. The last main category contained segments with the possibility to aggregate the effect of smaller loads, called Virtual Power Plants (VPP). These segments include real estate owners and power system operators. The responses have been compared to ancillary services selected in this study.

To evaluate if a certain ASPM is suited for provision of an ancillary service, a set of criteria is applied. The various criteria are derived from both the provision regulations in the ancillary service markets set by the Nordic TSOs and from identified barriers to participation in ancillary service provision. The evaluation criteria are further explained in the following list:

— **Capacity**: refers to the active power of the installed equipment that can be controlled.

— **Full Activation Time (FAT)**: refers to the time from activation signal to full activation of the resource capacity.

— **Duration**: refers to the time duration that the resource can be activated.

— **Quality**: meaning that the quality of the produced product or service should not be affected by activation of the resource.

— **Control**: refers to the possibility of controlling the resource independently of the remaining process and when needed, automatically.

— **Risk**: concerns the risk that activation of the resource would lead to damaged equipment (with process failure or decreased efficiency as result) or personnel.

— **Equipment**: refers to the necessary equipment or hardware that is installed and can be utilised.

Enabling Technologies

Throughout the interviews, the following examples of different characterising industrial processes or equipment have shown their potential to be used to realise the different ASPM:

— **Demand Reduction:** the method has been examined to be relevant mainly in the steel industry where an electric arc furnace is used.

— **Demand Increase:** the possibile use of the method has been observed in the steel and metal segment with the use of the electric arc furnace, as well as in mechanical pulp and paper where electric boilers could be used.

— **Thermal Storage:** the main equipment for thermal storage are hot water accumulators, other possible equipment is Phase Changing Materials (PCM) found in real estate companies for cooling and steam accumulators used in mechanical pulp and paper.

— **Process Buffer:** are found when a decoupling between different steps of the production is needed.

— **Battery Energy Storage (BES):** potential has been identified in backup systems to ensure uninterrupted supply, other applications are increased utilisation of solar in real estate companies and relief of strained grids in both grid operators and industry.

"Power production is the category that historically has been the main contributor to the balancing of the electricity system and provider of ancillary services."

- **Diesel Generator:** are installed for a number of applications to ensure important functions such as extinguishing water supply, cooling pumps, fans, compressors and control systems.
- **Direct Load Control:** has been observed mainly in small loads that have less direct effect on the main process such as ventilation, heat pumps, cooling machines, fans and stirrers.
- **Combined Heat and Power:** the possibility to produce power as an integral part of the process has been found in mechanical pulp and paper and in chemical pulp, then in the form of back pressure steam turbines.
- **Dual Fuel:** can be provided from processes that can be supplied both by electricity and an alternative energy source. This has been observed in refineries where pumps can be electric or driven by a steam turbine. Other processes include steam production in mechanical pulp and paper where both electric boilers and biomass furnaces can be used.
- **Shunt Capacitors:** are installed in almost all industries.
- **Tap Changing Transformers:** all companies in the electricity intensive segment and grid operators have tap changing transformers.
- **Voltage Source Converters:** mainly connected to relatively small loads such as pumps and fans.

Conclusion

The study has confirmed that the potential from industry to provide ancillary services is substantial. By the introduction of the ASPM, it has been shown that industry can deliver ancillary services for a wide range of needs. Not only from the traditional active power balance, but also in voltage support, system restoration and other services. The study has however, also confirmed that the utilisation of industrial resources is currently low, although the interest from both industry and power system operators is high.

Previous studies have revealed that electricity intensive industries in the processing industry have the highest potential of participation in ancillary service provision. However, the investigation of motivation for participation in provision of ancillary services indicates that these segments are sensitive to changes and might demand a high price of activation. However, five trends have been observed that should incite industries to reconsider the risk and re-evaluate their interest in providing ancillary services.

— The recent introduction of new regulations created by the European Commission are widespread and likely to be consistent for a long period of time.
— The study was performed in a system situated in the west of Sweden that benefits from large amounts of cheap regulating hydro power. This implies that the result, in which industrial involvement is technically and economically viable, has even greater potential in regions of the world with less available hydro power.
— Changes of production in the transition towards renewables and of consumption patterns due to electrification of industry and transport increase the need for ancillary services and increase the market potential.
— Economic and environmental drivers are pushing the electrification of industry which brings new and greater opportunities to provide ancillary services from processes that have inherent load shifting potential. These include electrolysers that produce hydrogen for chemical-, refinery- and steel making industries, as well as heat production in process heat, electric arc furnaces and plasma torches
— New markets aiming to include new providers of ancillary services are emerging across the globe, several examples are integrated in the **CoordiNet** project.

These trends also affect a segment that has gained little notice thus far on ancillary service provision – real estate companies. It is a segment whose process is insensitive to short time changes, and where an involvement in ancillary services could create positive profile value. In addition, the equipment in the real estate sector can offer modulated control through interconnected and smart control systems making it and electricity intensive industries very interesting candidates in future provision of ancillary services.

The study shows that the introduction of ASPM and the mapping and linking of industrial segments to ancillary services can facilitate a procedure for identifying not only internal processes for industries but also potential providers of ancillary services for power system operators. Above all, it exposes a tremendous potential to increase the utilisation of industry for provision of ancillary services.

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For further information about the subject discussed here and AFRY's services in Sweden, please contact:

Simon Nilsson

Technical Consultant
M: +46 72 205 65 71
simon.nilsson@afry.com

Anne Grevener

Analyst
Management Consulting
M: +46 72 233 84 81
anne.grevener@afry.com

Tord Karlberg

Head of BU Transmission & Distribution Sweden
M: +46 76 787 52 32
T: +46 10 505 30 91
tord.karlberg@afry.com

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