CLEEN innovations

How collaboration is supporting ABB's research and development work

JUKKA TOLVANEN, TERO AHONEN, JUHA VIHOLAINEN – In the past, innovations like the light bulb and the telephone often originated from individual people like Thomas Alva Edison and Alexander Graham Bell. Today, innovations still need innovative people to surface, but rather than a one-man show, cooperation and consortiums of various competences are often required for the development of new ideas. Within ABB, there is already a huge technical competence, and the potential to utilize global presence combines with knowledge of customer needs worldwide. ABB also benefits from cooperation with companies and universities in the development of new technology and services.

According to the well-known saying, “two heads are better than one.” In the fields of engineering and technology, development of new ideas may require diversity of know-how and therefore cooperation between different companies and organizations. For instance, innovations on how to improve the energy efficiency of electrical systems clearly require technical expertise, but also economical and social expertise in order to obtain totally new and feasible products and services.

Respectively, technical expertise may be required from several areas of engineering, requiring the participation of several companies. As a single company may hold world-class competence only in certain areas, cooperation between different companies and organizations can be the most feasible approach for new ideas and innovations, which may cover several different business segments.

Consortium provides foundation for research

Even though cooperation can be feasible, certain rules need to be fixed beforehand. For instance, intellectual property (IP) and financial issues need to be clear from day one in order to ensure sustainable and mutually beneficial cooperation.

One solution to deal with these issues is to have a common research center or community to manage R&D activities. In Finland, the strategic center for science, technology and innovation in the energy and environmental sector (CLEEN Ltd.) has been founded to catalyze international and cross-industrial cooperation in the energy and environmental technology fields. As a limited company owned by global companies and the most relevant national research institutes and universities, CLEEN facilitates cooperative knowledge building and the creation of innovative solutions, technology and services that are beyond the R&D capabilities of a single company or area of industry [1]. Two-thirds of CLEEN’s 44 owners are private companies including several global technology and market leaders, like ABB, Metso and Wärtsilä. ABB is one of the founders and an active member in CLEEN’s operations that has provided new possibilities for cooperative research with other companies, organizations and research institutions.

This kind of joint venture also improves the possibility of receiving external funding, which is often essential for wide research consortiums executing long-term (eg, three to five years) research. In Finland, the main public sponsor is the Finnish Funding Agency for Technology and Innovation (Tekes). Tekes supports a consortium of companies and research institutes with its new innovation program. This kind of support enables a change in the innovation culture from a one-company show to network-based open innovation.

Modern cooperation between companies and universities

CLEEN is part of a major overhaul of the Finnish innovation system. To advance this goal the Finnish government has initiated six centers for strategic science, technology and innovation that are exclusively owned and run by industry and academia. CLEEN is the one that concentrates on energy and environment.

According to Tommy Jacobson, CEO of CLEEN, the company strives to enhance open innovation between companies, universities and research institutions. It works as a network through which the participating international companies can conduct R&D work gaining new knowledge on a faster and deeper basis than would be possible by acting alone.

Jacobson explains that cooperation is more strategic for the companies involved when they allocate their own R&D human resources for several years and are willing to share their results, rather than just allocating funding for outsourced proprietary R&D. Such industry involvement also ensures wide interfaces for knowledge transfer, innovations and guidance.

An effective way to develop the programs has been found: First the companies define the theme that they consider important for their future businesses and for which they would be willing to allocate their own resources and share the deliverables. Then the universities and research institutes respond to this market pull with their research initiatives, creating a reciprocal science push. Jacobson points out that this also saves resources at the universities as they do not have to waste time on completing research applications that typically have a low success rate, but instead receive feedback that is immediate, interactive and iterative.

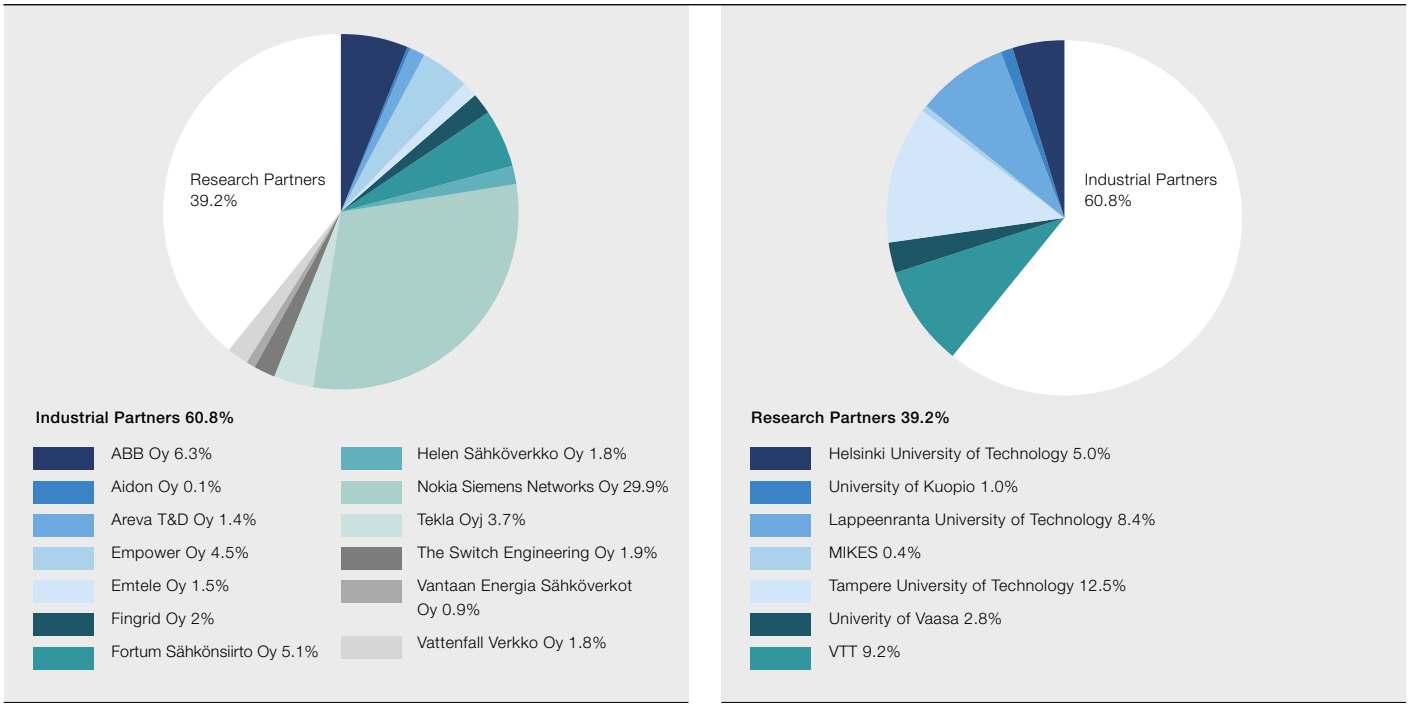
> CLEEN Ltd. has been founded to catalyze international and cross-industrial cooperation in the energy and environmental technology fields.

One major research area focuses on the energy markets and smart grids. Here the main contributors are Nokia Siemens Networks and ABB. Other areas on the agenda are, for instance, efficient energy use and distributed energy systems.

Smart grids and energy markets

A smart grid delivers electricity from many suppliers to consumers using two-way digital technology and an intelligent monitoring system that keeps track of the electricity flows in the system. Smart grids enable controllable multidirectional power flows on both a local and long-

1 Smart grids and energy markets (SGEM)



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distance scale. Compared with traditional electric grids, smart grids enable more efficient use and control of distributed electricity generation, and the intelligent use of electric car batteries as a part of the electrical distribution system. Research topics in the smart grids and energy markets (SGEM) program are:

- Future infrastructure of energy systems
- Intelligent management and operation of smart grids
- Customer gateways
- Development of energy and emission services allowed by the smart grid technology

The goal of the SGEM research consortium is to develop international smart grid solutions that can be demonstrated in a real environment utilizing Finnish R&D and innovation infrastructure. At the same time, the benefits of an interactive international research environment will accumulate know-how of the world-leading information communication technology (ICT) and smart grid providers. This consortium program has several participants from industry, research institutes and universities as shown in → 1. The industrial participants cover the areas of electricity generation and distribution, telecommunications and information technology. The research partners consist of five Finnish universities and two research institutes (MIKES, VTT). The time frame of this project is five years.

Efficient energy use

The efficient energy use (EFEU) program focuses on the development of methods that can improve the energy efficiency of devices and systems. The target sectors are industry and service where approximately 60 percent of the total produced energy is consumed. The primary goals of the research program are to:

- Develop new methods, business processes and systems that help to achieve radical improvements in energy efficiency
- Develop new methods that produce significant energy efficiency improvements with minor investments
- Create a national R&D network for energy efficiency development

Due to the cross-scientific nature of the topic, the expertise and active participation of different parties – such as the manufacturing industry, device manufacturers, service companies, engineering companies, universities and research organizations – is required. The time frame of the research work is three to 10 years before the product phase or service phase. The main results of the research will be innovative system concepts, dimensioning rules, methods for measuring and evaluating the system's energy efficiency, and energy-efficiency-related solutions and services. The research ideas will be piloted in demonstrations and will be later used in more application-oriented development work.

2 Research facilities at LUT for pumping systems

Innovations via academic research

Besides consortium programs, direct collaboration between industry and universities can be a fruitful source of innovation and new technology. Often cooperation between universities and industry provides synergy for both parties, as universities may have and suggest interesting research topics, and product manufacturers may benefit in the form of innovative R&D and testing of new ideas with universities' test facilities. This kind of cooperation has been successfully carried out between ABB and Lappeenranta University of Technology, Finland (LUT) in the field of electric motors and variable-speed drives (VSDs), which are an essential solution to improve the energy efficiency of rotating machinery.

Founded in 1969, LUT provides education and research in the areas of engineering and economics. The university's areas of strength include energy efficiency and the energy market, strategic management of business and technology, scientific computing and modeling of industrial processes, and expertise in Russian business and industry related to the above areas [2].

As the university has test facilities for pumping systems and electric motors, and strong expertise in the energy efficiency of these appliances, LUT has been able to carry out academic research, which has also helped with the R&D of new ABB products. Both direct torque control (DTC) of permanent magnet synchronous machines (PMSMs) and sensorless flow rate estimation for centrifugal pumps have been studied at LUT → 2 [3,4]. These research topics have resulted in several patent applications, scientific publications and also direct feedback to ABB's R&D team for drives.

Consequently, the research expertise of LUT has provided a good basis for cooperation with ABB on electric motors and variable-speed drives. In practice, the cooperation has been carried out at the Carelian Drives and Motor Center (CDMC), which is a part of the electrical engineering department of LUT. For ABB, this approach allows the development of innovative ideas with researchers in academia, and also the testing of upcoming products.

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For CDMC, this cooperation has provided an excellent source of new research topics and the possibility of extending its expertise in the area of energy efficiency of electric motors, VSDs and rotating machinery. The cooperation has allowed CDMC research staff to be innovative participants in the research and development process of new products and services. Depending on the project, the results of the research can also be published as PhD theses and journal articles, or in the form of patent applications. The research projects have been related to the control methods of VSDs, efficiency improvements of electric motors, and the control and diagnostics of rotating machinery such as centrifugal pumps.

Cooperation with other companies and universities often brings new and innovative ideas. One example of this can be seen in the following article "Audit benefits." R&D collaboration therefore should not be overlooked, as more extensive research projects can be formed and expertise from different areas can be utilized in the research. Whether this is reached through consortium research with other companies and research institutes or through direct collaboration with universities or research institutes, there are benefits for all concerned.

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Audit benefits

ABB and Lappeenranta University of Technology are collaborating on an energy audit project for more efficient and durable pumping systems.

The energy audit project (EAP) at Lappeenranta University of Technology (LUT) was started in autumn 2008. An energy audit is an analysis of the energy consumption of a given process or a system → 1. The clients are energy consumers mainly in industrial fields. The auditing process concentrates on finding inefficiently operating applications with rotating electrical machinery and such cases usually involve pumps.

The EAP is funded by ABB and run by LUT's Institute of Energy [1]. This project is the result of a long-lasting cooperation between ABB and LUT, especially in the field of researching the efficiency of pumping systems. The project has provided special knowledge about the energy efficiency of pumping applications. In addition, specific simulation tools to determine the energy efficiency of pumping systems were developed during this project.

Auditing industrial energy usage

The main goal of this project was to create an easy-to-use method for auditing from which all participants could benefit. The aim of the audit is to obtain information about the energy consumption of the system in its present state and to identify the factors affecting it. The second step is to identify the economic opportunities for improving the efficiency of the system and achieving cost savings. The end product of the audit is an action plan on how to achieve improved energy efficiency.

Significant results in research and development for pumping applications

The advanced use of variable-speed drives (VSDs) in the diagnostics of centrifugal pumps has been studied at LUT since 2005, when accuracy of the sensorless flow calculation function available in ABB's industrial drives was tested in laboratory facilities. Test results were then published in World Pumps journals in 2005 and 2006.

As VSD are capable of estimating motor operation without sensors on the motor shaft, they can also be used to estimate the operation of a pump or other load of the motor. For instance, the sensorless flow calculation function available in ABB's industrial drives utilizes the internal rotational speed and shaft power estimates of the drive to inform the user about the pump flow rate without additional sensors on the pump. This function can be used in an application where the pump flow rate is required information, but it is not applied for revenue metering.

Research projects have also been carried out to find new ways of detecting cavitation [1] and for energy-efficient control of parallel-driven pumps. These studies permit the main causes of pump failures to be eliminated, and the total energy consumption of pumping systems to be substantially decreased.

More durable and energy-efficient pumping systems

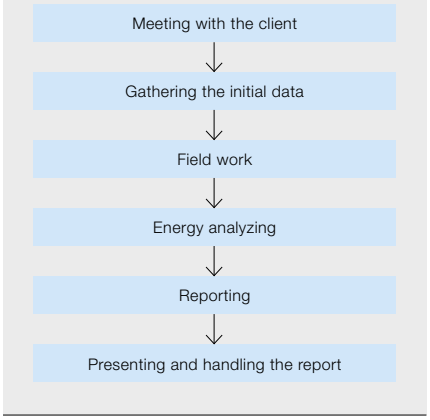
The sensorless detection of cavitation is based on the intelligent analysis of the converter estimates to determine

Significant energy savings could be achieved using advanced variable speed control with parallel-connected pumps.

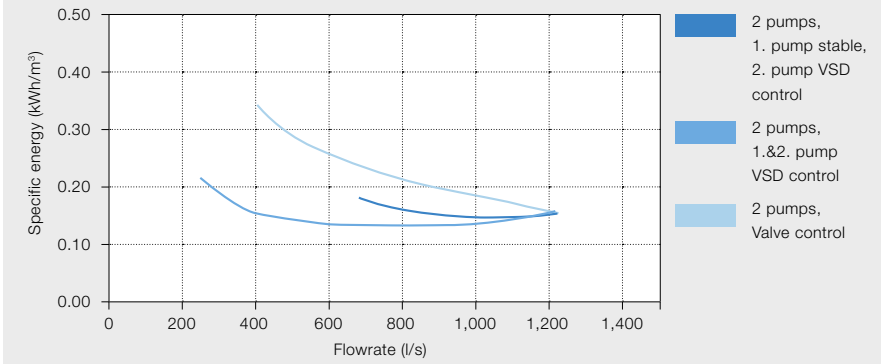
Footnote

1 Cavitation is the formation of gas bubbles in flowing liquid due to the pressure of the liquid falling below its vapor pressure. Shock waves caused by the rapid collapse of such bubbles can damage surfaces.

1 The LUT energy audit procedure



2 Specific energy consumption of different flow control methods for two parallel-connected centrifugal pumps



the abnormal operation of the pump. In the case of centrifugal pumps, cavitation is one of the widely known reasons for decreased pumping efficiency and pump failures. Because of this, several methods to detect cavitation have been developed. However, they are typically based on additional measurements that decrease their feasibility in several cases. The installation of sensors may be costly and the amount of pumps that should be monitored may be so high that it is reasonable to have a condition monitoring system for only a few pump drives. For this reason, sensorless cavitation detection can provide real benefits to the user, as there is no need for additional sensors and installations [2].

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In the case of parallel-connected pumps, their intelligent control by VSDs can provide substantial cost savings due to the lowered energy consumption. As parallel-connected pumps are often operated by applying the off/on control method, there is a huge savings potential by operating the required amount of centrifugal pumps at a lower rotational speed compared with the traditional off/on control method. This has been verified by test measurements carried out at LUT.

Several real-life research cases have also been conducted in industrial raw water pumping applications, power plants and municipal water stations. The results have shown that significant energy savings could be achieved using advanced variable speed control with parallel-connected pumps. One example of how the VSD can reduce specific energy consumption of two parallel operating centrifugal pumps is shown in ➔ 2. With the variable-speed control for both pumps, specific energy consumption can be minimized at lower flow rates [3].

Results of these research projects demonstrate the benefits of collaborative research and development: By combining the expertise of project participants, new solutions allowing efficiency improvements and cost savings can be more easily developed than by acting alone.

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