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# Hyosung Heavy Industries Power Technology Magazine



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## New Year's Message

**Hyosung will lead the power market with products and services that have high added value and competitiveness, which can innovate the power grid operating system.**



Happy New Year, everyone.

Last year 2020 was a tough year that was unprecedented in human history. COVID-19 that spread around the world at an unexpected rate has restricted cross-border movements, seriously affected our lives, and rapidly shrunk the global economy. On the other hand, this COVID-19 world has also brought us new opportunities. As in-person activity and human contact decrease, the market for products and services incorporating contactless and digital technologies is growing significantly.

The year 2021 will be a very important time to prepare for a world that will change after COVID-19. As the shift to a virtual, contactless world is accelerating in all fields, the digitalization of the energy industry will open up new opportunities for the entire energy value chain, enabling new business models and creating value on an unprecedented scale. In the future, the success of digital transformation will be the key to the long-term survival of a business.

Since our founding, Hyosung has strived to increase the social, environmental, and economic values of customers and contribute to improving the corporate values of customers and the overall quality of people's lives. We have boldly innovated our business based on various new technologies. With a variety of products that make the most use of their characteristics and an array of services that help unlock more opportunities, Hyosung enables customers' power grid innovation.

Transformation to eco-friendly/renewable energy is also an irreversible trend. As increased focus on the environment grows, countries around the world are declaring carbon neutrality and maintaining the stance of energy conversion by reducing fossil fuel generation and expanding renewable energy. The landscape of energy infrastructure is rapidly evolving due to changing social and customer environments, increasing demand for new financing strategies, and more participation opportunities for government agencies. In line with these social changes, Hyosung will lead the power market with products and services that have high added value and competitiveness, which can innovate the power grid operating system. I hope that in the new year, everyone will detect the signs of change hidden in the crisis and discover new opportunities through innovation.

Wishing you a very happy New Year.

Hyosung Heavy Industries Corporation

President **TAKESHI YOKOTA**



# Megatrends in the global energy transition

## ESS & STATCOM



### Changes into opportunities

Nowadays, people all over the world are experiencing epochal changes in their lives at the same time. We all know that our lives are being threatened by not only the Covid-19 pandemic but also unusual weather conditions due to climate change. National governments are competitively announcing their carbon neutrality to cope with it. This situation heralds a seismic shift in the energy paradigm. In the power supply sector, the trend for renewable energy will accelerate all over the world.

As for South Korea, the country has expanded the share of renewable energy in its entire power generation industry to about 11% (by 2019). Hyosung Heavy Industries has become a leading company in the domestic renewable energy sector, supplying Energy Storage Systems (ESS) and STATic synchronous COMPensators (STATCOM) and the relevant services as a result of successful approach to dealing with changes in the market. Besides, we have solidified our status as the country's No.1 business in terms of domestic market share of high voltage transformers and switchgears.

Our ESS is composed of a Power Conditioning System (PCS) boasting high efficiency and reliability, a Power Management System (PMS) for diverse usages, and batteries with optimal capacity and performance. We also provide a wide range of customized ESS consulting, system establishment, and Operation & Management (O&M) solutions. Looking at the country's ESS market, the government introduced the Renewable Portfolio Standard (RPS) System in earnest around 2010, resulting in the rapid growth of the domestic photovoltaic and ESS markets. At present, we are leading the domestic market with a market share of 30% (cumulative total of 0.54GW/1.8GWh as of December 2020).



We have steadily accumulated outstanding results since participating in the government-led ESS project for the Haengwon Wind Power Complex (800kW), Jeju Island in 2009, followed by the supply of an ESS (4MW/16MWh) to the Yeongheung Wind Power Complex, the country's first ESS linked to wind power, in 2015, and an ESS (7MW/18MWh) to the Yeongheung Photovoltaic Complex, the country's first ESS linked to photovoltaics, in 2017. Categorizing by function, 202 sites linked to renewable energy (335MW/1,089MWh), two sites for frequency adjustment (52MW/2MWh), 28 sites for peak power reduction (120MW/638MWh), and six independent micro-grids (4.6MW/6.5MWh).

We have also established local after-sales service centers, including Central, Western, and Eastern Centers and a factory in Sejong, where our personnel provide operation/maintenance technological support and consulting on system management. We also operate a system designed to provide a prompt service for dealing with accidents, thereby enabling our customers to operate their Hyosung ESS facilities optimally.

As for the company's global market status, we made an initial foray into an overseas market with a CLP ESS PJT (500kW) project in Hong Kong in 2012. Currently, we are carrying out projects to install and commercially operate ESSs in Oklahoma, United States (10 MW/multifunctional), in Bathgate, United Kingdom (750 kW/ multifunctional), in Nursling, United Kingdom (50MW/ multifunctional, in Senegal (10MW/frequency adjustment), and in Malaysia (2MW/peak power reduction). We are also enforcing a localization service in major overseas markets like the United States and the United Kingdom, where we run an organization centered around local engineers and sales personnel, to provide high-level front-end engineering and a prompt customer service. In the STATCOM sector, we are recording noticeable growth in the world market based on our performance at home - we were the first business to supply STATCOMs to KEPCO (Korea Electric Power Corporation) and get them up and running in record time.

A STATCOM prevents system instability in power transmission/distribution systems and maximizes power transmission capability. It also makes renewable energy sources such as wind and photovoltaics compliant with Grid Code. It eliminates power quality problems such as flicker and harmonic caused by industrial loads such as EAFs (Electric Arc Furnaces), large induction motors, and rectifier loads when they are integrated with the power system. We have supplied  $\pm 400\text{Mvar}$ —the world's largest—MMC STATCOMs to KEPCO based on the MMC technology that we developed in house.

MMC (Modular Multilevel Converter) is a high-end next-generation VSC (Voltage Source Converter) that has high-performance, low-loss, low-harmonic characteristics and provides high Reliability, Availability, & convenience of Maintenance. Based on such latest technology, Hyosung Heavy Industries analyzes the customer's power system in advance and designs and proposes the optimal system for problem solving in order to provide the best solution to the customer. Also based on our accumulated engineering capabilities, we suggest EPC solutions considering customer's profit maximization, also provide long-term maintenance/repair plans and services to satisfy the system's performance and lifespan.

The STATCOM system of Hyosung Heavy Industries has been recognized an excellence in technology and products around

the world not only in transmission network operators in India, Panama, the United States, Sri Lanka, and Peru but also in new business fields such as steel/renewables.

In recent years, the market demand for mobility of facilities is increasing, we are quickly responding to market changes by developing containerized mobile STATCOM and securing contracts for renewable energy integrated project in Japan. Mobile STATCOM will become an innovative solution to solve the temporary power load problems caused by delays in power system facility expansion, or power shortage caused by natural disasters such as hurricanes, extreme cold. In addition, it will be an economic solution for industrial/renewable customers who want to minimize EPC cost for mid-sized (less than 100Mvar) reactive power compensation.

Hyosung Heavy Industries' STATCOM division has established a manufacturing line of major components in PUNE in India and a maintenance organization in Pittsburgh, USA, and has been established as a global STATCOM professional manufacturer/integration provider and always trying to provide more satisfactory solutions by analyzing voice of customer and market trends.

### A global provider of power system solutions

Recently, the Korean government announced its Green New Deal Plan, which includes a total investment of KRW 73.4 trillion, with the aim of increasing the country's renewable energy capacity three-fold by 2025 (12.7 GW in 2019 → 42.7 GW by 2025), along with its 9th Power Supply Plan, which aims to increase the country's renewable power generation capacity to 77.8 GW by 2034. In this regard, a new market will be formed in the country actively responding to climate change issue, including the establishment of an eco-friendly power generation system for remote islands, an eco-friendly future mobility system, smart green industrial complexes, and a new market for ESSs for green energy supply systems. It is also expected that the demand for STATCOMs will increase rapidly, ultimately alleviating concerns about drops in the quality of the power supply.

As of 2021, we stand at the top of the substation-related power facilities market for power transformer and switchgear etc.

Henceforth, we will strive to grow as a business specializing in power system facilities in the global market, and to lead others in the megatrend for smart/DC grids, based on our accomplishments at home.



Jea-gune Kim  
Vice President  
Marketing Operation of  
New Business

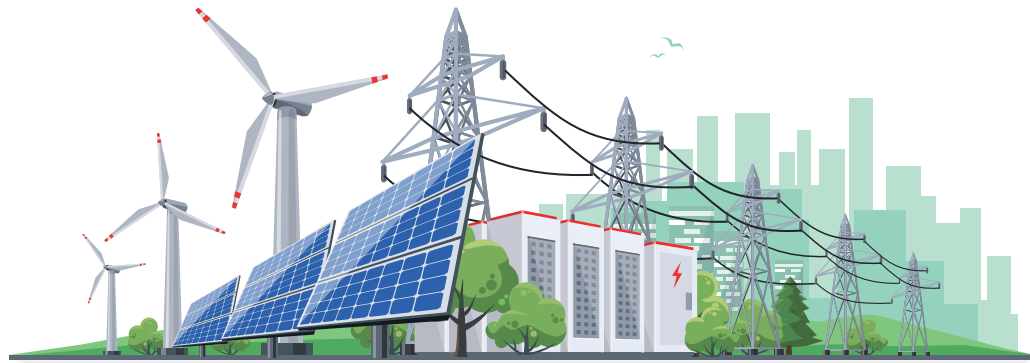


Hang-jun Yang  
General Manager  
FACTS & HVDC  
Technology Division



# A new step forward in system engineering-based energy storage and power compensation systems

## Solutions Engineering Business



Hyosung Heavy Industries' SEG (Solution Engineering Group) is moving forward with its solution-based to cope with changes in power system and electrical energy economics amid the increasing diversification of customer requirements, purchasing methods, evolution of technologies, and mega trend of 3D (digitalization, decarbonization, and decentralization).

Our SEG business will meet four major goals : **First**, we aim to expand our business focus from equipment supply to systems and services (devices, equipment packages, turnkey systems, asset management systems, etc.) This approach and expanded offerings will allow us to address the needs of private sector businesses (such as semiconductor, petrochemical factories) and renewable energy (solar photovoltaic, wind, fuel cell) power generation businesses in addition to utilities and independent power producers.

**Second**, we aim to provide consultative ideas, system configuration, and solutions (power systems for renewable energy plants, and data centers as well as mobile power systems for emergency disaster rehabilitation) based on advanced system engineering designs. This will enable Hyosung to meet our customers' diverse and growing needs amid the rapid development of technology, social and environmental changes.

**Third**, by taking advantage of advancements in power electronics technology and electricity storage technologies, we are carrying out a leading role in the Korean market by entering new business areas like reactive power compensation facilities (VSR, PST, STATCOM\*, etc.), energy storage systems (ESS), and DC network systems for more stable power supply.

**Fourth**, we are driving market creation by developing eco-friendly power equipment and digital substations to meet the requirements of the "New Normal" age.

**Finally**, Hyosung is expanding our solutions through dedicated business units in power generation/transmission/substation systems and power compensation/storage/asset management systems by offering technological services at the FEED (front-end engineering design) stage for customers asking for enhanced power system connectivity, efficiency, and reliability.

This paper introduces the engineering services and systems-based business carried out by Hyosung Heavy Industries' SEG, particularly energy storage and power compensation systems, and our technological capability for continued expansion into the global market.

## Solutions Engineering Business Model

### 1. Role of the Front-End Engineer

With the convergence of power systems with power electronics technology and IT, solutions are required to be more diverse, flexible, and adaptable. As a result, it is now possible to supply ICT-based, multi-functional, complex, and dynamic systems through the application of power electronics products, departing from the business model of simply supplying a series of products according to the customers' specifications. This early stage engineering and power system analysis is based on the VOC (Voice of the Customer), the design of new power electronics products, and the optimal solutions that meet customers' requirements. This occurs even before the selection of specifications through the use of intelligent EMS\*\* solutions. The Front-End Engineer is also responsible for solving the unknown needs of the customer by designing integrated solutions for existing products as well as new concepts that are based on communication with the customers and his/her extensive technological basis.

\* VSR : Variable Shunt Reactor / PST : Phase Shift Transformer  
STATCOM : STATic synchronous COMPensator  
\*\* EMS : Energy Management System

### [Case 1. ESS Front-end Engineering in the United States]

Recently, renewable generation such as solar photovoltaic and wind power plants have been rapidly replacing fossil fuel power plants, assuming an important role in the establishment of a new paradigm of power systems. They are also helping businesses enhance their social enterprise value by reducing their carbon footprint and generating sustainable, environmentally friendly electricity.

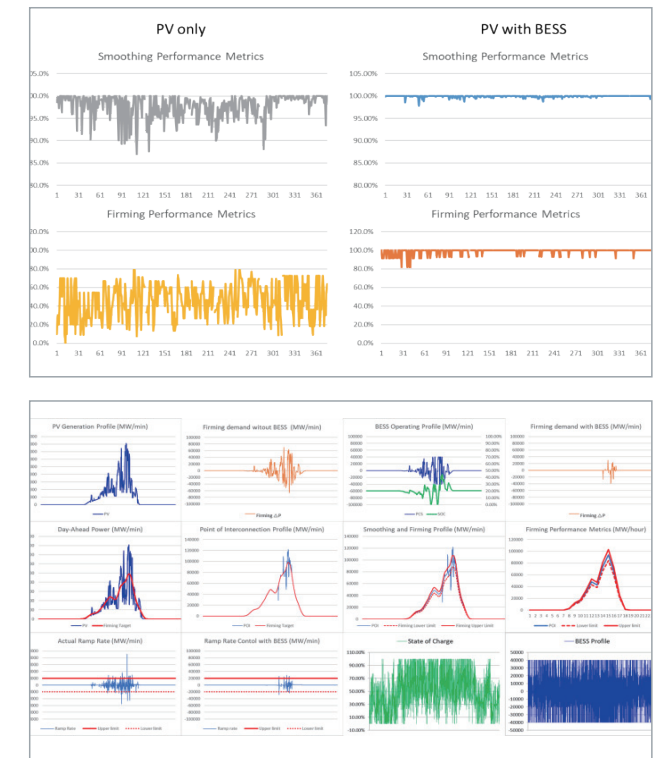
Unlike conventional fossil fuel power plants, renewable energy plants are characterized by intermittency, which poses an obstacle to their economic efficiency and profitability. However, intermittency can be controlled with the application of an ESS (Energy Storage System), whereas customer uncertainty can be minimized and profitability maximized by managing power plant operations at a predictable level.

To provide optimized solutions for renewable energy power plants, Hyosung Heavy Industries' SEG provides customers with assistance in calculating the required capacity and achieving the target performance based on analysis of their power plant's operation plans and the conceptual ESS engineering.

With regard to renewable power plants, Hyosung strives to protect its customers' profit structure by minimizing climate-related variations in output by using the ESS, thus maximizing electricity generation and helping to avoid any penalties imposed by utilities. SEG's three main roles are as follows:

- 1) to calculate the ESS capacity required to minimize TSO-related penalties by minimizing intermittency and smoothing the per-minute output of customers' renewable power plants and stabilizing the electricity generation.
- 2) to calculate the optimal ESS capacity required to maintain power generation at a fixed level, by grid-forming unstable power generation so it can be generated according to the timing of electricity sales assigned to the renewable plant.

3) to provide an ESS performance model and simulation designed around the optimal operating solution for a renewable power plant, and to maximize the customer's ESS investment based on the power supply contract.



[Fig. 1] ESS Performance Metrics & Profiles

### [Case 2. Proposed Microgrid]

A microgrid (MG) is a small-scale power system composed of generation, load, storage system, and STS (Static Transfer Switches) that can be isolated and connected with the bulk power system. The main purpose of an MG is to secure high-power quality by having the ability for the system to isolate itself in the event of power failure or power quality problem throughout the main electric grid. A representative MG system, such as a campus microgrid, encompasses several buildings of lecture halls, dormitories, and gyms, building-type photovoltaic facilities, EV charging stations, and ESS facilities. It is a small-scale power system that it is easy to establish, and it requires a stable supply of power. We have conducted front-end engineering of campus MGs in many countries based on our extensive experience. Another representative microgrid system is an island remote microgrid. Hyosung Heavy Industries has built a CFI (Carbon-Free-Island) system covering Gasa and Gapa Islands in South Korea, among others. Operated with the MGCC (Micro-grid Central Controller) playing a central role, MG maximizes economic efficiency and stability with AI including diverse algorithms.

### 2. Strengthening the Power Electronics-based Solutions Engineering Business

More than 100 years ago alternating current displaced direct current in the marketplace. The advantages of the AC equipment included advantages such as ease of converting voltage, generation of power via the rotating field, and use of inertia currently, however, another great change in the energy



system paradigm is taking place with the application of power electronics technologies using semiconductors in power systems. Power electronics technologies have enabled converting AC into DC or DC into AC with rapid switching of semiconductors and generation of the required voltage and current including filter design. Power electronics technology is used to stabilize the frequency/voltage required by the power system, and also in renewable energy power generation, which is mainly direct current. Hyosung offers its customers a variety of solutions characterized by effectiveness and economic efficiency using STATCOM products designed to improve the voltage stability of the power grid and PCS (Power Conditioning System) through which photovoltaic, wind power, and energy storage devices are linked to the utility grid.

#### [Case 1. Completion of the World's Largest STATCOM]

In 2018, on a turnkey basis, Hyosung completed all works related to the design, production, inspection, testing, transportation, installation, approval, and commissioning of the  $\pm 400\text{Mvar}$ -class STATCOM at Korea's Shin-chungju and Shin-youngju substations, the two largest single STATCOM facilities in the world, on a turnkey basis.



[Fig. 2] New  $\pm 400\text{Mvar}$  STATCOM in Yeongju

We developed a large capacity/low loss STATCOM with the installation of an MMC (Modular Multi-level Converter), a device that turns the waveform of power converted by the converter into something close to a normal AC power waveform. This is an updated technology that Hyosung developed in-house.



[Fig. 3] Hyosung's MMC STATCOM

The STATCOMs installed Shin-chungju and Shin-youngju substation serve to stabilize the power network which transmits generated power along the East Coast to other areas including the Greater Seoul Area, improving power transmission efficiency by  $\sim 10\%$ . This has made it possible to provide a more stable power supply to the Greater Seoul Area, which translates into benefits worth 300 billion won per year to customers.

#### [Case 2. Successful Entry into the United States' ESS Market]

The industrial ESS market of the United States accounts for 28% of the global ESS market. The capacity of the newly installed ESSs is 0.5 - 1 GWh per year and is expected to increase to around 4.8 GW by 2022. Hyosung supplied an ESS with a capacity of 12MW in 2019 as part of the Rush Springs ESS project in the U.S.

The system was installed for the purpose of regulating power frequency and shifting energy, and it has been operating stably and successfully.



[Fig. 4] View of the ESS Project in Oklahoma

Hyosung's established experience and capability related to renewable power generation, along with our own PCS product line recently achieving UL certification, are unmatched in the ESS industry. This successful entry into the US market, which has traditionally been resistant to Asian manufacturers, reveals the promising future of our ESS technology.

#### [Case 3. Successful Entry into the British ESS Market]

The Bathgate Project was proposed as a total containerized system with 750kW capacity.

We offer a wide range of products of different capacities that have acquired CE/UL certifications for PCS, an essential component of the ESS used for this project. During the design process, we conducted tests for the application of Grid Code (G99) in the United Kingdom. We designed and configured additional circuits to ensure that the client's requirements are met, demonstrating our technological capability to succeed in a variety of markets. Its control system operates and monitors the entire ESS by collecting information concerning the PCS and batteries. As our control system operates the ESS in its entirety, the user provides minimal commands and can deal with any errors immediately.

The containers housing the system are configured according to local fire prevention regulations. Such an integrated system reduces the elements required to be operated by the client and enables smooth and streamlined functionality.



[Fig. 5] View of the Bathgate ESS Project in the UK

Our entry into the British market, a large market with an estimated 2 GW worth of supply over the next five years, is regarded as a positive sign for our expansion into overseas markets. In this project alone, customers can generate profits by participating in the capacity market, and it is also possible to form a small VPP (Virtual Power Plant) through a local network with additional future projects. This local VPP are opportunities to our customers to realize additional profit streams.

#### 3. Solutions for Renewable Power Generation

Hyosung intends to become a "Total Solutions Provider" and a leader of the clean energy industry in step with the Fourth Industrial Revolution amid changes in the environmental paradigm, and in compliance with global climate agreements. Furthermore, we have achieved outstanding results in the photovoltaic, wind power generation, ESS, and fuel cell sectors by using renewable energy sources to meet the requirements of the government's Green New Deal/Renewable Energy policies, and the diversification of the energy supply. We provide total power solutions based on the project experience we have accumulated over the years and our continuous technological development and improvement.

As for our **photovoltaic power generation solutions**, we have accumulated a wealth of experience in the EPC sector through the course of executing diverse projects in Korea (153MW in total) and overseas (93MW in total) over the past fourteen years, starting with the construction of the Samnangjin Photovoltaic Power Plant (Korea) in 2007. We do everything we can to maximize our customers' satisfaction by providing them with first-rate technological services including profitability analysis, consulting, and support for the acquisition of permits, approvals and authorizations.

Recently, we have completed a number of solar power generation power system projects including a 154kV substation, a photovoltaic power plant (24.2MW), and an ESS (22MW) at Jara Island, Jeonnam, Korea. The project was conducted with the participation of the local government and population through the enactment of a municipal ordinance mandating the sharing of profits from renewable energy development, the first such ordinance in the country. The project has proven our outstanding technological capability, know-how, and construction capability as a "Total Solutions Provider."

As part of our **wind power generation solution**, we developed a 750kW on-shore wind power generator, the first of its kind in Korea, in 2006, a 2MW on-shore wind power generator in 2009,

and an off shore 5MW wind power generator in 2014. Both were certified by Germany's DEWI-OCC, an international certification agency. We also supplied a 2MW on-shore wind power generator to the city of Taebaek in 2011 and constructed two additional wind systems in Gangwon-do, an 18MW system in Taebaek and a 30MW system in Pyeongchang, providing both cities with an opportunity to earn revenue from power generation.



[Fig. 6] View of a photovoltaic power plant on Jara Island



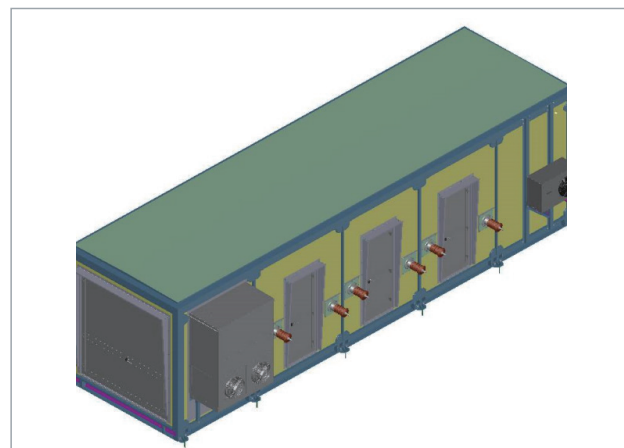
[Fig. 7] View of a wind power 30MW power plant in Pyeongchang

#### 4. Mobile Solutions

The mobile substation is a set of power supply facilities comprised of a transformer, switchgear, and other devices installed on a trailer, which can be dispatched to a given location at the request of the customer. As such, it offers the advantages of mobility and a prompt response to an urgent need and mobility. A mobile substation can be sent to meet the following needs: to replace a malfunctioning power facility; to provide a connection to the power system; to resolve a long-term power stoppage; and to provide a temporary power supply in a mine or oil field etc. As a Total Solutions Provider of major substation facilities, we have developed our own line-up of diverse mobile solutions including mobile GIS, ESS, and STATCOM, in addition to mobile substations. As we produce transformers and switchgears in one factory, we can ship out a mobile substation after testing a unit without having it exposed to the outside environment while connecting gas to the oil spacer. Our compact GIS-based mobile substation makes it possible to provide compact solutions, using rotating bushings through the installation of up to 6 bays for a 145 kV-class mobile substation, up to 4 bays for a 245 kV-class substation, and up to 1 bay for a 420 kV-class substation on a 40ft E-house.



Hyosung also plan to develop mobile substations that integrate environmentally-friendly solutions and digital technologies capable of addressing the rapid changes in the power system sector.



[Fig. 8] Container/Mobile STATCOM

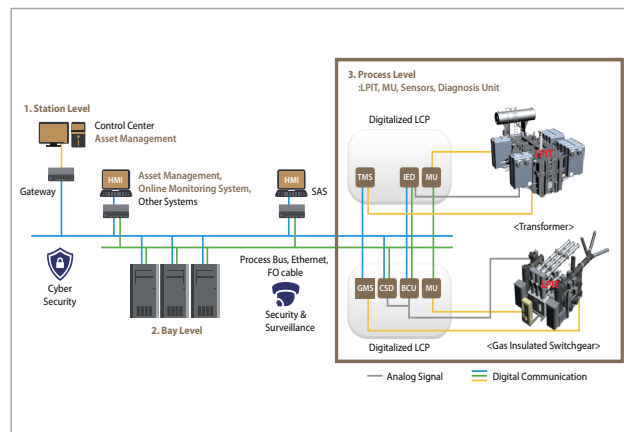
## 5. Digital Solutions

We provide digital power facility solutions following the Industry 4.0 and DX (Digital Transformation) trends. We have commercialized cloud and platform software-based asset management solutions, Micro Grid and VPP (Virtual Power Plant) solutions, a real-time event data-based AI forecast/management model, and IEC 61850 -based Process Bus solution products. These products have optimized customers' cost efficiency and enhanced their reliability.

### [Digital Substation]

A digital substation refers to a substation equipped with digital control and protection functions based on the establishment of a communications network/system that satisfies the IEC 61850 standard. It offers such advantages as wider customer choice by securing the interoperability of digital equipment within a substation, enhanced safety, minimal land use, and optimized asset management.

The semi-digital substations centralized on Station Bus (IED-monitoring system) for general purposes were introduced in the mid-90s, and the fully digital substations including the Process Bus (LPIT, MU) were commercialized in 2000 by pilot projects in Europe and China, in particular.



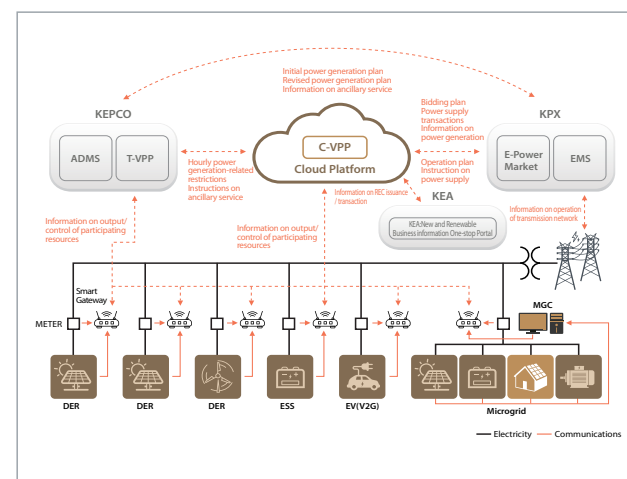
[Fig. 9] IEC 61850 Configuration of a digital substation based on IEC 61850

We have conducted R&D in the field of digital substations since the late 1990s, and now provide diagnosis, monitoring and asset management solutions featuring AI, cloud and platform technologies and IEC 61850-based digital solutions.

Notably, our Process Bus solution provides customers with a number of advantages, including a significantly reduced land requirement (e.g. reduction of cabling and trench works by 80%, GIS length by 5-10%, and the relay room by more than 50%) and enhanced stability through an optical communications network. Furthermore, we have developed ARMOUR, a solution designed and capable of the following: Generate a plan for forecasting the status of, and optimally operating and maintaining, a substation using more than 10,000 sets of real fault/trip data and AI; display a 95% status forecast; reduce failure costs by 95% and operation/maintenance costs by 30%; and provide Cloud-based remote monitoring and platform-based software solutions for extensibility.

### [VPP(Virtual Power Plant)]

A VPP is a Cloud-based power plant that manages dispersed energy resources and processes power production and consumption as if the power originates from one power resource, for power transactions in the wholesale market.



[Fig. 10] Configuration of the VPP system

A VPP integrates the various renewable power resources that are linked to the power distribution network into one predictable and controllable resource, thereby contributing to the supply of energy to the regional (or national) power network. It also absorbs the variance of renewable power resources through the real-time provision of power distribution network-related ancillary services and contributes to enhancing the stability and reliability of the power supply.

A VPP provides information on customers' asset management and profits from transactions on a real-time basis, using a Cloud-based operating system. It also generates the maximum possible profit for customers using AI-based power price calculation, which is a power generation plan based on an estimate of the amount of renewable power generation, and ESS-based real-time compensation of fluctuations in output.

As a Total Solutions Provider, Hyosung Heavy Industries supplies a comprehensive and impressive product line-up ranging from switchgears and transformers, the core components of power systems, to Cloud-based power equipment Asset Management Systems. In the new field of products that converge power electronics technologies with IT, we play a leading role in putting into practice the government's policies for expanding the adoption of renewable energy sources, as well as private businesses' plans for "RE100" (Renewable Energy 100%), by supplying renewable energy power generation systems, ESS, and STATCOM to our customers. In particular, our Solution Engineering Group, is striving to satisfy specializes in system engineering, is striving to satisfy customers' requirements and boost their profitability by proposing optimal solutions involving the convergence of intelligence-based operation with existing businesses and products, and by providing future-oriented solutions such as power electronics technology-based solution engineering, renewable power generation-related solutions, and mobile/digital solutions.

Hyosung is dedicated to maximizing customer satisfaction by strengthening its technological prowess, paying close attention to customers' needs and analyzing their problems proactively, and applying our front-end engineering capability to the provision of innovative solutions.



Jeong-bae Kim  
Vice President  
Solution engineering



Dae-hee Choi  
General Manager  
System Solution  
Engineering Team



Seung-hwan Roh  
Deputy General Manager  
Domestic Solutions  
Engineering Team



# New Transformer of environmentally-friendly era

## Ester filled Transformer

Environmentally friendly transformers are core feature required in the present era. Recently, fires and pollutants caused by power supply devices have emerged as a social issue, and there has been an increase in demand for environmentally-friendly, biodegradable power devices that do not cause pollution. Hyosung Heavy Industries supplies a lineup of eco-friendly biodegradable ester oil transformers that can substitute traditional mineral oil devices to meet environmental requirements.



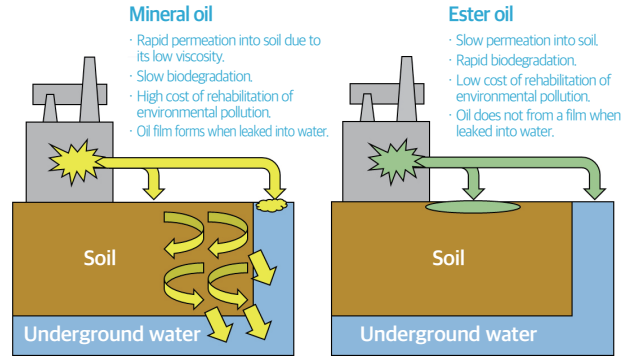
Ester oil transformers are eco-friendly and offer a variety of benefits related to fire safety, moisture tolerance and cost.



[Fig. 1] Merits of ester oil transformers

### Environment-friendliness

We support the establishment of environmentally-friendly infrastructures for both mankind and the environment by supplying renewable energy to the grid through our eco-friendly transformers. Unlike mineral oil, ester oil has low toxicity, permeates the soil slowly, and biodegrades. As such, it entails fewer risks than mineral oil even in the event of a leak. For this reason, ester oil is suitable for transformers installed in areas that are vulnerable to environmental pollution, such as offshore wind power plants and substations, underground substations in downtown areas, and renewable energy power generation complexes.

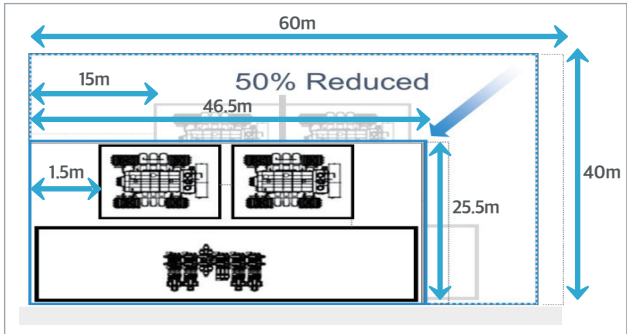


[Fig. 2] Comparison of insulation oil leakage  
(Source: insulation oil manufacturer C)

### Fire safety and cost savings

Fire safety is another great advantage of ester oil. Ester oil has a fire point above 300°C and thus is classified as "K" grade. Its fire point is higher than that of traditional mineral oils and has a self-extinguishing property. Ester oil offers the following advantages:

- Reduction of the distance between transformer and firewall, thus requiring a smaller space for installation.
- Lower cost for basic transformer structure.
- Lower cost for insulation oil leak prevention facility.
- Lower cost for firefighting systems.
- Ease of installing the transformer inside a building.
- Fire safety and reduction of insurance cost.



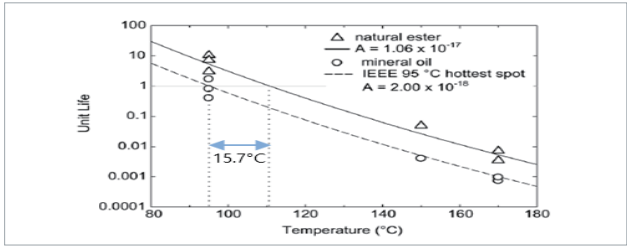
[Fig. 3] Space-saving effect of ester oil transformers  
(Source: FM Global recommendations)

	Mineral Oil TR	Synthetic Ester TR	Natural Ester TR
Initial Cost	1	1.15	1.05
Operation Cost	0.01	0.02	0.02
Maintenance Cost	0.3	0.36	0.36
Maintenance Intervals (Year)	5	5	5
Transformer Lifetime	50	60	60
Maintenance Times	10	12	12
Maintenance Cost per Visit	0.03	0.03	0.03
Civil Works	0.61	0	0
Fire wall	0.14	0	0
Control Building Walls	0.27	0	0
Boundary Walls	0.27	0	0
Possible Land Extension	0	0	0
Downtime Cost	0.001	0	0
Downtime Frequency (Fire)	0.01	0	0
Downtime Cost per Event	0.1	0	0
Remaining Value	-0.4	-0.5	-0.5
Total Cost of Ownership	1.52	1.03	0.93

[Fig. 4] Comparison of total cost (mineral oil vs. ester oil)  
(Source: insulation oil manufacturer M)

### Superior moisture tolerance

Meticulous maintenance to avoid insulation deterioration is important to prevent transformer failure. Moisture in a transformer has an adverse impact on the deterioration rate of insulation. Compared to mineral oil, ester oil has higher saturation moisture content, so it is effective in keeping a transformer's insulation materials dry. This means that the insulation of ester oil transformers deteriorates far more slowly than that of mineral oil transformers even under high temperature or overloaded operating conditions (in case of cellulose-based paper, it can maintain the same lifetime as paper in mineral oil at 15.7°C higher temperature).



[Fig. 5] Comparison of unit life of insulation materials impregnated with mineral vs. ester oil (Source: IEEE C57.154 Annex B)

### Research

As a leader in power supply systems, Hyosung Heavy Industries conducts continuous R&D aimed at stabilizing and improving the performance of ester oil transformers, with focus on the deterioration and insulation-related characteristics of ester oil used in transformers, in order to develop and supply better products to our customers.



[Fig. 6] A test of insulation oil deterioration characteristics  
(conducted by Hyosung)

*"The safety of our customers and environment is top priority"*

As the frontrunner of eco-friendliness in the power industry, we have supplied more than 160 ester oil transformers around the world. We aim to contribute to the better lives of our customers.



[Fig. 7] View of the ester oil transformers supplied by Hyosung to ITER (International Thermonuclear Experimental Reactor) in France and a refinery plant in Oman



Myung-gong Son  
Deputy General Manager  
Transformer Technology Development Team



Tae-seong Park  
Associate  
Transformer Technology Development Team



# Optimizing reactive power in the transmission grid using variable shunt reactors

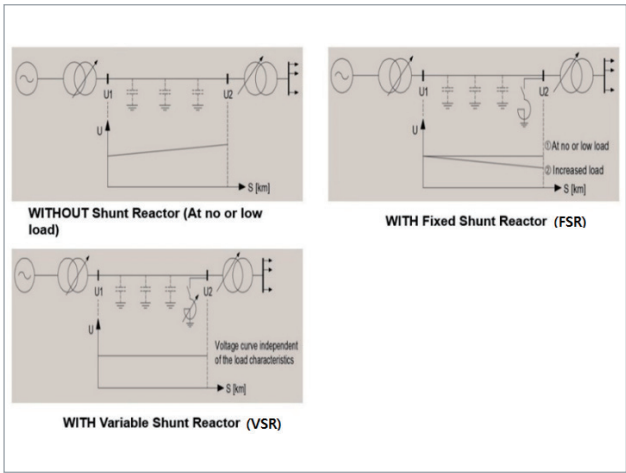
## Variable Shunt Reactors

With our strong commitment to quality and technological prowess, we aim to provide our customers with products developed with innovative technologies to meet their needs for voltage stability, power quality, and integration of renewable energy. Our shunt reactors are used for voltage stability and regulation by optimizing reactive power flow on long-distance transmission lines and underground cables. Here, we introduce our highly economical, and reliable Variable Shunt Reactors (VSRs).

\*VSR: Variable Shunt Reactor / \*FSR: Fixed Shunt Reactor

### Overview of VSRs

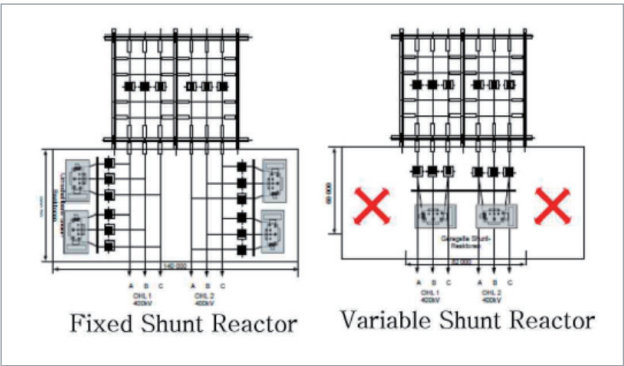
When the Ferranti effect occurs on a transmission line, i.e., when the voltage becomes higher at the receiving end than at the sending end, in an event of light load or no load due to significant charging capacitance to earth of a long-distance transmission line or an underground cable, the reactive power can be absorbed and the voltage at the receiving end can be stabilized by using a shunt reactor.



[Fig. 1] Voltage stabilized with the use of FSR & VSR

Where the load fluctuation is high or a renewable energy power generation source is connected, the system voltage can vary significantly with changing load and generation, making system operation difficult and reducing reliability. Sometimes, during these conditions, the occurrence of an excessive voltage surge associated with switching can cause a malfunction of the power devices. In such cases, the use of a VSR can improve voltage regulation and switching capability, which helps enhance the reliability of the system and reduces the possibility of breakdown.

The VSRs also require less number of devices like circuit breakers or earthing switches, which means less installation space is required. One VSR can replace two fixed shunt reactors or one expensive SVC (Static Var Compensator).



[Fig. 2] Comparison between FSR and VSR

### Merits of the VSR

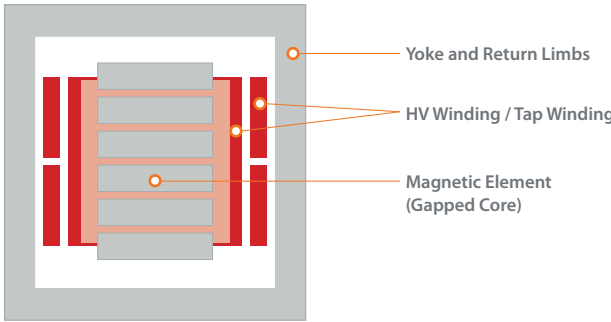
- Allows voltage regulation within normal range.
- Reduced the installation space and purchase cost of equipment.
- Reduces the stress on switching devices (Very Fast Transient Overvoltage).

### System conditions favoring VSRs

- A network where the load and generation vary regularly (e.g. solar power/wind power).
- A substation where load variance between night and day is large, such as in downtown areas or areas with many factories.
- A system where overvoltage surges occur due to frequent switching of shunt reactors connected with the GIS.

### Hyosung VSR Design

In general, the structure of a VSR is not so different from that of an FSR, but a VSR has a separate coil for the adjustment of reactive power.



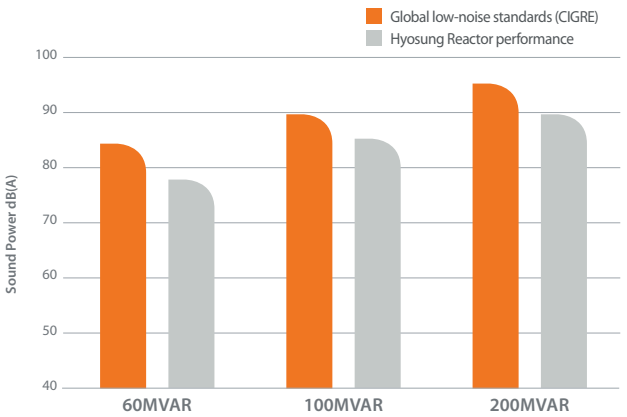
[Fig. 3] VSR's structure (including OLTC)

The typical regulation range of the VSRs is as shown in Table 1. It is possible to design one with greater variance.

Rated Voltage(kV)	Regulation Range (%of Maximum Rated Power)
110	35% - 100%
220	40% - 100%
345 or 400	50% - 100%
500	55% - 100%

[Table 1] VSR's regulation range per rated voltage

The gapped core should be fixed tightly to minimize vibration, and the bundles of each phase should be balanced precisely at the upper and lower fixtures. This assembly work requires highly precise technical skills to minimize noise and vibration. We supply reactors with a lower noise rating than the international standard, using our own low-noise technology.

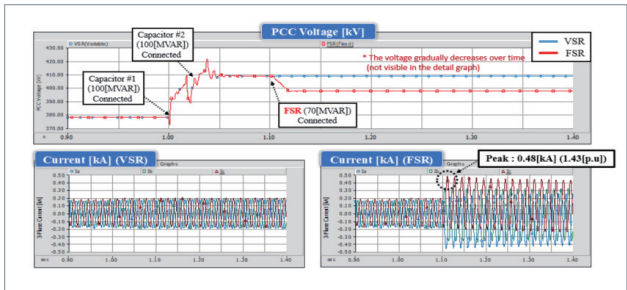


[Fig. 4] The noise level of our reactors compared to the global standard



### Analysis of VSR-applied Systems

When a VSR is specified, we optimize its performance by conducting the system analysis based on the load profiles provided by the customer.



[Fig. 5] Result of FSR & VSR-related system analysis

### "New low-noise, eco-friendly technology"

Since the development of the gapped core-type shunt reactor in the 1990s, we have supplied more than 200 shunt reactors with ratings below 22.9kV-30MVA and more than 400 shunt reactors with ratings between 154kV-765kV to more than 30 countries around the world.

In the power market, the customer requirements are becoming stricter and the competition between the suppliers is intensifying.

Increasing focus on the environment has led to the growth of renewable energy, with extensive use of cable networks, and has resulted in concerted efforts to lower noise levels.

We supply reactors that are customized for specific applications. We continue to develop more sophisticated reactors to meet our customers' increasingly complex requirements based on the experience and the know-how we have accumulated over the years, including low-noise reactors requiring less and less space and VSRs designed to enhance power system performance.



Moon-sik Kang  
Deputy General Manager  
Transformer Technology Development Team





# Need for large-capacity GIS

## Gas-insulated Switchgear

In major markets in the Middle East and North America, the demand for power is increasing due to urban concentration, but securing land to build substations is becoming increasingly difficult, and system capacity needs to be increased. To meet such a need, Hyosung Heavy Industries is striving to develop a wide range of large-capacity GISs for customers to choose from when they need to increase their power supply capacity.

### Increasing demand for power

The North American GIS market was worth some \$300 million per year as of 2020, with a total of 2,430 power supply companies operating under a privatized power supply scheme. Power grid load is increasing, particularly in major cities in the eastern United States, such as New York and Washington DC, due to new demand for power from Data Centers, the linkage of renewable power generation facilities including photovoltaics, and increased demand in downtown areas. In connection with this increase in load, power supply companies are investing in enhancing the breaking capacity of the existing power grid, rather than in building a new power supply network, in an attempt to guarantee safety with the minimum possible investment. As such, the demand for large-capacity switchgears (higher than 63kA, 80kA) is on the rise.

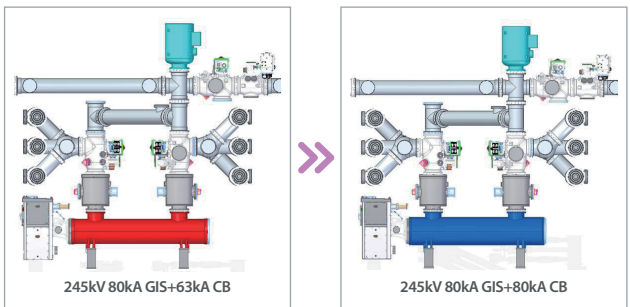
In the Middle East, this rising demand for power is most conspicuous in Kuwait. The country's energy consumption has been increasing year after year due to the extremely hot climate and the high rate of population growth. Under the "New Kuwait 2035" policy announced in 2017, which aims to promote Kuwait's emergence as a hub of business, culture, and education in the Middle East, the demand for energy is expected to continue rising. Under this policy, Kuwait will carry out projects to improve its SOC, including major ports and roads, and its national health system, and develop new towns. As such, the demand for power is expected to increase from 19.4 GW in 2019 to 36 GW by 2035.

### How to cope with growing demand

Typical methods of coping with the projected increase in demand include the separation of systems through voltage boosting, the use of current limiting reactors, and the raising of short circuit current capacity, etc. The separation of systems via voltage boosting requires new investment in the relevant facilities and may entail difficulties in the installation of the transmission infrastructure, such as power towers, in downtown areas. However, such a need can be met with the use of existing substations without building any additional infrastructure or making new investments, by increasing the capacity of the existing GIS. The recent advances in GIS production technology make it possible to use smaller plots of land than before and to reduce the work period, leading to a drastic reduction in the total cost. Meanwhile, the use of current limiting reactors entails problems associated with the high price of reactors and the high cost of maintaining switchgears. However, the use of technology for raising the capacity of GIS makes it possible to maintain the system at minimum possible expense and to obtain the effect of securing the quality of the power supplied. The use of such a technology can minimize resistance from local people and the environmental impact assessment-related restrictions associated with the construction of high-voltage substation facilities, which are regarded as noxious facilities, in downtown areas, and thus could be the most reasonable alternative to customers managing power transmission/distribution systems. In other words, increasing the existing power facilities will offer the best possible solution in terms of the need to circumvent regulations, reduce costs and improve the quality of the power supply. To cope with such a situation, we succeeded in developing a 245kV 63/80kA GIS, and worked with our customers in North America on the design for new projects. Furthermore, in 2020 we completed our lineup of 420kV 80kA GISs, whose breaking capacity has been enhanced to cope with the market trend in the Middle East.

### GIS rating and design

Our large-capacity GISs are designed to be operated and maintained according to the customers' needs, as follows: 1. Separation/replacement of switchgear concerning required capacity. Following an increase in power demand, a 245kV 80kA GIS operated with a 245kV 80kA GIS part and a 63kA CB can be replaced with an 80kA CB to meet the capacity increase during operation.



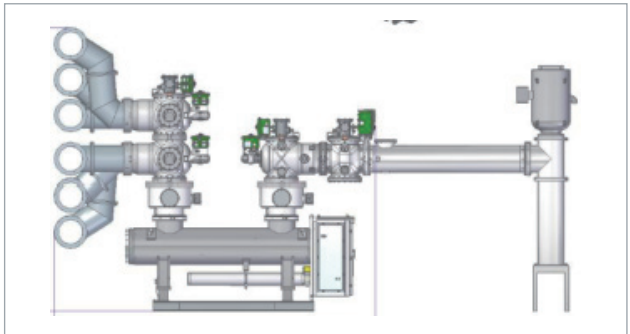
[Fig. 1] Replacement of large-capacity GIS

2. We have completed our lineup of large-capacity switchgears with the development of products designed to meet customers' demand, i.e. GISs with 245kV 63kA/80KA for North America, and GISs with 420kV 80kA for Kuwait.

Rated voltage	245kV	245kV	420kV
Short circuit current	63kA	80kA	80kA
Frequency	60Hz	60Hz	50Hz
Rated current	4000A	4000A	6300A

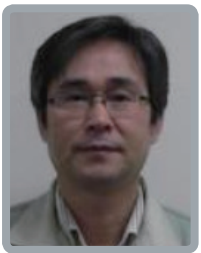
[Table 1] Line-up of our large-capacity GISs

3. We developed our 245kV 63/80kA GIS by reflecting the requirements of our customers in North America, who favor a spring operating mechanism, with the application of Self-blast Interrupter. 4. We developed our 420kV 80kA GIS to be the most compact product in the market. It has secured movement and system stability using double-motion puffer circuit breaker with hydraulic mechanism. The breaker is also condenser-free.



[Fig. 2] 420kV 80kA GIS Layout

The heavy concentration of power consumption in the urban area will continue to increase, so it is necessary to strengthen the capacity of the transmission line. In this regard, we can provide the most efficient power system solutions designed to meet customer needs by establishing a full lineup of large-capacity GISs. With continuous urbanization and increasing power demand, we will provide compact and stable products specialized for substation facilities.



Jin-ho Kim  
Vice president  
HV Switchgear



# Benefit of custom MV GIS and environmentally-friendly GIS

## Benefit of MV GIS and Non SF<sub>6</sub> Solutions

Hyosung Heavy Industries' MV GIS provides customers with optimal solutions that can meet diverse requirements. Customers speak highly of our compact GIS and DAIS (Dry Air Insulated Switchgear, Non-SF<sub>6</sub>), which are custom-designed.



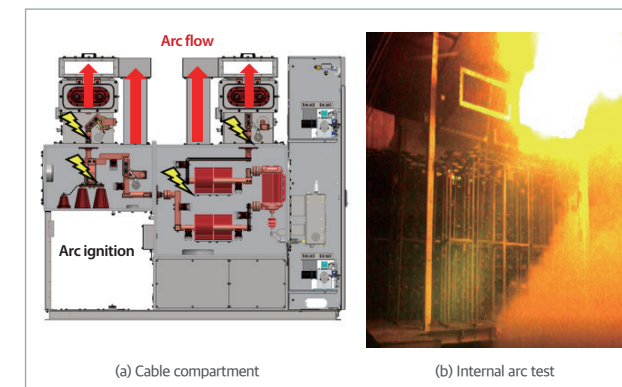
The current trend among customers is to switch from traditional AIS (Air Insulated Switchgear) to Medium Voltage GIS (Gas Insulated Switchgear) due to the lack of available land in downtown substation areas and the rising price of land. Furthermore, due to the crisis caused by climate change, the use of MV GIS, which applies environmentally-friendly insulation mediums with zero global warming potential (GWP) rather than traditional SF<sub>6</sub> gas, is on the rise.

Our MV GIS is an optimal product designed to meet customers' requirements in step with the global trend. These products make it possible to create the optimal customized design for each substation, while design flexibility makes it possible to respond to diverse technological demands, including the use of maintenance-free, removable VCBs (Vacuum Circuit Breaker). We have supplied our switchgear to electricity companies and businesses specializing in electrical / electronic goods, semiconductors, and renewable energy. Our customers using our products benefit from our decades of experience and know-how, benefit customers. Our MV GISs is a first-rate product that is maintenance-free, compact, and arc-resistant, etc. It can accommodate large-capacity electric currents (~4000A) and meets diverse customer specifications such as single or double bus type and sophisticated monitoring systems. Being highly compact, MV GIS need less than half the amount of land required to install a traditional AIS, as shown in Fig 1.



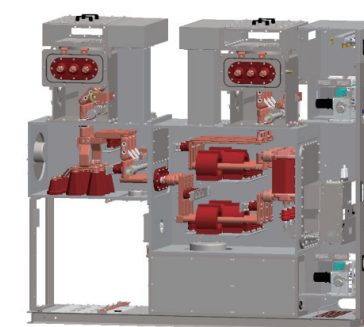
[Fig 1.] Comparison of substation installation

MV GIS is contained in a tightly sealed outer case which protects it from climate conditions like heat, moisture, dust or even animal damage. This allows our customers to reduce their maintenance expenses and grid maintain reliability.

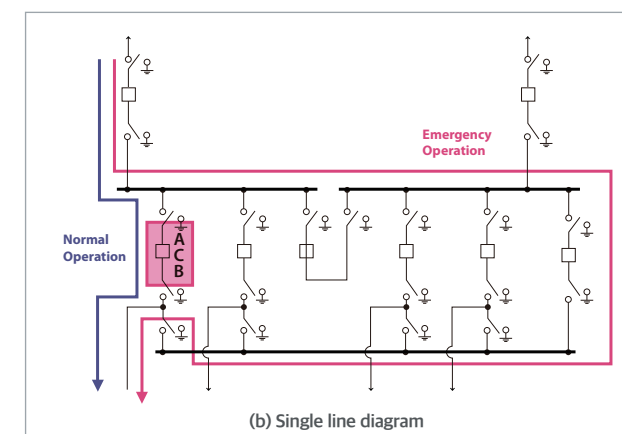


[Fig 2.] Arc flow and internal arc test

Fig. 2 shows how an internal arc occurring in the gas compartment is discharged. We used an internal arc simulation program to conduct research on the optimal arc flow in each compartment, leading to an efficient design according to the arc discharge pressure. We obtained arc-resistance certification from the STL for the AFLR 40 kA 1s (IEC 62271-200), Type 2B 40 kA 1s (IEEE C37.20.7). The test proves that the operator can be safely protected from an arc-related mishap during circuit breaker maintenance due to the removal of the circuit breaker. Our products ensure that, in the event of an arc-fault, it is contained only to the location of the fault, and this section can be replaced rapidly because the gas compartments are modularized.



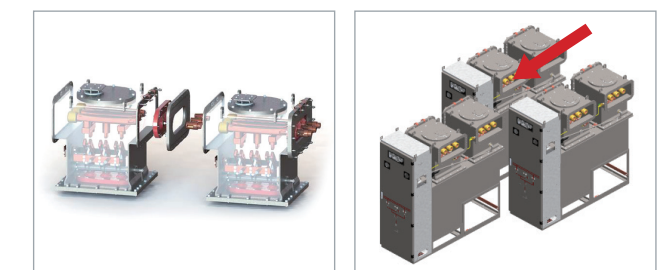
(a) Basic layout



(b) Single line diagram

[Fig 3.] Transfer bus system of MV GIS

Fig. 3 shows the basic structure of a transfer bus system and a single-line diagram for normal/emergency operations. A transfer bus system is an optimal solution that allows for maintenance of a circuit breaker without taking out the outgoing feeder circuit. During normal operation, the system receives power through #1 main bus and supplies it through a circuit breaker. During maintenance of a circuit breaker, however, it is linked to #2 main bus, and 3-position disconnecting & earthing switches at each end of the circuit breaker safety ground the service area while maintaining power to the circuit. It is common practice to install a CT only on the secondary side of a circuit breaker, but our fully customizable design allows us to place CT's on both the primary and secondary sides to allow for differential protection on the breaker itself. It is also possible to custom design the location of the cable connection whether our customers have underground or overhead cables, or even rear access cable connections.



[Fig 4.] Structure of removable flange

Fig. 4 shows the structure through which to replace an outgoing feeder panel, using the removable flange structure. We designed the removable flange structure instead of a structure composed of main bus spacers installed in each panel. Previously, it was difficult to replace a cubicle if it was located in the middle of a line-up. However, by adopting a removable flange structure a cubicle can be replaced without difficult.



[Fig 5.] Viewport camera system

Fig. 5 shows the placement of a viewport camera system designed to check the close-open-earth status of the 3-position switch. The operator can check the switch position through the LCD screen mounted on the front door of the device, which prevents operator errors as they can visually check if the switch is performing as intended via the cameras installed on each switch.





[Fig 6.] Seismic test

Our MV GIS is made with high-performance VCB (E2, M2, C2 class)<sup>1)</sup> and can provide an array of solutions to our customers, such as a 0.5g-level earthquake-proof design, a prevention/diagnosis system using partial discharge sensors, and a VCB 3-position switch interlock system designed to prevent misoperations.

**Note 1) VCB Class**

- E2** : Highest possible grade of electrical endurance  
(Capable of cutting off a 100% short-circuit current 50 times)
- M2** : Highest possible grade of mechanical endurance  
(Capable of activating the circuit breaker 10,000 times)
- C2** : Highest possible grade, with a very low probability of restrike of the charging current

As the GWP of SF<sub>6</sub> gas is very high (about 23,900), its use in a device is likely to be restricted from an environmental perspective. Dry air, an optimal insulation medium that can replace SF<sub>6</sub> in an MV GIS, but exhibits lower insulation properties, which poses an obstacle to compact design.



[Fig 7.] Dry Air Insulated Switchgear

Our product (DAIS) uses dry air as an insulation medium, and is similar in size to existing SF<sub>6</sub> GIS thanks to the use of materials with excellent electrical, mechanical and chemical properties.

We launched our first DAIS products on the market in 2013, and we have supplied a total of 658 panels since then. These products use dry air with zero GWP and have optimal structural design for safe operation and maintenance. One of their advantage is that their performance does not deteriorate due to long-term use because they feature an outstanding insulation material that is highly effective in tracking resistance and glass transition temperature (Tg 130°C).

As our products have passed the acceleration test with the application of an overvoltage 1.6 times higher than rated voltage, thereby demonstrating the reliability of their insulation properties and guaranteeing a shelf life of 30 years. We proved their reliability of our designs by conducting a 3-month-long load demonstration test. The same customizable options and product performance of our MV GIS also apply to our DAIS products.

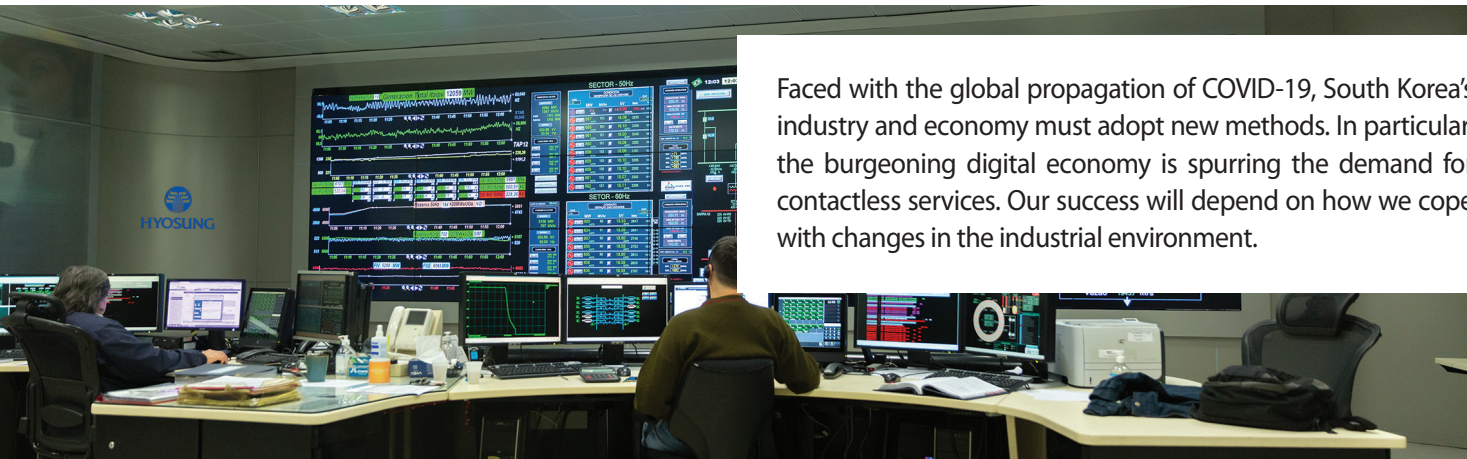
**We have supplied our MV GIS and DAIS products to numerous customers including electricity authorities and businesses specializing in electrical/electronic goods and semiconductors, whose products require outstanding reliability and safety, and our quality has been recognized. Our compact MV GIS and DAIS products, the fruit of unceasing R&D and the reflection of customer requirements, have won international standards certifications such as IEC and IEEE. We will continue to deliver optimal product solutions based on customized designs that meet our customers' diverse requirements and put their safety first.**



Jae-hun Jeong  
Director  
MV and LV Switchgear

# Provision of a new paradigm through remote support for installation of heavy-duty electrical products in the COVID-19 era

## Service of Power Utility

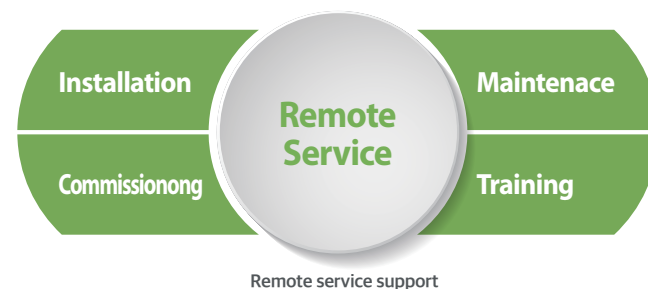


Faced with the global propagation of COVID-19, South Korea's industry and economy must adopt new methods. In particular, the burgeoning digital economy is spurring the demand for contactless services. Our success will depend on how we cope with changes in the industrial environment.

In this new COVID-19 era, our industry faces uncertainties caused by spatial and temporal restrictions affecting the need for the presence of a manufacturer's personnel for the installation, inspection, and commissioning of heavy-duty electrical products. The current situation during this era could possibly weaken the uninterrupted supply of energy and, for that matter, our industry and economy.

### Remote service support

Hyosung Heavy Industries provides contactless services to ensure the operational stability of customers' businesses based on our accumulated experience and know-how by fully utilizing the digital industrial environment developed through convergence between information/communications technology and industrial worksites.



Our remote service offers the following values to customers.

#### Standardization of product installation

Workers maintain the consistency and secure the product installation according to the standardized work processes specified by the manufacturer.

#### Elimination of potential risks

Product installation, inspection, and commissioning is carried out in close cooperation with customers to secure an uninterrupted power supply and ensure the stability of the customers' facilities.

#### Effective response process to mishaps

Damages are minimized by promptly handling any mishaps that arise during installation and operation.

#### Efficient operation

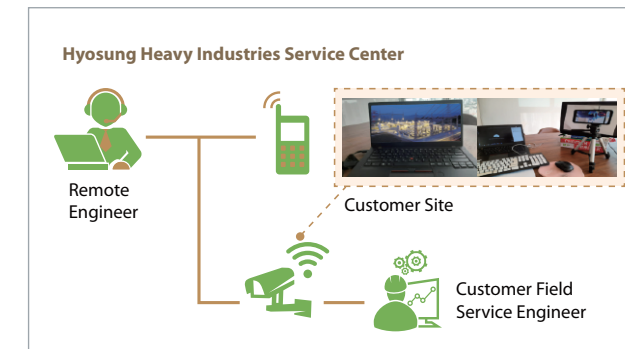
Remote services improve operational efficiency by minimizing the resources required for visits to worksites.

#### Higher safety and security

Remote services alleviate concerns about the spread of the virus by providing contactless communication with customers and preventing security violations by outsiders.

### Remote installation and commissioning

For the remote installation and commissioning of heavy-duty electrical products, supervisors specializing in specific products engage in direct communication with customers' onsite personnel. The availability of onsite workers with sufficient experience in installing the product can enhance overall work efficiency and help customers to reduce both costs and work period. The use of close-up/long-range cameras to view the product and the worksite will enhance the efficiency of the remote service greatly.



Our product installation supervisor provides information on work procedures and criteria for a specific product to enable customers' onsite personnel to check in advance and ensure perfect installation.

When conducted interactively, such a process minimizes errors by onsite workers. This service is provided consistently, efficiently, and in a way that guarantees safety.

#### Reference

- Australia & New Zealand (2020)
  - Substation Transformer PJT : 132kV, 220kV
  - Power Plant Transformer PJT : 300kV
- Colombia & Peru & Panama (2020)
  - Substation Transformer PJT : 20kV ~ 500kV
- UAE & Iraq (2020)
  - Nuclear power plant Transformer PJT : 27kV
  - Substation Transformer PJT : 400kV
- Philippines (2020)
  - Substation Transformer PJT : 13.8kV ~ 69kV

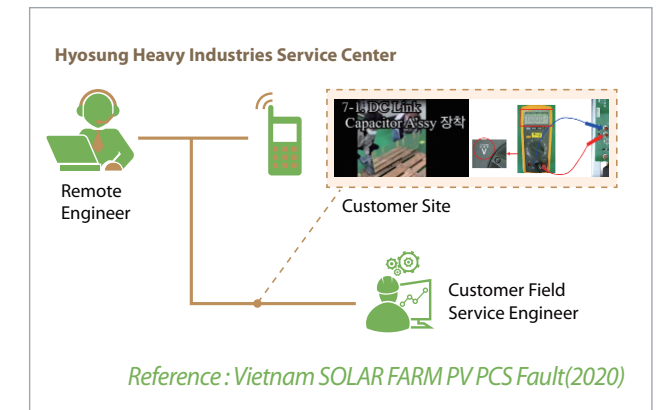
※ Customer Comment for Remote service.

We had been following each process as recommended standard details of scope of work by Hyosung of this project as it was one of the most importance to us, Thank you once again for your all your effort specially to Hyosung service engineer.

### Remote checks

In the event of any setback during the operation of a product or a product needs to be inspected, we execute remote countermeasures immediately in order to help customers limit their losses and resume normal operations as soon as possible.

We proactively provide each customer with detailed inspection while service personnel is dispatched to the jobsite (if needed) in order to enable them to initiate the necessary steps to minimize their losses.



Reference : Vietnam SOLAR FARM PV PCS Fault(2020)

### Remote education

We provide remote education for our customers-as part of our support for sustainable industrial operation.

Reference : Thailand Bangpakong PJT(2020)

### "Solution for Power Utilities"

We aim to provide our customers with smarter, integrated solutions and expand the scope of our remote services, taking upon ourselves the task of stabilizing and providing added value to customers and partner businesses amid the acceleration of digital industrialization in the new COVID-19 era. We provide remote services via a solid and sophisticated infrastructure to assist our customers' sustainable business success.



Dae-jung Lee  
General Manager  
E&S Team



# A new way of communication with customers. Remote Factory Acceptance Test (RFAT)

## Acceptance Examination

Since the concept of the Fourth Industrial Revolution was introduced at the World Economic Forum Annual Meeting in 2016, major enterprises have made new attempts to lead the future business paradigm, notably the Smart Factory. Companies around the world have recognized an urgent need to adapt to a rapid shift in the paradigm of their business operation to ensure their survival. This includes new ways of communication and interaction with their customers, amid concerns over the spread of COVID-19 as part of their day-to-day operations, the likes of which has never been experienced.



As a company with first-rate technological capability in the field of heavy electrical equipment, the core of industrial energy, Hyosung Heavy Industries is striving to realize the goals of "Creating value for customer satisfaction," "Generating maximum value with minimum resources for humanity and the environment", and "Maximizing Quality, Affordability, Delivery and Safety on time by eliminating waste". The company defines the Smart Factory as "a highly efficient, waste-free production system that is operated on a data-based platform which integrates the flow of logistics and information, and incorporates the new concept into every area of its business including design, materials management, processes, logistics, and customer service." The production of our heavy electrical equipment includes testing and inspections of product integrity at which the customer is present. In an effort to provide the maximum possible value to customers who use our products, we communicate with them throughout the entire production process, including the final Factory Acceptance Testing (FAT) schedule, as part of our

rigorous management of production and quality. Sometimes inevitable situations occur which make it necessary to change our production schedule or ask the customer to accept a change in the FAT schedule that was already confirmed a few months earlier. This usually results in losses due to stand-by and affects other production schedules.

To avoid such a situation, we have devised a way of having customers present on such occasions using only a computer or smart device without actually needing to be there in person.

In the initial stage of the method's adoption, it was difficult for customers to judge the status of a product accurately due to the low-resolution video feed or effective engagement in real-time communication with us due to the slowness of the internet connection. However, we have managed to establish an advanced contactless testing environment by remedying previous errors and by exploiting epoch-making core technologies of the Fourth Industrial Revolution, such as IoT, 5G, mobile, and cloud computing.

Now, we are in the ideal position to maximize our and our customers' interests by enabling them to check product integrity through the RFAT, regardless of the restrictions on travel due to COVID-19. This also allows us to keep product manufacturing on schedule.

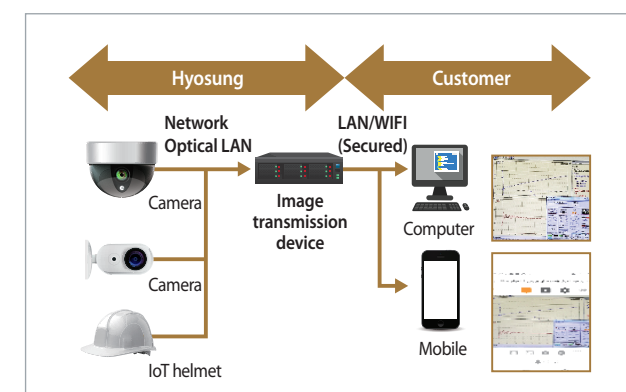
RFAT refers to the process of having a customer check the production status of their product and whether the specifications have been met without visiting the factory in person, using indirect means like documents, photos or video images.



[Fig. 1] RFAT platform

- The relevant video devices include a combination of fixed/movable cameras, depending on the product to be inspected or tested. The wearable IoT helmet is mounted with cameras, two-way radio, and communications modules.
- Customers attend the inspection or test via smart device or a computer simply by connecting with a web-based program, thus enabling them to communicate with the inspector on a real-time basis, and to carry out all necessary process, as in a typical FAT.

We make it a point to operate optimized RFAT suited to a product's specific characteristics. The Transformer Division communicates with customers on a real-time basis, using cameras for the product and the testing equipment, while the inspector from the GIS Division similarly uses an IoT helmet, and the Electrical Motor Division provides live or recorded video feed.



[Fig. 2] RFAT diagram

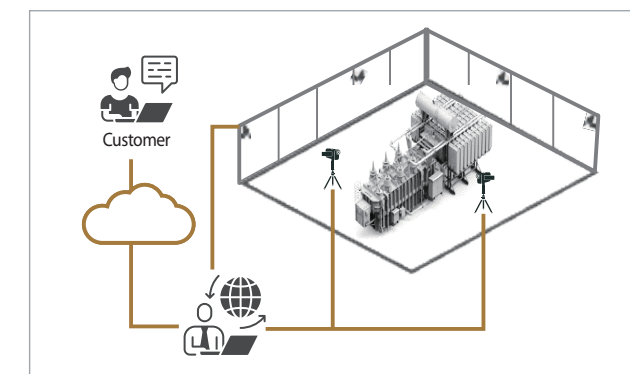
RFAT, which is carried out remotely, enables customers to save their valuable time and dispense with the cost of long-distance travel, aside from protecting them from possible safety accidents. Unlike the existing FAT framework, which allows a customer to check only from a single camera angle, RFAT makes it possible to check the status of a product from various angles and to check video images recorded on a real-time basis without having to jot down the inspection or test results. Video images are also kept permanently and can be used for a variety of purposes.

For a manufacturer, the time saved on product testing means a shorter production lead time and less time spent waiting, as well as saving on the cost of storing and managing a product.

**FAT:** Factory Acceptance Test / **RFAT:** Remote FAT

**IoT:** Internet of Things / **VIU:** Value In Use

**ICT:** Information and Communication Technology



[Fig. 3] A case of RFAT

It was extremely difficult to carry out a traditional in-person FAT in 2020 due to the restrictions caused by the COVID-19 crisis, but we nevertheless managed to conduct a total of 79 RFATs. We will continue striving to expand the scope of application of the RFAT platform in order to provide the highest possible value to our customers, deal with the changes in the environment, reduce the time and cost required for inspection and testing, and sophisticate the system from the perspective of customer convenience.

We expect that the post-COVID-19 era will require us to change the way we conduct our business amid the ongoing development of the "Contactless culture" and the combination of online and offline technologies. We will also continue striving to provide our customers with VIU (Value In Use) by expanding the application of ICT, and the analysis and use of Big Data, and by overhauling our security process, in order to move beyond mere real-time communication between customers and our factory by fully utilizing our RFAT.



Klaus-Dieter Hildebrandt  
Vice President  
Changwon Plant Manager of Hyosung Heavy Industries





### Overseas EPC know-how based on a wealth of experience

Recently, rapid changes have taken place in the electricity market due to the need to improve overall operational efficiency, boost eco-friendliness, and promote renewable energy. As such, it is necessary to address such changes technologically. In addition, because of the differences in each country's electric power industry, the experience and know-how accumulated by businesses in the power EPC sector are highly valued.

This article intends to introduce Hyosung's efforts to reduce the construction work period of power facilities and meet customers' needs based on our abundant experience in the execution of turnkey projects in more than 25 countries over the past 30 years.

# Striving for the construction schedule compression in global turnkey project!

## Global Turnkey Solution Provider



Map showing the countries where Hyosung has conducted turnkey projects

### A leading specialist in EPC turnkey projects with a wealth of experience

As a business specializing in substation-related EPC (Erection, Procurement, Construction) turnkey works, we have accumulated technological capability. We provide a fast-track service in which critical path efficiency management is applied to each project. Since our first project at a 33kV AIS substation in Bangladesh in 1988, we have executed more than 100 EPC turnkey projects in some 25 countries.

In the 1990s, we mainly completed projects involving 33/132/275kV substations and transmission lines in Asia. In the 2000s, our work was expanded to extra-high voltage (400/500kV and 800kV) facilities in South America, Africa, and the Middle East. In recent years, we have focused on STATCOM and ESS projects in connection with the need to enhance power supply efficiency and secure stability in renewable power generation facilities.

### Major work record

A power EPC project can be described as an assembly of power-related technologies that reflect the characteristics of diverse devices which need to be operated and maintained safely and reliably. Such a project needs to consider not only the layout of each system, building, and basic design, but also ground reinforcement for the facilities and even the rainwater and drainage facilities.

#### ① AIS substation

##### Aminbazar 400kV AIS Substation, Bangladesh

We completed Bangladesh's first two 400kV-class AIS substations and are carrying out the construction of Aminbazar 400kV AIS Substation. This region is situated below sea level and thus

requires large-scale soil formation and the driving of 20- to 30-meter long cast in-situ piles into the ground for reinforcement. We are carrying out the civil and architectural engineering work by drawing on our abundant experience in this country, while striving to enhance the quality and shorten the work period.

#### ② GIS substation

##### Hassi Messaoud 400kV GIS substation, Algeria

A GIS substation requires a sophisticated technical process to link the buildings with the outside GIB (Gas Insulated Bus). We successfully completed the Hassi Messaoud Project to construct the country's largest GIS substation on a 60,000m<sup>2</sup> site, in part of the Sahara desert where many oil refineries are located, and where the temperature can reach 65°C.



400kV GIS, Algeria



220kV GIS, Qatar

#### ③ Transmission line

##### Sululta Transmission Line, Ethiopia

The construction of a transmission line consists of foundation work for the transmission towers, the erection of the towers themselves, and the linking of electricity conductors. As the project area covers a large area and long distances, the job is difficult to manage, and it can be very dangerous as it involves working high up on tops of steel towers.





AIS Substation



ESS



GIS Substation



STATCOM

We have successfully completed this project in Ethiopia, and are now operating a 215-km-long 400kV transmission line. It was necessary to interrupt the power supply on an existing line when our work crossed it, but we completed it without interrupting the power supply, by using drones and the Double Pulley Block method, thereby shortening the work period. Meanwhile, to complete a project that involves building a 54-km-long 500kV transmission line in Laos, we used drones when installing the cables between steel towers over the Mekong River, thus reducing the work period by about one month.

#### ④ ESS / STATCOM

##### ESS in Oklahoma, U.S. /STATCOM in Panama

(NOTE. STATCOM (Static Synchronous Compensator) and ESS (Energy Storage System) are power compensation devices.)

We recently completed an ESS project in Oklahoma, USA, and are currently executing a STATCOM project in Panama, which is scheduled for completion by May 2021. Both projects have drawn on the extensive experience we have accumulated in South Korea. An ESS system is generally composed of batteries, inverter transformers, and a PCS (Power Conditioning System). Depending on the characteristics of a given project, ESS system can vary by type. The ESS we installed in Oklahoma belongs to the container type, but there is also a building type, and we are currently developing an enclosure type. We are capable of carrying out all three types based on our experience in the construction of substations. A STATCOM is similar to a substation, but differs from a substation, as the work requires reflection of the characteristics of various devices. The work is liable to design delays and trials-and-errors.

We are successfully carrying out the work for an EPC project, the first of its kind ever carried out in Panama, based on the extensive experience we have accumulated worldwide. We are applying our know-how in many areas, such as STATCOM O&M in buildings, RIV interruption, interlocking systems, and the insulation of re-bar in the foundations of air-core reactors among others.

#### Hyosung's efforts to shorten the work period

##### ① STATCOM Project, Connecticut, U.S.

###### Helical pile installation

The United States is known as a market where labor costs are high and labor laws are strictly applied. As such, hiring the minimum possible number of workers and completing the job within the shortest possible time are the two most important factors to complete the project on budget. To meet such requirements, we are using new work methods, such as prefabricated buildings and the use of helical piles.

As regards prefabricated buildings, the size of the rooms must be considered when designing a building, so that each one can be manufactured at the factory and then delivered to the construction site.

This project we are currently involved in consists in replacing an existing SVC facility with a STATCOM. The work requires the installation of new devices while utilizing the existing building as much as possible. We will be able to finish the work of driving in the helical piles by employing only one third of the workers that would usually be required to drive in concrete piles, thereby shortening the work period by more than 600 hours.



A machine driving helical pile into the ground

The helical pile system, which is installed by twisting into the soil itself consisting of steel shaft with helical flights, is used to provide foundational support for structures. The work can be done with a minimal amount of equipment and workers, provided that an excavator and torque head are available. Furthermore, it generates little noise or dust.

##### ② Great Colombo Project, Sri Lanka

###### Construction plan management by Zone Plan

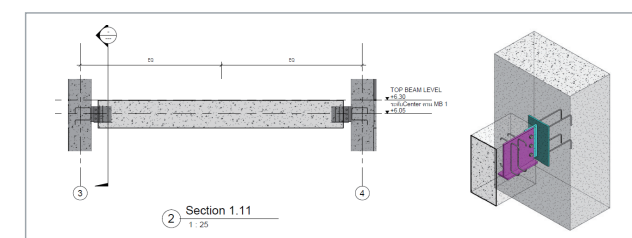
In GIS construction, it is important to manage the schedule for taking the GIS into the building, so the architectural work must be done in time for their transportation and installation. We handled the tight schedule by adopting a zone plan for this jobsite. We carried out the installation and architectural works simultaneously by dividing the rooms according to the GIS installation schedule, and then started working on the rooms for the switchgear and the ancillary devices simultaneously. In this way we succeeded in shortening the working period by about one month.

As for the Colombo B Project we are executing right now, we plan to suggest the 'Plaster Master' to the client with a view to shortening the period for the plastering work.

##### ③ Rayong 115kV GIS Project, Thailand

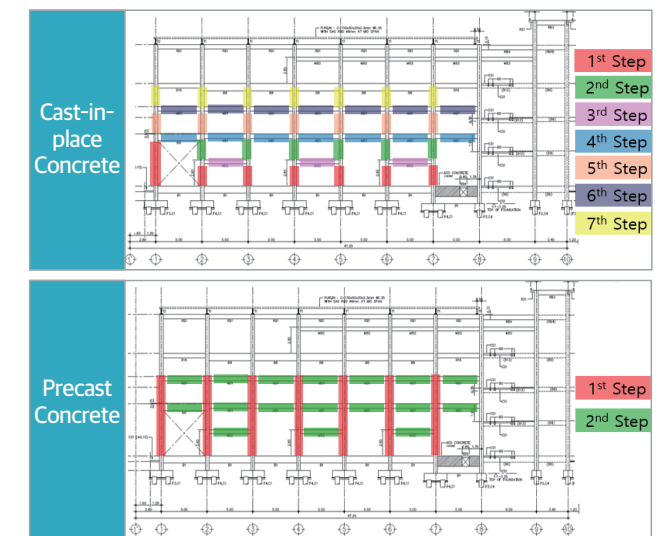
###### Application of the Precast Structure Method

Safety always comes first in electrical power-related work, which makes it difficult to obtain a client's approval of a new working method. However, we suggested a precast method that has never been used at this construction site, obtained the client's approval, and consequently shortened the work period by about one month. Precasting is a method of assembling columns and beams at a site after making them beforehand, rather than curing concrete directly on the building structure. Joints are attached together by inserting H-beams and steel plates, as well as using bolts and welding, and are finished by reinforcing them with steel bars and non-shrink concrete.



At this construction site, we applied the method to the main columns and beams on the first and second floors to increase work efficiency. Compared to the concrete-laying method, which requires the laying of reinforcing bars, the installation of casts, and the curing of concrete, precasting offers the possibility of shortening the work period by assembling beams etc. previously made at a workshop.

We were able to further boost efficiency in the work process by doing the work inside the building and operating a workshop on an idle plot within the site.



This method is particularly effective in countries where the climate conditions are adverse, as it makes it possible to continue with the work regardless of the weather. We will consider applying it to other projects in the future based on the experience we accumulate at this time.

#### ***"Technology that meets the customer's needs"***

**We will continue striving to meet our customers' requirements with the application of new working methods and efforts to shorten the work period. We will also endeavor to enhance the quality of our work in EPC turnkey projects based on the know-how and experience we have accumulated through overseas projects and the technological excellence of our products, including GIS, transformers, switchgear, STATCOM, and ESS.**



Choon-ha Lee  
Manager  
Substation Construction  
Management team



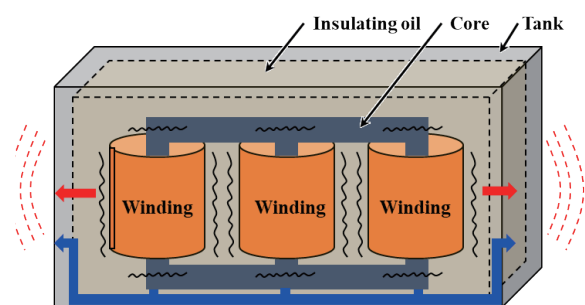
# Development of low-noise (50dBA) technology for 154kV-class transformers

## Research & Development

As residential areas are rapidly expanding towards areas where substations are located, noise from substations has emerged as a social issue. The constant noise generated by ultra-high voltage transformers inflicts physiological and psychological damage on nearby residents. As such, transformer manufacturers including Hyosung prioritize the reduction of noise as part of their efforts to enhance their competitiveness in the market.

Hyosung's R&D has resulted in the development of a low-noise (50dB) transformer through tireless R&D.

The noise emitted by a transformer is caused by the structural vibration of the tank. Vibration is caused by two factors, the electromagnetic force of the windings and the core's magnetostriction, and it follows two distinct paths: through the insulation oil (marked in red) to the tank, and from the active part to the tank (marked in blue).

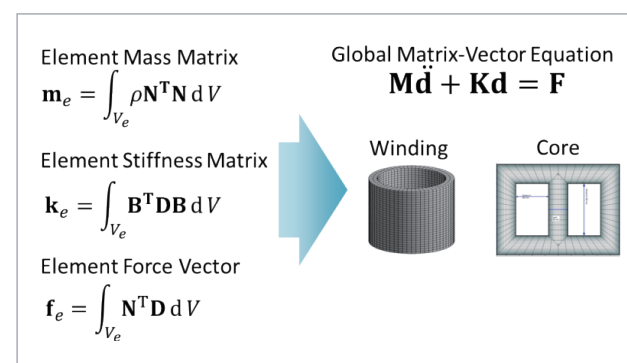


[Fig. 1] Vibration transfer path and noise radiation

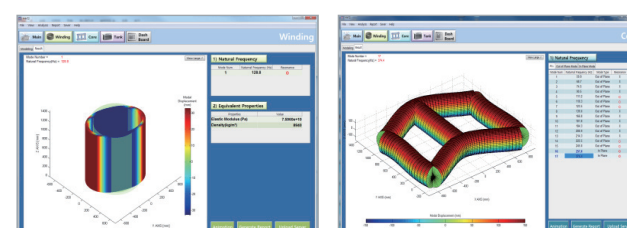
Accordingly, to reduce noise, it is essential to reduce the vibration of a transformer's tank. Therefore, it is necessary to conduct research on how to reduce the tank's vibration and how to cut off the path by which vibration is transferred from the windings and the core to the tank.

First of all, Hyosung established a technology to predict the natural frequency of the main parts of the transformer, such as tanks, iron cores, windings, and pipes, and prevented the phenomenon of noise increase caused by the amplification of vibration due to resonance. The natural frequency prediction technology was established as a numerical analysis program based on the finite element method (FEM); in order to obtain the equivalent properties necessary for the simple modeling of a complex-type product and to confirm the accuracy of the prediction technology, about 200 experimental data were used. The prediction technology was verified by conducting natural frequency experiments and simulations. As a result of the study, when the natural frequencies of the core, windings, and tanks occur near 120Hz, which is a mechanical excitation force, and its harmonic component, the noise was confirmed to have increased

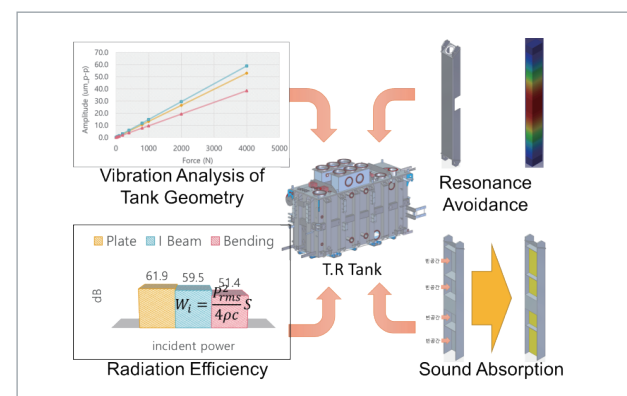
by 2~4dB. Therefore, the starting point of low-noise transformer development is the "stabilization of vibration and noise by avoiding mechanical resonance of the product" as the first step.



[Fig. 2] Finite element model for predicting natural frequency

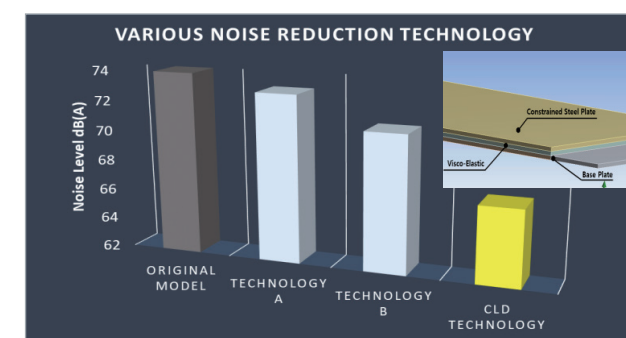


[Fig. 3] Resonance prediction/avoidance design program



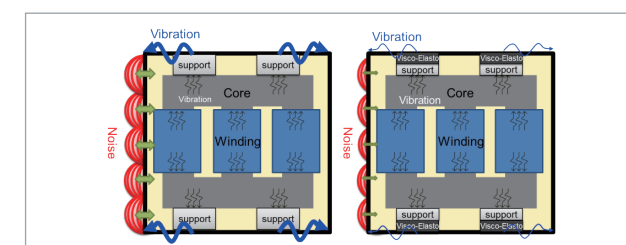
[Fig. 4] Tank design with noise radiation efficiency

As noted earlier, the noise caused by structural vibration follows the source of vibration, the transfer path, and noise radiation in that order, so it is very important to reduce tank vibration from which noise originates. An ordinary method of reducing noise from the tank is to increase the tank's thickness or to install double walls or a noise-absorbing/shielding device. However, such a method has a disadvantage in that it increases the size, weight and cost of that tank. The Hyosung Research Institute is using a method of reducing noise as much as possible while maintaining the thickness of the tank, based on research on vibration analysis, sound resonance avoidance, sound radiation efficiency, etc. In addition, the latest construction methods such as CLD (Constrained Layer Dumper) were applied to reduce the radiated noise caused by the vibration of the transformer tank. This method is a vibration-reducing method by using a viscoelastic material between the tank and the constrained steel having a certain area, and it can effectively reduce the vibration of the structure.

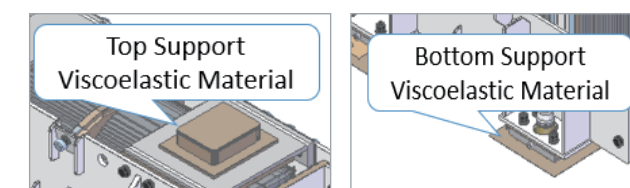


[Fig. 5] Difference in noise level when using different noise reduction methods

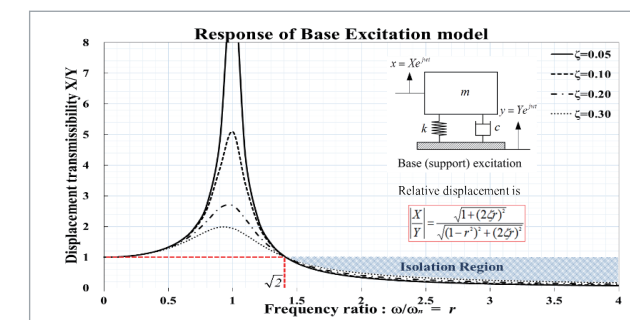
Our research shows that the most efficient method of reducing transformer noise was CLD. Using a method of optimization based on experimentation and the interpretation of diverse design elements, we reduced noise by an average of 4-6dB by suppressing vibration of the tank as much as possible. We are also using a method of suppressing tank vibration through the adoption of CLD, which uses the inner surface of the tank and existing structures. In addition, in order to minimize the noise radiation generated by vibrations transmitted from the active part to the tank, a technique using a viscoelastic material applied to the vibration transmission path between the active part and the tank was developed. This method is used as a standard for low-noise transformers. If the clamping force between the active part and the tank is strong, the vibration of the winding and the core is transmitted directly to the tank and amplified; hence the need to insert a damping material between the active part and the tank. Since vibration isolation is closely related to the natural frequency, it is very important to choose a material with good rigidity and damping properties. We also found and applied materials that can retain their initial physical and chemical properties over the entire 30-year life of the transformer.



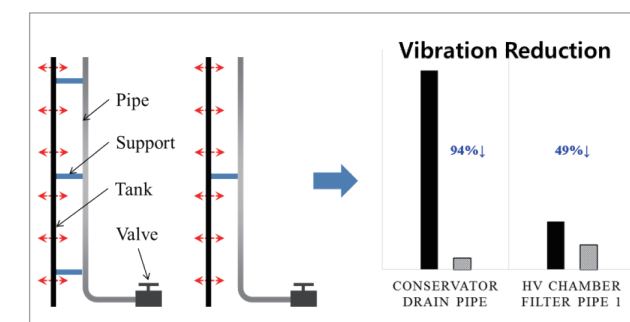
[Fig. 6] Vibration isolation between the active part and tank



[Fig. 7] Viscoelastic material at the top/bottom of the active part



[Fig. 8] Theoretical concept of vibration isolation



[Fig. 9] Vibration isolation of pipes and accessories on tank

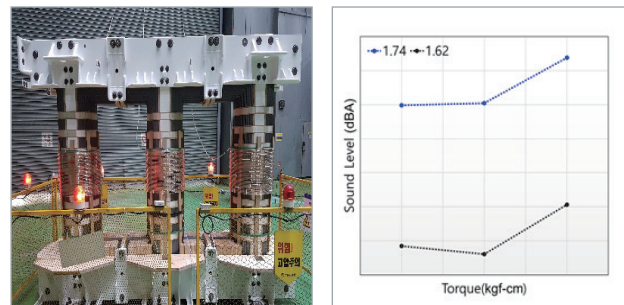
Various types of pipes and instruments attached to the tank are directly affected by the vibration of the tank. This problem is called "base excitation," and the vibration tends to be amplified and reduced by the relationship between the frequency component of the vibrating tank and the natural frequency of pipes and instrumentation. In general, it is deemed better to design a structure wherein pipes and instruments outside the tank are very strongly connected. From the perspective of vibration design, however, this design results in the greater amplification of vibrations of pipes and instruments than the vibrations of tanks. As a result of analyzing more than 100 cases of measured data wherein the vibration of pipes and instruments was higher than the vibration level of the tank, the natural frequency of the attachment was observed to be higher than the vibration frequency of the tank at about 70%. At least 50 to 90% of vibration was confirmed to have been reduced compared to the initial installation condition when the design was performed to lower the natural frequency by lowering the rigidity through the removal of support of the pipes and attachment with high natural frequency.

The strong support design between the tank and pipes and relay increases the natural frequency by increasing the system rigidity, and the vibration transmission path from the tank is added to increase the vibration. In addition, excessive vibration of the instrument may cause damage due to malfunction or damage of the instrument, so vibration isolation design is essential. The pipes and relays of Hyosung transformers have a vibration isolation design that effectively reduces the transmission of vibration from the tank.

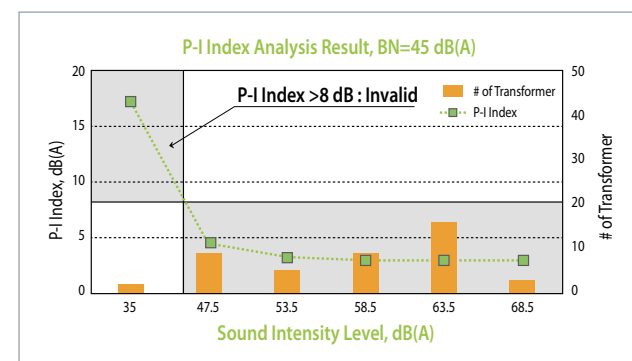


The manufacturing and test environment is also a very important factor in the development of low-noise transformers. As noise has been reduced with the development of low-noise transformers, the noise from a transformer is very sensitive to deviations in manufacturing and background noise. If the transformer noise is 50dB, noise may vary by as much as 2-3 dB due to a deviation in manufacturing, even in the same transformer model. Furthermore, with this type of low-noise transformer, the measured value may become different due to background noise and reverberation condition. As such, it is also necessary to conduct research on the manufacturing and noise environment.

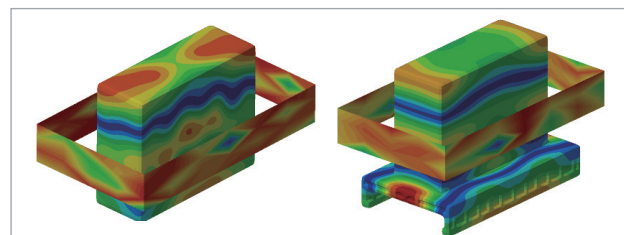
Hyosung has conducted various research studies related to production for low-noise transformer. First of all, we conducted research on the core's compression force, verified a structure wherein the core can be compressed evenly, and prevented in advance the noise deviation that can occur in products by calculating the level of tightening torque that can result in minimizing vibration. We also demonstrated the effect of reducing vibration through noise assessment for production quality (e.g., core's air gap), windings' compression force, iron stack shape, location/number of yoke bands, shape of the core's support, etc.



[Fig. 10] Noise analysis by core compression torque



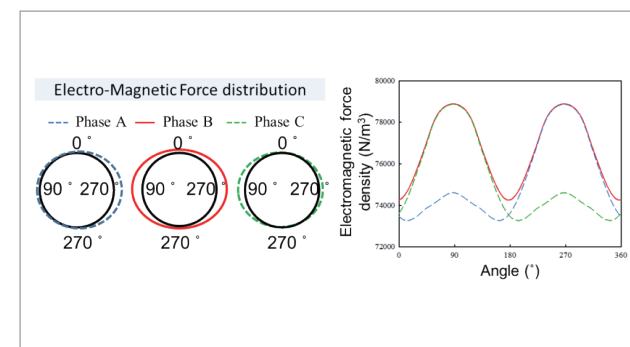
[Fig. 11] Measurement limit when the background noise is 45dB



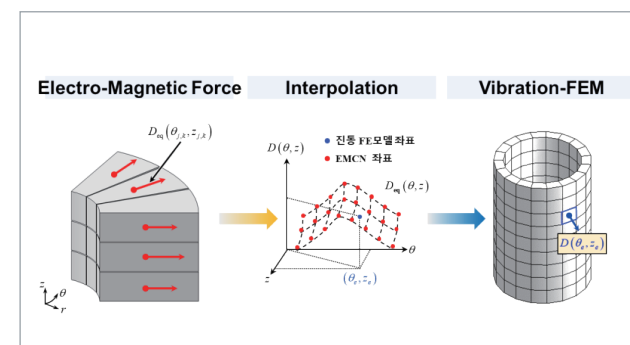
	Total Sound Level, dB(A)		
	On the floor	On the working table	Difference
Simulation	68.0	71.5	3.5
Test	70.0	73.1	3.1

[Fig. 12] Experiment/Simulation result due to position

We are also conducting research on the noise environment, which is essential when measuring and analyzing low-noise transformers. We set the limit of transformer noise that can be measured using the P-I index, a major indicator in noise evaluation. In the IEC standard, the P-I limit is defined as 8dB. The P-I index is an index representing the difference between sound pressure and intensity, showing a larger difference in environments with greater reverberation and background noise. Accordingly, background noise needs to be managed to measure low-noise transformers. A survey of the P-I index with the background noise managed at 45 dB shows that the measurable transformer noise is around 50dB. At present, we are conducting measurement and analysis with the background noise managed for low-noise transformers. We also conducted a noise evaluation wherein we compared how the differences in the measurement condition of a transformer influence the level of noise emitted by such transformer.



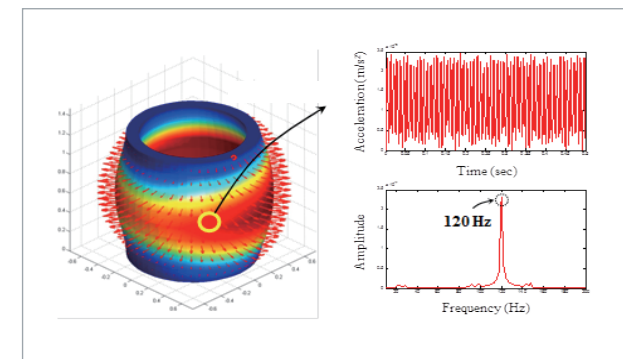
[Fig. 13] Electromagnetic force applied to the windings



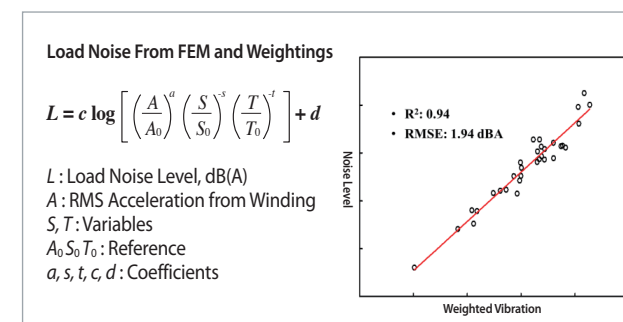
[Fig. 14] Model mapping of electromagnetic force and vibration

Finally, the method of predicting transformer noise accurately based on the aforementioned methods is a very important factor in the design and manufacture of low-noise transformers. If the noise measurement results differ from the prediction due to inaccurate noise calculation technology, both the manufacturer and the customers will incur considerable losses.

Thus, each manufacturer conducts research aimed at producing a more accurate noise prediction model by updating its own noise calculation model and comparing it with the results of experiments. We have established a highly accurate, mathematical model by using the relevant theories and experimental database, and we are updating it in order to be able to predict load noise originating from the electromagnetic force of the windings and no-load noise resulting from the magnetostriction of the core.

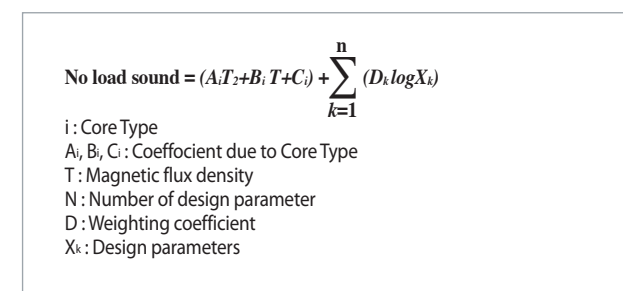


[Fig. 15] Winding vibration response by electromagnetic force



[Fig. 16] Load noise prediction model and accuracy

First, a finite element model was established to predict the noise of the windings that generate vibration by electromagnetic force. The equivalent electromagnetic force acting in the radial direction of the winding was calculated as a mechanical response and converted into a vibration response of the winding. We established a load noise prediction model with very high accuracy (average of 0.2 dB with standard deviation of 1.3 dB or lower) using the winding vibration response obtained through an electromagnetic-mechanical coupling analysis model and via numerical analysis and regression. These results can be said to be very superior to the regression equation that consists only of experimental data or multibody FEM analysis and takes a lot of time. We also established a no-load noise prediction formula by adding design factor-related formulas based on the noise formulation per size of magnetic flux by each core's specification in order to predict noise originating from the core.



[Fig. 17] No load noise prediction model

	Mean Error (dB) (Test-Estimation)	Standard Deviation (dB) (Test-Estimation)
Load Noise	0.2	1.3
No-Load Noise	0.5	1.8

[Fig. 18] Evaluation of accuracy of noise prediction model

In a comparison using the measurement data of more than 200 transformers, the no-load noise prediction model has a high level of accuracy in prediction (average of 0.5 dB with standard deviation of 1.8 dB). Such a high accuracy could be obtained as it included the abovementioned natural frequency avoidance technology, a low-vibration/low-noise technology, a vibration isolation technology, and various environmental factors in addition to the ordinary electrical design of transformers. Such technologies have enabled us to design low-noise transformers and meet our customers' requirements.

### "Proactive research to meet the market requirements"

To cope proactively with customers' requirements concerning the development of low-noise transformers, we continue carrying out the relevant research. First, we have strived to stabilize vibration/noise with resonance avoidance design and minimize noise from vibration transfer using a vibration isolation design related to the tank, active part, and tank vibration control technology. We have also conducted research on the noise measuring environment most suitable for low-noise transformers. Finally, we have attempted to minimize difference between our products' measured values and predict by developing a highly accurate load/no-load noise prediction model. Based on our dedicated research and efforts, we successfully developed a 50 dB-class, low-noise transformer in 2017, and are continuing with our research aimed at reducing transformer vibration and noise to meet the market requirements.



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Deputy General Manager  
Noise & Vibration Tech. Team



Chul-jun Park  
Deputy General Manager  
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## Epilogue

This technology magazine was published by Electricity PU of Hyosung Heavy Industries.

Since founded in 1962, Hyosung Heavy Industries has aimed to increase the corporate value of customers at home and abroad and contribute to the development of local communities and the quality of life.

In today's electricity market, demand for new technologies is emerging in line with rapid market changes, such as expanding the use of renewable energy and accelerating digitalization to respond to environmental issues.

In response, Hyosung Heavy Industries has been constantly developing and supplying products that are essential to customers based on various new technologies and is striving to enable customers' power system innovation with services that can further increase customer value. We hope that the technologies introduced here will be helpful to our customers. For more information on the contents of this magazine and others, feel free to contact us anytime.

Thank you for reading.

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