2023 VOL.3

POWER TECHNOLOGY MAGAZINE

HYOSUNG HEAVY INDUSTRIES

POWER TECHNOLOGY MAGAZINE

HYOSUNG HEAVY INDUSTRIES

POWER TECHNOLOGY MAGAZINE 2023 VOL.3 HYOSUNG HEAVY INDUSTRIES

HYOSUNG HEAVY INDUSTRIES

www.hyosungheavyindustries.com
119 Mapo-daero, Mapo-gu, Seoul, Republic of Korea
TEL +82-2-707-6000 I FAX +82-2-707-7799

Contents

Greetings from the CEO 03

The First 400kV class Transformer with Synthetic Ester Oil in Korea 04
Hyosung Heavy Industries, Global Top Green-Energy solution provider

Switchgear designed for Underground Substation (Low Vibration) 06
A Case Study on the Development of Switchgear for Underground Substation in Singapore with Vibration Reduction Design

Building the Largest Battery Energy Storage System (BESS) in Africa 08
Hyosung Heavy Industries signed Package-2&3 Contracts of BESS Phase-1 Projects from Eskom, a South African Electricity Utility

Changes in Power Industry Landscape, Power Facility Asset Management 10
Power Facility Asset Management(APM: Asset Performance Management) Technology Trends and ARMOUR

Solution Engineering Technology 14
Provides Customized Solutions based on System Engineering

Mobile Solution for Power Facilities of Hyosung Heavy Industries 16
High-Quality Mobile Solution Provider with an Eco-Friendly and Compact Configuration

Securing Quality Competitiveness through FIT(Fast Innovation Team) Activities 20
FIT Activity to Achieve Top-Notch Quality

Building an Intelligent Factory through Digitization and Making the Factory status visible in Real-time 22
Quality Improvement and Maximization of Production Efficiency through Process Automation

MVDC for Improving the Receptivity of Renewable Energy 24
MVDC: Medium-Voltage Direct Current

Editor's message 26

CEO Greeting

We have overcome the unprecedented era of COVID-19 and returned to our daily lives. In the meantime, Hyosung Heavy Industries sought new growth opportunities in the rapidly-changing market environment, demonstrating resilience in its ability to adapt the challenges and uncertainty of the business landscape. Electrification is the most critical means to achieve carbon neutrality and energy transition for a sustainable future. The power grid that supports human life has a more important mission than ever before. As a total energy solutions leader providing guidelines to the global power industry, Hyosung Heavy Industries is moving towards its mission of achieving a low-carbon society through innovation in the power systems.

Hyosung Heavy Industries is committed to focusing on the mission that customers and communities demand through R&D, particularly on decarbonizing power equipment and innovating a flexible and stable power grid. We contribute to reliability and efficiency of transmission and distribution networks by supplying the most critical equipment such as transformers and switchgear worldwide. Moreover, it plays a key role in the ongoing energy transition of the world with next-generation technologies such as Battery Energy Storage Systems, STATCOM, and DC solutions. We are also proudly improving the lifespan of power equipment operation through the digital-based power facility asset management solution (ARMOUR), the first service to be provided in Korea. In response to the global concerns on the environment, We are promoting the transition of its product range to environment-friendly solutions by developing sustainable insulation oil transformers, and eco-friendly gas-insulated switchgear that utilizes dry air.

Above all, Hyosung Heavy Industries focuses on providing solutions that customers want by listening more closely to "VOC (Voice of Customer)" that has been the basis of the company's philosophy and will approach customers more closely as a more localized organization.

Total Energy Solution Leader for Tomorrow,
Hyosung Heavy Industries!

Hyosung Heavy Industries Corporation
President **TAKESHI YOKOTA**

"Hyosung Heavy Industries, a Total Energy Solution Leader, is dedicated to meeting the demands of both its customers and society by consistently conducting R&D, with a focus on achieving carbon neutrality and energy transition for a sustainable future. The company prioritizes listening to the VOC to better understands customers' needs and provide customized solutions that meet their specific requirements.

The First 400kV class Transformer with Synthetic Ester Oil in Korea

Hyosung Heavy Industries, Global Top Green-Energy solution provider

The demand for Green Energy is increasing worldwide, and eco-friendly power equipment are becoming essential to today's power grid.
In the transformer industry, the development of transformers using ester-based insulation oil is being promoted as an eco-friendly alternative to mineral oil.
This is an attempt to solve the problem of soil and water contamination and fire caused by the outflow of mineral oil.
While the development of ester oil transformers have been focused on transformers in the voltage class of 154kV or lower, the development of extra-high voltage transformers of 345kV to 500kV has been expanding in recent years.
Hyosung Heavy Industries has been conducting research to develop eco-friendly biodegradable ester oil transformers to meet these market requirements, and has secured global top-level technological competitiveness through the successful supply of 400kV class synthetic ester oil transformers, first of its kind in Korea.

Development and production of ester oil transformers

Hyosung Heavy Industries (Hyosung) has been supplying over 180 natural and synthetic ester oil transformers up to 154kV to the domestic and global markets. It has successfully supplied and installed 33kV 60MVA synthetic ester oil transformers for National Grid in the UK, 2019.
Hyosung's 400kV synthetic oil transformer was developed based on insulation performance test and cooling performance test using winding models. As a result of its technological and price competitiveness, Hyosung was able to break into the UK market, which was previously dominated by Siemens, and win additional supplies of 33kV 60MVA transformers and 400kV 240MVA transformers.
In November 2022, Hyosung successfully developed and produced Korea's first 400kV synthetic ester oil transformer.

Figure 1 | Synthetic ester oil transformer – 400kV 240MVA

Figure2 | Synthetic ester oil transformer – 33kV 60MVA

Characteristics of ester oil

Ester oil is divided into the synthetic ester oil and natural ester oil, and the characteristics of each oils are as follows.

Key features of ester oil

- Fire safety due to high fire point and low net calorific value → Cost saving from reduced installation space
- Excellent biodegradability according to OECD 301 → Eco-friendly in case of leakage
- Loss of K-class(300°C) characteristics due to fire point degradation → Dedicated facilities only for ester oil need to be built
- In the case of natural ester oil, the pour point is high, so cold start is required in some cases

Table 1 | Comparison table of insulating oil

Item	Mineral Oil	Synthetic Ester Oil	Natural Ester Oil
Fire point	170°C	315°C (Min. 300°C)	310°C (Min. 30°C)
Net Calorific Value	46 MJ/kg	30.8MJ/kg	40.5MJ/kg
Flash Point	160°C (Min.135°C)	275°C (Min.250°C)	315°C (Min.275°C)
Pour point	-60°C	-56°C	-18 ~ -23°C
Biodegradability	9.7%	89%	94%
Breakdown (2.5mm gap)	70kV	>75kV	>73kV
Moisture Saturation (20°C)	55ppm	2700ppm	1100ppm
Viscosity (40°C)	7.7mm²/s	29mm²/s	33mm²/s
Permittivity	2.2	3.2	3.2
Oxidation Stability	Good	Excellent	Poor

Technical characteristics of ester oil

1) Insulation performance

Table 2 shows the differences in the relative permittivity of fluid and impregnated cellulose in ester oil compared to in mineral oil. The insulation stress distribution in the transformer windings depends on the permittivity difference. Figure 3 shows the dielectric field distribution according to the permittivity difference. When designing an ester oil transformer, it is important to be aware of these differences and reflect them in the transformer design. Hyosung obtained a high technical evaluation score from the customer by demonstrating verification test result using developed winding models for 400kV ester oil transformer.

Table 2 | Relative Permittivity of insulating oil

Item	Synthetic ester	Natural ester	Mineral oil
Fluid	3.2	3.2	2.2
Impregnated Cellulose	4.7	4.5	4.4

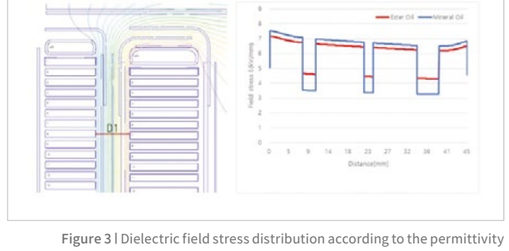


Figure 3 | Dielectric field stress distribution according to the permittivity

2) Cooling performance

As shown in Figure 4, ester oil has a higher viscosity than mineral oil. High viscosity will slow the flow of insulating oil, reducing cooling performance. Hyosung Heavy Industries conducted a test to verify the cooling performance of ester oil, established design standards to increase cooling efficiency, and has an internalized cooling design software for ester oil transformer.

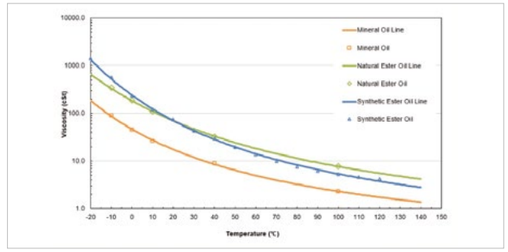


Figure 4 | Viscosity graph by type of insulation oil

Market status of ester oil transformers

Ester oil transformers will continue to increase with renewable energy policies. In Korea, it is expected to be used in urban substations and underground substations that require eco-friendly solutions, and marine power substations and wind turbines that are expected to play a pivotal role in renewable energy generation. In the global market, the synthetic ester oil transformer market is growing significantly in Europe, and the natural ester oil transformer market is growing significantly in North America. In addition, the market for ester oil transformers is expected to increase significantly in the future as the interest in ester oil transformers is increasing at major power utility companies around the world.

"

Hyosung has been conducting technology seminars on ester oil transformers for global power utility customers in Latin America, the Middle East, Asia, and Australia for the past few years to meet the growing demand in ester oil transformers.
By successfully developing 400kV ester oil transformers, Hyosung has secured global top-level technological competitiveness, and established a production system that can fundamentally prevent mixing with mineral oil by building dedicated facilities for stable production.
Based on this, it is expected that 345kV ester oil transformers for the offshore wind power plant project in Korea will be also delivered successfully, and we plan to expand the business in ester oil transformer in other global markets including Europe, and the Americas.

Myong-Gong Sohn
Performance Manager
Transformer Technology Development Team

Tae-Jin Yoon
Performance Manager
High Voltage Transformer Specification Design Team

Switchgear designed for Underground Substation (Low Vibration)

A Case Study on the Development of Switchgear for Underground Substation in Singapore with Vibration Reduction Design

Urbanization due to modern society's rapid development, the need to increase the system capacity of electric power systems and new business opportunities have been formed. When constructing a new substation within an already established and complex urban area, there are numerous issues to address. Many cities have been constructing city-friendly substations, and improve space utilization by constructing underground spaces under already existed parks, or high rise residential buildings or shopping complexes. Such installations though, have the potential of damaging the building due to the vibration generated by switchgears. Such vibration can also raise concerns and anxieties to the building's residents. Therefore, countermeasures are needed. To resolve this issue, Hyosung Heavy Industries has successfully developed an anti-vibration design based on the company's own specialized techniques and technologies. In this article, we are sharing a project case, in which our know-hows and technology was much appreciated by the customer.

The circuit breaker generates a large load (e.g. impact) by open and close operations, or open/close series operations, which in turn generates vibration in the structure (GIS). And due to the system's dynamic characteristics the vibration is transmitted to external structures (building).
To reduce the impact of the load, which can range from a few to dozens of tons depending on the type of GIS, a frame is welded and bolted between the GIS and the installed surface to firmly support the GIS. However, such installation method transmits much of the vibration of the GIS to the building, arousing customer's dissatisfaction.

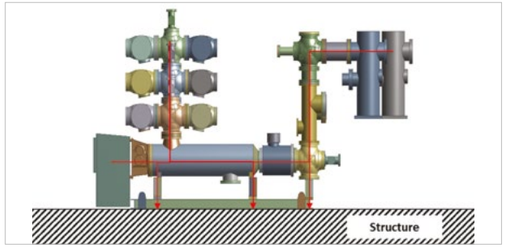


Figure 1 | Vibration transmission path

Thus, to lessen the vibration transmitted into the buildings, it is critical to secure an anti-vibration design alleviating the vibrations generated in the device itself by circuit breaker's operation or reduce the vibrations transmitted to the building. Standards for the vibration are limited by the human sensory response scale as shown in the following standards.

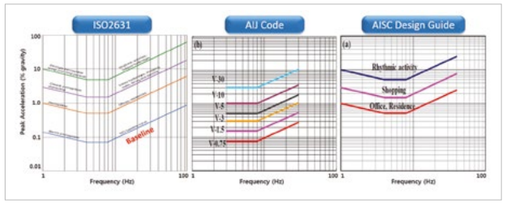


Figure 2 | Vibration standard & Meister curve

The vibration level requested by the customer was a vibration level equivalent to Classification 1, Rank-1 of Architectural Institute of Japan (AIJ Code), which means the demand is corresponding to a continuous vibration(V-0.75) in residential environments such as bedrooms or living rooms, a very low vibration level.

Customer's need according to the vibration standard

Classification & Rank		Residential	Office	
		Living Room & Bed Room	Conference Room	Office Room
Classification 1	Rank 1	v - 0.75	v - 1.5	v - 3
	Rank 2	v - 1.5	v - 3	v - 5
	Rank 3	v - 3	v - 5	v - 5
Classification 2	Rank 3	v - 5	v - 10	v - 10
Classification 2	Rank 3	v - 10	v - 10	v - 10

In order to meet such low vibration levels, we have mapped the vibration characteristics of the GIS model by conducting a pre-test according to the ISO2631-1, and have identified the resonance Frequency of the GIS for reducing the floor vibration.

During the initial design stage, the measured vibration was exceeding the target, and dampers for vibration reduction were required. Therefore, we calculated the system's natural frequency and damper stiffness, in order to choose optimal dampers.

$$a_w(t_0) = \left\{ \frac{1}{\tau} \int_{t_0-\tau}^{t_0} [a_w(t)]^2 dt \right\}^{\frac{1}{2}}$$

where,

$a_w(t)$ is the instantaneous frequency-weighted acceleration
τ is the integration time for running average
t is the time (integration variable)
t_0 is the time of observation (instantaneous time)

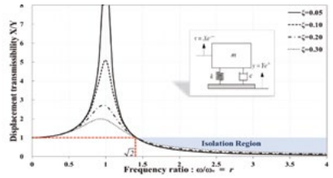


Figure 3 | Test procedures & theoretical vibration transmission rate

To choose the right dampers based on the calculation results, we evaluated the stiffness depending on the material, size and thickness, and have decided proper damper stiffness and pattern satisfying the designed natural frequency.

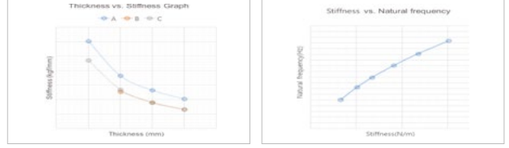


Figure 4 | Test results in damper stiffness & natural frequency

A rubber pad adopted as a damper, has a static load section with linear property. If the load delivered to the pad is too small or too large, it can result into an increase in vibration compared to applying a suitable load to them. If the distributed load according to GIS weigh surpasses the aforementioned stiffness and natural frequency, the expected vibration reduction is not achieved. Hence, careful selection of pad quantity and set up locations is needed. When selecting the pad's locations, the GIS's center of gravity must be taken into consideration as well as frame size.

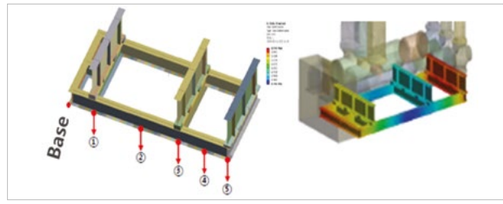


Figure 5 | damper quantity and its set-up spot selection

In order to verify vibration reduction design, we carried out test corresponding ISO 2631-1 with GIS. The test results showed a 75% reduction of vibration. In addition, we secured know-hows on various handling methods for installation and transportation as well as jack-up measures.

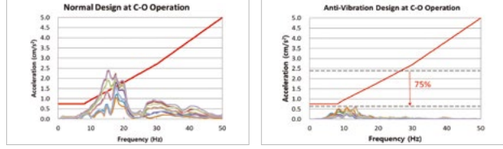


Figure 6 | Comparison before and after adoption of anti-vibration design, 75% reduction effect

Hyosung Heavy Industries has performed extensive research in order to minimize GIS vibration and lower the vibration transmission to the floor, to meet the increasing customer's demand for low-noise and low-vibration GISs.
First, through the evaluation of floor vibration before applying anti-vibration techniques, we identified the frequency range, and degree of reduction needed, and set the natural vibration of the system and damper stiffness. Then, through analyzing the vibration responses by damper type, we selected the right dampers that can minimize the vibration of the GIS.
Lastly, selected the optimal damper locations by establishing mathematical models assuming the GIS as rigid body, and then verifying it through tests, finally succeeding in meeting the targeted level of the AIJ V-0.75 standard.
Based on such research activities, we succeeded in winning Singapore's Labrador underground substation project, and are continuing to develop our anti-vibration technologies.

Sung-Ho Lee
Performance Manager
Gas High Voltage Switchgear Development Team

Building the Largest Battery Energy Storage System (BESS) in Africa

Hyosung Heavy Industries signed Package-2&3 Contracts of BESS Phase-1 Projects from Eskom, a South African Electricity Utility

Hyosung Heavy Industries Corporation ('HYOSUNG') has been awarded a full-turnkey contract for design, supply, installation and construction of 68MW 292MWh Battery Energy Storage System (BESS) from the state-owned electricity utility company in Republic of South Africa, Eskom Holdings SOC Limited ('ESKOM'). This contract includes extension work of existing substation along with five years of maintenance (O&M) service after completion. This BESS system will be installed on a site near the existing substation, and will store energy for 4~5 hours during off-peak period, and discharge for applications such as peak shaving, ancillary services, energy support, etc. This will provide stability and flexibility to the grid to support sustainable renewable energy conversion in South Africa.

South Africa's renewable energy transition supported by BESS installation

South Africa, possesses a total of 52GW in power generation facilities. This consists of half of the continent's capacity. South Africa has declared carbon neutrality by 2050 through Low Emission Development Strategy (LEDS) in 2020, and is currently implementing an intense energy transition program (Just Energy Transition, JET). It will diversify its fossil fuel-oriented energy sources, starting with retiring of a 1GW Komati coal-fired power plant. The government is planning to shut down 6GW by 2025 and 22GW total over the next 15 years. This is supported by the introduction of BESS as a solution for stable power system operation with solar and wind-based distributed generation.

4-years of preparation for Eskom contract finally comes to fruition

In 2018, ESKOM, financed by World Bank (WB), African Development Bank (AfDB), and New Development Bank (NDB), announced Africa's first utility scale 360MW 1440MWh BESS installation plan in two stages. HYOSUNG has gradually worked on the bidding strategy through understanding customer requirements and performing a thorough market analysis.

One thing HYOSUNG realized in the early stage was that safety, health, environment, quality (SHEQ) management capabilities are no less important than technological capabilities by listening to Voice of Customer (VOC). Therefore, we tried to secure technological reliability through activities like holding technical seminars for customers (Nov. 2018) and publishing BESS white papers (Dec. 2018), also tried to satisfy HSEQ conditions by obtaining ISO45001 certification (safety and health) for BESS (Feb. 2020) and strengthening hazardous material handling procedures with external experts' consultation.

Another success factor was proper product selection and localization through constant communication with our customer. Considering the relative difficulties of after service and operating management in Africa, we achieved customer satisfaction by proposing a mobile modular type inverter (Power Control System, PCS) that facilitates initial action in case of maintenance rather than our previous central type inverter. We also recommended a preemptive measure to hire and train local engineers needed for 5 years of O&M under HYOSUNG's South African subsidiary.

Despite the global COVID-19 pandemic period, a total of six personnel including sales, construction and electrical engineers were dispatched to South Africa for several months. They searched for trustworthy local partners and create the most competitive bid proposal. This proposal reflected local circumstances of the market and customer. As a result, HYOSUNG was able to become a preferential negotiator and finally won the contract.

Eskom's Sere Wind Farm
(Image : Eskom)

Pre-emptive design to shorten the construction period, and localization

Recognizing the importance of shortening the design period to meet the short-term construction deadline, HYOSUNG conducted preemptive engineering after becoming a preferred negotiator, prior to the final contract. Through early establishment of a design organization and concentration of our design capabilities from April 2022, we successfully conducted a design review presentation for the client in September. In October, we obtained approval for Issued for Construction (IFC). As a result, we were able to complete the main design within 3 months after signing the contract.

To solve the issue of replacing the two main transformers of the existing substation within the BESS lead time, we carried out the parallel power outage schedule using a mobile transformer. This reduced the construction schedule by 3 months compared to the original sequential transformer replacement period. In addition, we are strengthening communication and cooperation with customers and partners through active localization of dispatched execution organization, while effective project management such as eliminating engineering bottlenecks and judging critical paths based on local engineers' experience and know-hows.

Communication and cooperation with local communities are vital for successful local construction in South Africa. Foreign companies are encouraged to blend into local communities and contribute to economic empowerment of the neighborhood. In response, HYOSUNG is strengthening communication and cooperation with local residents by hiring personnel who has a deep understanding and leadership in the region as Community Liaison Officer (CLO), and is actively carrying out local contribution activities (Supplier Development, Localization & Industrialization, SDL&I) by forming a consultative body including the project owner.

Mobile transformer to shorten construction period

Groundbreaking ceremony in Elandskop, KZK in DEC, 2022
(Image : Eskom)

"South African Eskom project is expected to be completed in the first half of 2023. It is expected to improve the current poor power supply condition such as frequent local power outages (Load Shedding, forced power cut due to lack of power supply), and contribute to the stability of Eskom's power grid by providing applications like ancillary services in the long term.

The African region is expected to become an attractive market in the future as it is actively planning to expand renewable energy sources and establish related infrastructure, of one which is BESS. Through continuous contribution to the stabilization of the power system and the expansion of renewable energy by utilizing technology and experience in power industry (e.g. power transformers and switchgears), Hyosung Heavy Industries will actively participate in the market as a Total Solution Provider.

Dae-Hee Chio
Performan Leader
ESS Business Director

Eugene Eun-Sung Lee
Performance Manager
Global BESS Business Team Manager

Jae-Gon Kim
Performance Manager
Global BESS Business Team
(African Market Leader)

Changes in Power Industry Landscape, Power Facility Asset Management

Power Facility Asset Management(APM: Asset Performance Management) Technology Trends and ARMOUR

*ARMOUR : Asset Remote Management system for Operational Utility's Reliability

As technologies based on the 4th Industrial Revolution, such as Big Data, Artificial Intelligence, Block-chain, Cloud, Internet of Things, develop, they are also bringing about new changes in the electric power industry. These changes will revolutionize the landscape of the electric power industry and create new markets, new services, and new values. One of these hegemony changes in the electric power industry is power facility asset management.

Power Facility Asset Management Overview

The rapid industrialization in numerous developing regions during the 1970s led to a surge in the number of power facilities. As a result, time-based maintenance (TBM) was mainly carried out to assess the status of these facilities. With the advent of power facility sensors since the 2000s, sensors are now being installed in power facilities to monitor their status online. This has led to the widespread adoption of Condition-Based Maintenance (CBM), which performs maintenance based on the facility's condition when abnormal signs occur.

Due to the ageing of power facilities, there is an increased risk of failure, which can cause significant production losses. Consequently, reliability and stable power supply have become increasingly important in the operation of power facilities. Asset owners and managers now expect service providers to offer systematic and cost-effective support in conducting accurate condition assessments, predicting remaining life, and establishing maintenance policies for power facilities.

With the development of the 4th Industrial Revolution, technologies, such as big data analysis, artificial intelligence and Internet of Things, have brought about new changes in the field of electric power technology. There is a need for a power facility asset management solution that provides systematic management services throughout the entire life cycle of power facility assets by combining products/services/operating systems such as real-time operation data of facilities, failure prediction through condition data analysis, optimal maintenance strategies based on accurate condition assessment of facilities, and decision-making on new facility investment using the 4th Industrial Revolution technology.

Power facility asset management means establishing optimal maintenance and investment plans for power facilities. This is based on technical evaluations, such as facility soundness, failure rate and remaining life, and economic evaluation, such as maintenance and failure, and social costs using offline data (manufacturing, operation, inspection, failure history, etc.) and online data (DGA, PD, etc.).

Overseas Power Facility Asset Management Technology Trend

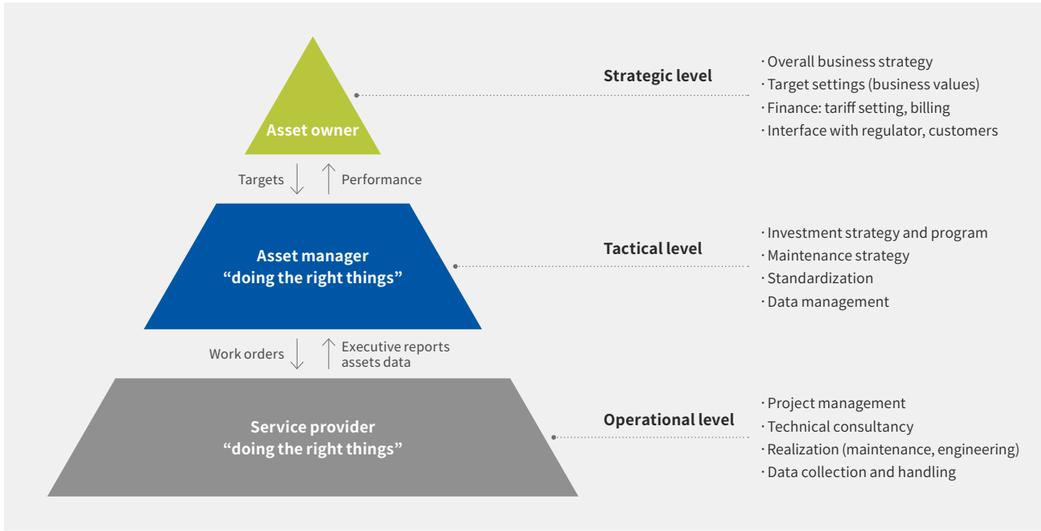
Globally, since 2000, research on the establishment of optimal maintenance and investment plans for aging power facilities has become active. As a result, in 2004, the British Standards Association established PAS (Publicly Available Specification) 55, which is a specification and guideline for asset management for facilities such as power and water resources, aviation, and railroad.

Based on this, ISO (International Organization for Standardization) established ISO 55000, an international standard for asset management, in 2014. A white paper, "Strategic asset management of power networks," was published in 2015 to establish an international standard for asset management for power facilities."

According to "Strategic asset management of power networks", the composition and core functions of an asset management organization looks like Figure 1. An asset owner is a person who sets goals to expand the value of the company as a whole, and a service provider is a person who operates and provides field operations such as asset data collection and maintenance. The asset manager is the person who plays the role of overseeing the above two groups.

Since PAS 55 was enacted in 2004, power utilities such as American Electric Power (AEP), Hydro-Quebac in Canada, National Grid in England, and EDF (Électricité de France) in France have been operating asset management systems. DNV GL (Det Norske Veritas and Germanischer Lloyd), ABB, GE, Alstom, Double, etc. develop and provide asset management systems. Among the heavy electric power companies in Korea, only Hyosung Heavy Industries developed it in 2016 under the name of ARMOUR, and in 2021, it has provided its services to substations under the Mozambique Power Utility (EDM: Electricidade de Moçambique).

Figure 1 | The asset management organization composition and core functions



Korean Power Facility Asset Management Technology Trend

As ISO 55000, an international standard for asset management, was enacted by ISO (International Organization for Standardization) in 2014, research and development on power facility asset management is underway in Korea.
Korea Electric Power Corporation (KEPCO) began to develop AMS (Asset Management System), an asset management system that can optimize asset management of power facilities, in 2020, based on big data related to power facility operation owned by KEPCO. The goal is to establish it in the first half of 2023. Hyosung Heavy Industries is the only one among the three major heavy electric power companies in Korea that developed it in 2016 under the name of ARMOUR, and is providing services to SK affiliates and GS Caltex. Hyosung Heavy Industries signed an MOU with KEPCO for business cooperation in the field of preventive diagnosis and asset management in June 2022. We are promoting the implementation of a more powerful business model by integrating the solutions of both companies, and we expect full-fledged services to be available from the first half of this year.

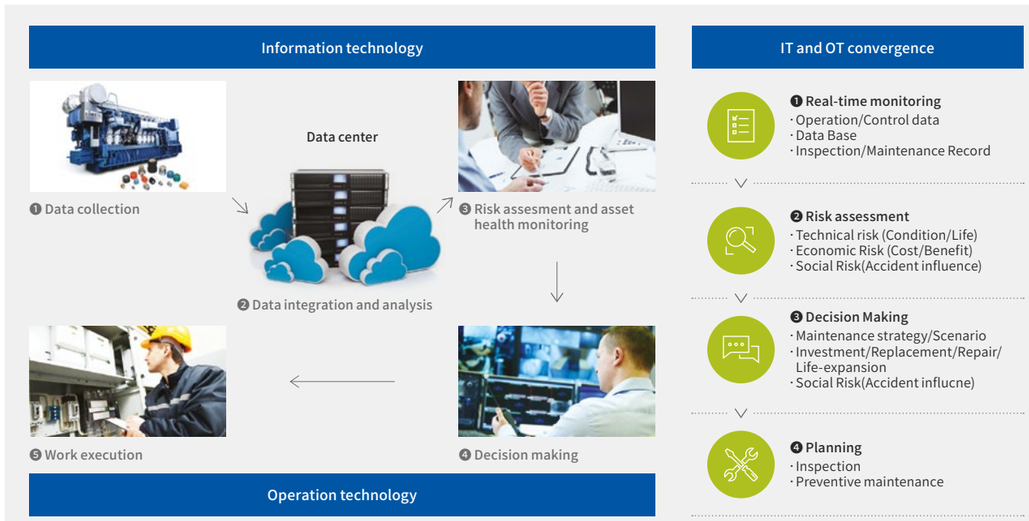
Hyosung Power Facility Asset Management Solution - ARMOUR (Asset Remote Management system for Operational Utility's Reliability)

1) ARMOUR Process

ARMOUR consists of four phases and is a comprehensive solution that comprehensively acquires monitoring, control, and operation data on facilities and assets secured while managing and operating existing substations, and supports customer maintenance decision-making through data computerization, communication, and analysis as shown in Figure 2.

1. Computerize and digitize online and offline data by real-time facility status monitoring to store and manage all data in a cloud-based data center
2. Performs risk assessment that performs technical risk analysis on the condition and lifespan of facilities through data center data analysis, economic risk assessment in terms of cost and profit, and social risk assessment through accident impact and environmental analysis
3. Based on the risk assessment results, establish maintenance strategies for new investment, replacement, repair, and extended use of facilities through remodeling, and derive decision-making scenarios.
4. Save and update data collected from facility maintenance through decision-making, actual execution of preventive maintenance and results

Figure 2 | ARMOUR Process



2) ARMOUR Algorithm

In order to systematically manage the life cycle of power facilities, it is necessary to predict failures and the remaining life of facilities through technical and economic risk analysis. This is based on the life model of each power facility, and to establish optimized maintenance and replacement strategies. In particular, extra-high voltage transmission and substation facilities with large scale and high importance should be evaluated in units of sub-systems that make up each facility. Figure 3 shows the basic configuration of the ARMOUR algorithm, which can be largely divided into 4 steps.

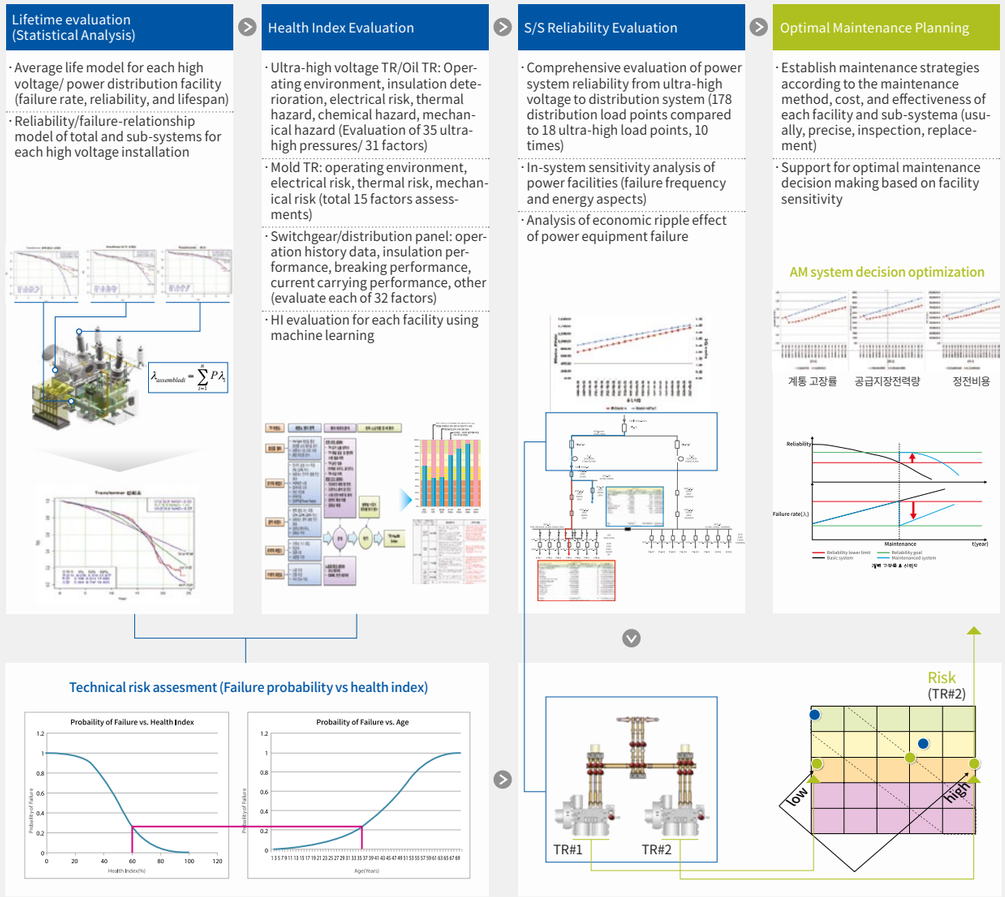
❶ Lifetime model and historical database
Life modeling stage of facility was derived through analysis of failure, maintenance data and reliability data of key parts for about 37 years accumulated as a power equipment manufacturer. It includes failure/inspection data acquired through operation.

❷ Health Index evaluation of each facility
The health evaluation algorithm is evaluated through more than 30 factors and more than 100 data regarding the risk of accidents and each required function based on the design, manufacturing, and diagnosis technology of power facilities. By applying an artificial intelligence-based health evaluation model, we made up for the disadvantage of being able to evaluate devices requiring inspection as normal because the accurate risk was not reflected when the evaluation score of a small number of the existing weighted average method was low.

❸ Evaluation of substation reliability and importance of each facility
ARMOUR implements a Risk Matrix through Probability of Failure (PoF) reflecting life model and soundness evaluation results and Consequence of Failure (CoF) analysis by analysis of failure rate, reliability, power supply interruption cost, outage cost, and failure recovery cost from the perspective of the entire substation.

❹ Decision
ARMOUR quantitatively evaluates the effect of improving substation reliability by the maintenance strategy of each power facility and power facility replacement. It prioritizes according to the improvement effect. ARMOUR establishes a maintenance strategy in consideration of limited budget and priorities. It estimates substation reliability improvement effect after strategy execution, evaluates the timing of future maintenance, and applies an optimization algorithm when establishing a maintenance strategy to manage the most goals among numerous scenarios. It will calculate the optimal investment scenario that satisfies the value (cost, performance).

Figure 3 | ARMOUR Algorithm



> Hyosung Heavy Industries has developed ARMOUR, a power facility asset management solution that combines big data-based IoT and ICT that can realize Smart substations aiming for Industry 4.0 through continuous technology development based on the experience of Korean and international ultra-high voltage power equipment manufacturers over the past half century. Developed in 2016, and built in extra-high voltage substations worldwide, the service continues. Hyosung Heavy Industries holds 9 Koraen patents and 6 international patents related to power facility asset management. Starting with the 2017 Top 10 Railroad Technology Awards, it has been awarded multiple awards including the 2020 IR52 Jang Young-sil Award, the 2021 Smart Construction Challenge Railroad Corporation Chairman's Award, and the Korea Electronics and Telecommunications Research Institute President's Award at the 6th Industrial Revolution Festival in 2022.

Bong-Cheol Lim
Performance Manager
Digital System Business Team Manager

Jong-Bin Lim
Performance Manager
Digital System Business Team

Solution Engineering Technology

Provides Customized Solutions based on System Engineering

The power industry is rapidly transforming with the demands of the era and the development of technology for environment. As we all know, the key keywords for change are Decentralization, Decarbonization, Digitalization expressed in 3D and Reliability, and Efficiency. In line with these trends, Hyosung Heavy Industries has a variety of power products, including Eco GISs, Eco Transformers, Phase Shifting Transformers (PSTs), Variable Shunt Reactors (VSRs), STATCOM, DC Solutions, and ESS besides conventional power products represented by Gas-Insulated Switchgears (GISs) and transformers, and provides all solutions including customized system consulting, system construction and O&M (Operation & Maintenance) based on its strength and understanding.

Solutions Engineering to Achieve Globalization

Since 1988, we have carried out more than 100 projects in about 25 countries and expanded our business from distribution voltage to 800kV extra-high voltage. We have experience to provide various solutions in almost all regions including the Asia, Americas, Europe, and Australia. Based on this long experience and know-how, we have the following capabilities:

First, proposes the basic design for the system based on the “voice of customer” (VOC).

Second, provides various calculation reports such as fault current, grounding system and lightning system using software such as ETAP and EMTP.

Third, provides services from design to purchase, construction, testing and commissioning as “Total Solution Provider”.

Fourth, provides consulting services for maintenance technology and system management and has a rapid response organization in the event of an accident.

In order to provide high-level engineering and rapid customer response service required by our customers, we have established local business organizations with local engineers and salespersons in major markets such as the United States, Japan and Malaysia to help our customers operate their facility optimally.

In addition, solution engineering personnel are deployed in global strategic locations to strengthen technical proposal capabilities, local market analysis (market sensing) and execution capabilities.

Case 1. HICO in USA

We have EPC capabilities that include design, installation, test and transportation which are crucial capabilities to expand our product businesses, including transformers, GISs, STATCOM, ESS and dry air insulated switchgears (DAIS). Depending on the size of the project, we can execute it on our own or utilize strategic outsourcing companies and proven EPC companies. In the case of a product, solution engineering and project management personnel are deployed forward to collaborate with headquarters. In the case of other EPC services, HICO is in charge from bidding to execution stage. In order to expand our business, we are continuing to find and verify additional companies in addition to our current partners by customer/region/EPC sector. Ongoing major projects are as follows.

- [HV-GIS] Idylwood, Fern Road
- [MV-GIS] Crystal City
- [STATCOM] Glenbrook (Completed), McGrau Ford
- [Micro Grid] Locks Campus

GLENBROOK/
2x±75MVar STATCOM

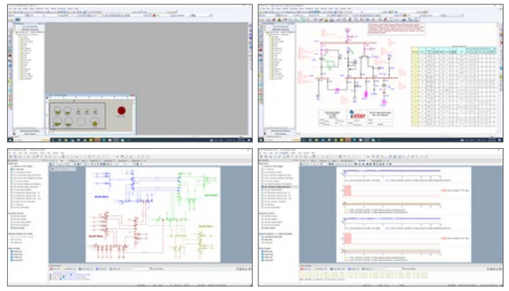
Locks Campus Micro Grid/
Overall Site Plan)

Case3. India

We have established a solution engineering organization to carry out global projects to continue our growth in Hyosung T&D India. We can provide services for solution businesses including basic design, various calculation reporting and electrical/civil design approval. We contribute to the global solution engineering business by improving our technical capability through engineer training on products such as Eco GISs, Eco transformers, PSTs, VSRs, STATCOM, DC Solutions, and ESS. We have executed the following projects.

Bidding design
- Kuwait/400kV Substation Project, 132kV Substation Project
- Ethiopia/400kV Substation Project

Execution design
- Sri Lanka/ STATCOM Project
- UAE/ STATCOM Project
- Ethiopia/400kV Substation Project



Software use case/ ETAP, EMTP

Case2. Malaysia

Since the initial delivery of GIS in 1993, 600 bays of GISs and numerous transformers have been supplied to more than 20 substations. Sales, solution engineering and installation personnel are deployed forward to strengthen local sales power even during the COVID-19 period. The local organization in Malaysia provides consulting services for maintenance and system management. In July 2022, we held a technical seminar with TNB, Malaysia Electric Power Authority, and conducted in-depth technical meetings on Eco transformers, Eco GISs and digital substations. Through this, we have identified customer interest in replacing old GIS, securing network stability, maintenance, and optimizing asset operations. Based on years of experience with KEPCO, we have developed a rapid response organization in the event of an accident. This service is provided so that customers’ GIS facilities can operate in optimal condition. We are planning to expand business to neighboring countries like Singapore. In addition, based on the currently established organization, we intend to expand the business area to transformer maintenance, STATCOM, ESS, etc.

TNB/Technical Seminar,
2022/07

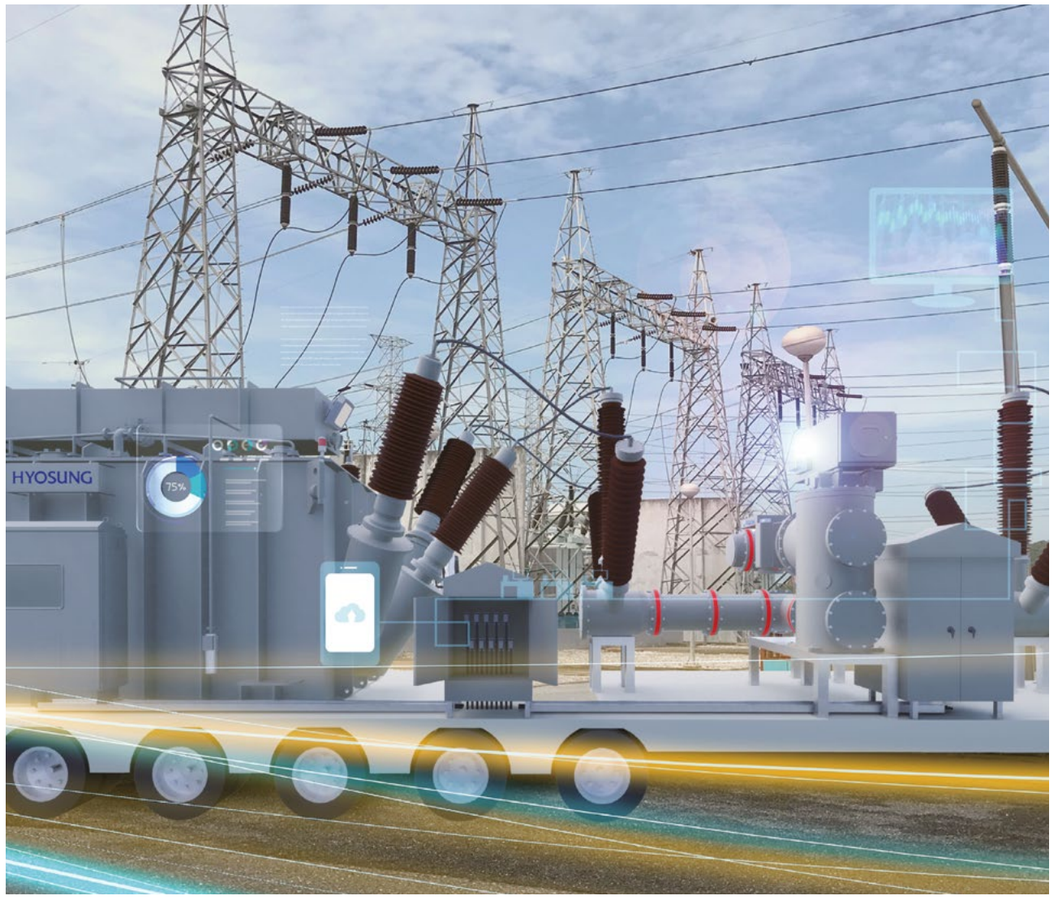
> “Customer diversity is increasing with advancement in power systems which are related with new technologies and renewable energies Interaction with each other regarding the planning, design, construction and operation of power system is important. Hyosung Heavy Industries always listens to its customers’ voice of customer (VOC)’. Based on technical know-how accumulated over time we seek to provide the best solution that reflects the customer needs by expanding our business areas in the global market through localized organization.

Ryun-Ki Kwon
Performance Manager
Global Solution Engineering Team

Mobile Solution for Power Facilities of Hyosung Heavy Industries

High-Quality Mobile Solution Provider with an Eco-Friendly and Compact Configuration

Hyosung Heavy Industries offers a mobile substation, which consists of a transformer, switchgear, and other devices installed on a trailer that can be dispatched to a customer's location. The benefits of mobile substations, such as speed, mobility, and compact configuration, make them a reliable replacement for malfunctioning power facilities or when there is an urgent need to connect to the power system, address long-term outages, or provide temporary power facilities for mining and oil fields.
Mobile substations can be installed quickly and easily to provide power supply when needed.
As a Total Solutions Provider for major substation facilities, we have developed a range of mobile solutions, including mobile GIS, ESS, and STATCOM, in addition to mobile substations.
Hyosung Heavy Industries is scheduled to supply a 230kV class mobile substation for Ethiopia Electric Power, which is an eco-friendly solution that reduces carbon emissions and minimizes SF_6 and mineral oil processing during a short construction period.



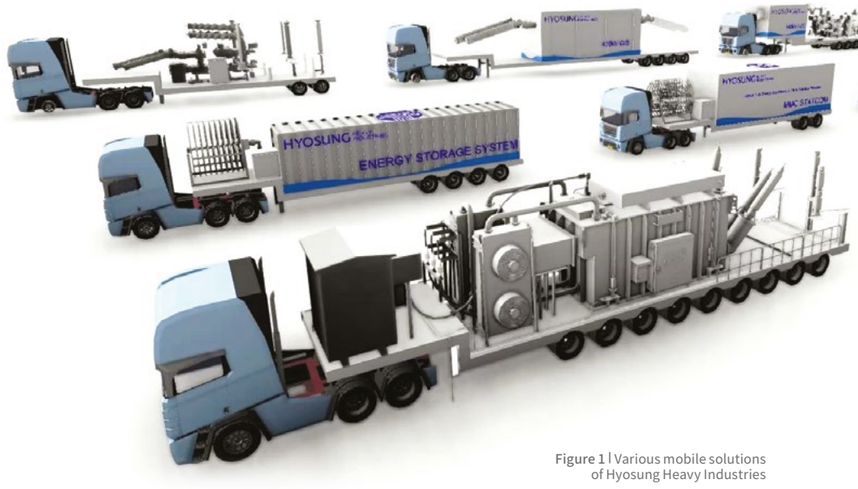


Figure 1 | Various mobile solutions of Hyosung Heavy Industries

Mobile Substation

The emergency type mobile substation is a representative of the mobile substation that has been used for accident recovery in the electric power market since the 2000 year. It is mainly used for transformer replacement. It can respond quickly and can be rapidly installed on site within a few hours. It must be designed in accordance with the transport regulations of the applicable country. In particular, for emergency transportation, the width and height of the transformer are limited, and the allowable length is affected by the curvature radius of the existing road. Care must be taken during design and operation stage.

Hybrid insulation was utilized in HV transformers to achieve a 30% weight reduction, while also enabling a higher temperature rise than what is typically allowed. If a flat type conservator is applied instead of a cylindrical conservator, it helps to reduce the overall height of the transformer, and it is also common to apply cooler with a pump that is more efficient than a radiator with fan for the cooling system.

In general, emergency type mobile substations are commercialized up to 230kV and are used up to 420kV in some countries.

Hyosung Heavy Industries can supply HV GIS products that can be transported without the need to remove air bushings by applying rotation bushings. This solution allows for the use of a 420kV mobile substation, which is not possible due to the phase-to-phase clearance issue of air bushings.

If there are multiple operating voltage in the power system, a transformer can be designed with various taps and provide a various voltage to minimize your mobile substation maintenance & stocks. The following table (1) is an example of using the mobile substation for some countries. In addition to transformer voltage, protection setting and CT / VT ratio selection depending on the expected load have to be considered.

Table 1 | Mobile Substation Voltage Suggestion by Country

Category	A Country	B Country
EHV Level	132kV, 110kV	230kV, 150kV
Distribution Voltage Level	33kV, 13.8kV	33kV
Proposed Mobile Substation	132-110kV/33-13.8kV	230-115kV/33kV

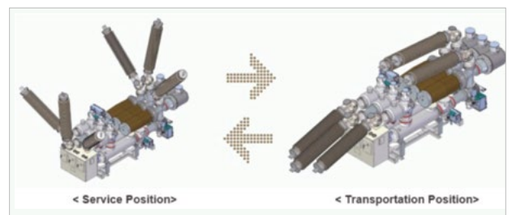


Figure 2 | Rotation Bushing View

Mobile GIS

In an emergency type mobile substation generally only 1 set of high voltage CB is required, so AIS or MTS type CB is often applied. However, with the development of circuit breaker mechanism technology and electric field analysis technology, GIS has become more compact. Utilizing these advantages, if GIS is applied to mobile substations, its utilization can be increased.

Figure 3 below, is a 145kV Mobile GIS designed by applying 145kV 3-phase common enclosure type GIS. To meet the various needs of customers, the external interface can be available with an air bushing or cable head, and can be installed on a trailer or skid. It can generally be transported inland with up to 6 GIS bays.

Figure 3 | Mobile GIS View for Air bushing and Cable head

Utilizing this Mobile GIS, it can be used as an H-type cluster substation with a 2TL+Section+2TR structure linked to a 100-200MW class medium-sized renewable project, and has the following advantages.

- Increase grid connection capacity and minimize connection waiting time
- Improvement of load flow of renewable power generation facilities and increase of system reliability by connecting double circuit lines
- Minimize distribution line construction and suitable to eco-friendly policy

The local control panel (LCP) of mobile GIS can be installed in the E-House including BCU and protection relay. By installing GIS and an E-house together on one trailer or skid, the internal cabling and test can be complete in factory before shipment. This reduces the energizing time at site. Table 2 is a comparison of the installation/test period at the site of a general HV substation and a mobile substation for renewable connection.

Table 2 | Site Installation/Test Time Comparison

Category	Conventional Substation	Mobile Substation
Design	6 month	1 month (Standard)
Manufacturing	6 month	6 month
Site Installation	3 month	0.5 month
Site Test	5 month	1 month
Total	18 month	Less than 8 month

Mobile GIS can also be utilized during replacement or overhaul of old substations. In particular, mobile GIS and new substation can be installed first in the remaining space of the old AIS substation, and then we can replace bay by bay without an outage. By connecting the Mobile GIS to the transmission line, bus-bar, and transformer feeder of the existing AIS substation, the substation can keep operation as normal and the separated AIS power products can be removed. Then, installation and test work such as cables or GIBs required for new GIS can be carried out.

Mobile STATCOM for Grid Resilience

The general function of FACTS equipment is to prevent voltage collapse through reactive power compensation and to compensate for power factor. With the connection of renewable energy, the grid codes for each country are being strengthened, and voltage fluctuation rates must be complied. The installation of renewable energy is increasing in remote areas, and as a result, additional construction of new transmission lines increases accordingly. There are increasing cases that existing substations cannot temporarily satisfy the grid code according to this change. And in some regions, due to the peak load time differance, there are substations that require reactive power compensation only seasonally or temporarily during certain national events. In this situation, deploying Mobile STATCOM can ensure grid resilience promptly and optimize the investment in compensation facilities.

The mobile STATCOM is divided into the following transformer, reactor and STATCOM modules.

Figure 4 | Overall View of Mobile STATCOM

In the STATCOM module, a converter is installed in middle position of valve room, and the initial charging facility and relevant CT/VT are installed together. The maintenance of STATCOM valve is possible by installing the door on the front and withdrawing it through a separate lifting device. Since at least two redundancy converters are basically included, continuous operation is possible even if a converter failure occurs. There is a cooling system on the right, but unlike the building type, maintenance is difficult in the vicinity due to the narrow space of the container. A separate maintenance space was secured inside the cooling skid, and a crane hoist and beam were installed on the ceiling to enable lifting of heavy equipment such as pumps.

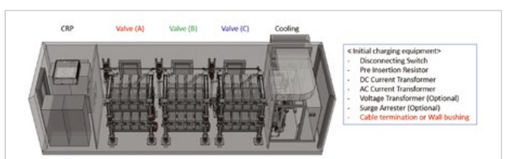


Figure 5 | Internal View of STATCOM Valve Module

Mobile MV Station for Fast Electrification

MV stations for ESS and PV connection are available as separate product models called skid type MV Station. Basically, it is composed of PCS, inverter transformer and RMU on one skid module. When connecting PCS and inverter transformer, the bus duct is generally used due to high current, and mv cable is used to connect RMU. For the compact skid design, it is important to coordinate the height of the inverter transformer's LV bushing and PCS bushing in same height to be directly connected in the horizontal direction. In order to prevent the installation error of bus duct due to height difference, the vertical tolerance of skid and civil base must be 5mm or less.

In addition, energy storage battery or MV switchgear for connection with the distribution system can be installed in a separate e-house. When designing the MV switchgear, the arc must be easily evacuated and the system must comply with local fire protection regulations.

Since renewable energy are often located in remote areas, there are many power plants waiting to be connected due to the insufficient transmission and substation capacity. For solar power generation, the installation time for solar panels is very fast, which allows for the preparation of a 100MW solar power plant within one year. To connect to an HV-level substation, a typical substation with a 24-month delivery time is necessary. However, a mobile solution can significantly reduce installation and testing time on-site. The development of standardized models of transformers and GIS can also reduce design and manufacturing lead times.

Figure 6 is a layout of applying mobile solutions of HV GIS, transformers, MV switchgear, and MV station for PV/ESS.

Figure 6 | Overall View of Containerized MV Station

230kV Mobile Substation for Ethiopia Electric Power

Hyosung Heavy Industries plans to supply a 230kV class mobile substation as part of the Ethiopia Electric Power Authority's Southern Extension of the National Electricity Grid Power Transmission Project. It will provide an eco-friendly mobile substation with an optimal and compact configuration based on standardized engineering documents and advanced technology for power facilities. The composition of mobile substations to be supplied in the future is as follows.

- 245kV GIS with LCP(1Bay)
- 230/33/15kV 50/50/50MVA Power TR(1Set)
- 33kV GIS (6 bay) in E-House
- 15kV GIS (6 bay) in E-House

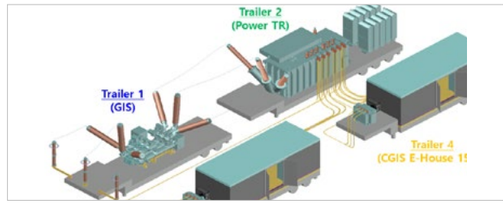


Figure 7 | Mobile Substation for EEP

"The need for mobile substations is increasing in line with rapid changes in the power system. In addition to disaster recovery, which is the traditional use of the mobile substation, it is possible to expand the utilization of various power products such as mobile GIS, mobile STATCOM, and MV Station for ESS/PV.

Mobile solutions provided by Hyosung Heavy Industries are modular and interchangeable, making it easy to expand and applicable in different industry areas (e.g. oil & gas, mining etc). Also, it is another advantage that transportation to the site is easy and compact design reduces footprint & construction work. It will be beneficial to developers of renewable energy projects because it will reduce the overall construction cost.

Min-Soo Kim
Performance Leader
Global Solution Engineering Team

Securing Quality Competitiveness through FIT(Fast Innovation Team) Activities

FIT Activity to Achieve Top-Notch Quality

Hyosung Heavy Industries actively promotes the deployment of FIT (Fast Innovation Team) with the aim of achieving the Zero Defect (ZD) quality level by rapidly investigating and eliminating a variety of quality issues. For a company to survive, it is imperative to achieve "customer satisfaction." Hyosung Heavy Industries places its emphasis on the quality of its products and its response to any customer concerns. FIT activities are at the forefront of such efforts. FIT is a response that is used when similar or the same quality problems occur repeatedly. The team liberates experts from their routine tasks to collaborate with other specialists in a designated FIT room, where they can work without any distractions, ensuring a prompt and effective resolution of issues with a 100% success rate.

Overview of the activities of the FIT (Fast Innovation Team)

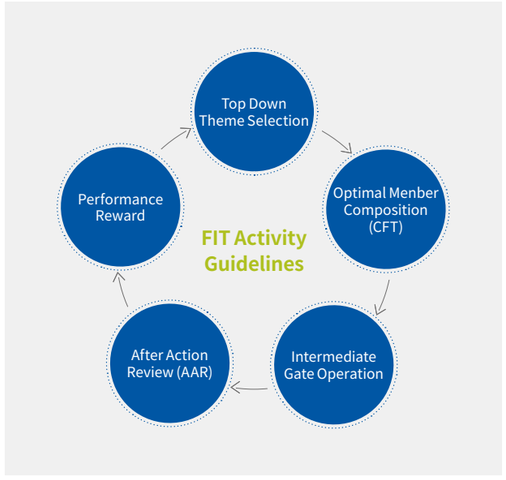
"Fast, Sustainable and we will not give up until its done!" this is the mantra and motto of our FIT Team! Quality problems later develop into uncontrollable losses and customer dissatisfaction if the root cause is not identified and eliminated. FIT is a CFT (Cross Functional Team) of dynamic experts who are dedicated to help eliminate major and chronic quality problems at an early stage and quickly implement improvements. Once issues are identified and resolved team members return to their original departments.

With the ability to deploy fast & strategically the CFT can concentrate their efforts on improvement compared to the normal day-to-day business demands. This team can get to the root of the problem and ensure that sustainable and fundamental measures are put in place to prevent a recurrence.

Defectiveness within our products is unacceptable. It is the duty of our team to restore quality and the reputation of all Hyosung Heavy Industries products through a responsive process called "FIT activity."

FIT activity guidelines

1. For FIT activity, the responsible executive selects top-down subjects and members for important issues. Leadership is an important key factor in quality management that decides on success or defeat.
2. Experts are selected from suitable related teams to form one optimal team, the CFT (Cross Punctual Team). This CFT is a rapid responsive, flexible and cooperative team that consists of experts from between these supporting organizations.
3. Gates are placed in the activity phases (problem identification, root cause analysis, problem resolution and maintenance) and the executive decides whether to pass the gates or not. From a product and process point of view, adequate advice and guidance in each phase of the activities is the key to whether this process is a success or a failure.
4. The team conducts an after action review on all issues at the end of the response activity to improve problem-solving ability and share activity content.
5. In accordance with our management philosophy "Good performance should be rewarded", reasonable rewards should be made.



1st Year (2021) FIT Activity Theme

Division	FIT Activity Theme	Type
Power Transformer	Review of the Causes and Measures of past defects to Zero Insulation defects	Quality
	Review of the Causes and Measures of past defects to Zero gas defects	Quality
	Review of the Cause and Measures for Zero fire occurrence during operation	Quality
	Review of the Causes and Measures of past defects to Zero oil leakage	Quality
	Review of the Causes and Measures of past defects to Zero rust	Quality
GIS	Zero work defects due to site work errors	Quality
	Prevention of quality problems after shipment by improving the detection of factory tests	Quality
	Raising the standardization rate of 245kV GIS design	Overall
Distribution Transformer	Realizing Customer Satisfaction by improving appearance quality of Mold Transformers	Quality
Panel/IPB	Gas Leakage zero for North America 38kV CGIS	Quality

2nd Year (2022) FIT Activity Theme

Division	FIT Activity Theme	Type
Power Transformer	Quality problems zero during erection due to deformation and damage	Quality
	Standardization of tank components	Overall
GIS	Raising the standardization rate of 550kV GIS design	Overall
	Raising the standardization rate of 170kV GIS design	Overall
	Raising the standardization rate of common parts	Overall
	Quality problems zero of Drive in GIS	Quality
Distribution Transformer	Realizing Customer Satisfaction by Improving Appearance Quality of Distribution Transformers for Japan	Quality
Panel/IPB	Review of the Causes and Countermeasures of Past Defects for IPB Painting peeling	Quality
	Expansion of standard drawings to prevent structural design defects	Quality
Purchasing	Quality problems zero when establishing sourcing bases from India and Vietnam	Quality
	Improvement of excessive Quality of Purchasing Materials for Welding Enclosures, Casting, and Processing Products	Overall
Logistics	Development of major customer packaging design programs	Overall

3rd Year (2023) FIT Activity Theme

Division	FIT Activity Theme	Type
Power Transformer	Suppressing the increase in the factory test lead time by establishing bidding standards for special tests	Overall
	Quality improvement of defective parts after shipment	Quality
	Quality improvement by clarifying the work subject between winding assembly and main body assembly	Quality
GIS	Product quality improvement through RCA of Pune factory assembly finished product defect	Quality
	Raising the standardization rate of 246A1,175D GIS design	Overall
	Preventing product damage and securing safety by establishing standards for lifting by product	Overall
	Quality problems zero through standardization of supporter	Overall
	Establishment of quantitative cost assessment criteria for products subject to design standardization	Overall
	Site NC reduction through RCA of past site NCs	Quality
Distribution Transformer	Quality improvement of missing parts and broken parts after shipment of distribution transformer	Quality
	Customer satisfaction through improvement of painting quality of mold transformer core	Quality
Panel/IPB	ODM/OEM panel enclosure standardization and supplier finding	Overall
	Part quality improvement through RCA of part defect	Quality
STATCOM	Cause analysis and countermeasures establishment for BPS operation time deviations	Quality
Welding Machine	Problem solving of adaptive control spot welding control device voltage detection signal distortion	Quality
	Quality improvement through starting performance and developing algorithms	Quality
	Accessory component standardization and packaging method improvement	Overall
	Problem solving of adaptive control spot welding voltage detection signal disturbance	Quality
	Problem solving of performance degradation issues during welding and DB performance improvement	Quality
QC(PCS)	Securing test reliability by improving power system stabilization PCS test method	Quality
QC(GIS)	Securing test reliability by improving CB operation test method	Quality
QC(Power Transformer)	Improvement of test reliability and time reduction by improving impact test problems of Power Transformer	Quality
Purchasing	Reduction of defects in suppliers with frequent defects	Quality
Logistics	Packing quality improvement by improving packaging methods of major materials	Quality

"Hyosung Heavy Industries' FIT activity is now in its 3rd year. Year one and two have helped the team to create a baseline that continually evaluates and refines future responses. Year three will see an upgrade in processes and experience that help achieve practical results. To this end, we will supplement the overall package of procedures, taking into account the previous deficiencies and making improvements. Enhancements that are only implemented after problems have arisen solve the majority of issues but do not guarantee sustainability. This is a task that must be pursued on a continual basis. Changes and innovations that already exist in the company continue, and in this regard, we are confident that the FIT activities will be recognized as high-quality innovation activities that represent Hyosung Heavy Industries and will survive and continue "always and in any case".

Klaus-Dieter Hildebrandt
Vice President
Responsible for quality and production innovation of Power PU

Dong-Woo Kim
Performance Manager
Global QA Team

Building an Intelligent Factory through Digitization and Making the Factory status visible in Real-time

Quality Improvement and Maximization of Production Efficiency through Process Automation

Along with the 4th industrial revolution, such as control automation, IoT/network, big data, and AI, the way we work is gradually changing from manual work in the past to digital/automation. “Iron core automatic stacking equipment” is equipment developed to flexibly respond to the changing manufacturing environment, and it is equipment that improves quality and production efficiency by replacing human work with equipment.

Background of introduction of iron core automatic stacking equipment

The manufacturing environment is changing rapidly, such as changes in the business environment due to working time restrictions, productivity decline due to an aging society, lack of young talent and population decline, entry into an era of global low growth, and transition to a non-face-to-face and remote society due to COVID-19. Major advanced countries have established government-led manufacturing revival strategies to promote the expansion and advance-ment of smart factories, and are actively responding to changes in manufacturing trends such as flexible production of multiple products. Building a smart factory using IT technology as a tool for strengthening manufacturing competitiveness and innovation in order not to fall behind in these environmental changes is an essential element for corporate survival in the era of the 4th Industrial Revolution.

Hyosung Heavy Industries is striving to realize ‘customer-oriented management’, ‘an organization that responds quickly to environmental changes’, and ‘acceleration of digital transformation (DX) for data-base management’. We are promoting smart factory activities to build a flexible and highly efficient production system by establishing DX operation in which all areas from product design to shipment are combined with digital technology, and increasing competitiveness through data computerization and process automation.

As part of smart factory activity, Hyosung Heavy Industries’ power transformer division introduced an “Automatic Iron Core Stacking Equipment” to improve productivity and quality. Our company has successfully introduced the iron core stacking facility for large transformers worldwide for the first time, and it is pos-sible to stack iron cores with a length of 4 meters or more. Global companies have introduced automated equipment for stacking iron cores for small trans-formers, and most competitors stack iron cores manually by workers, as we have done it in the past.

To create the iron core shape of a single transformer, 10,000 to 14,000 repetitions of lamination work are required. This can result in worker fatigue, potential defects, and serious safety accidents due to the risk of operator error. In order to solve this problem, we have been thinking about how to use automated equipment to laminate the iron core process, which was manually laminated by workers, for years. In the past, various development problems occurred such as the machine did not recognize the position where to place the iron core, or the inability to transfer only one core-sheet at a time, or the poor lamination quality. However, with the 4th Industrial Revolution, there have been innovative developments in technologies such as automation, sensors, and IoT. With the help of these innovative technologies, we have supplemented the failure experience from the past and realized the automation of the iron core lamination process.

The iron core stacking machine automatically stacks iron cores prepared in advance according to the design specification. This reduces the man-hours and allows for flexible adjustment of production personnel according to changes in the external environment. In addition, by automatically measuring the iron core stacking manufacturing tolerance, human errors can be prevented in advance, and product reliability will improve through precise measurement. We have innovatively improved productivity and quality by automating the iron core process. In the future, we plan to maximize profits for customers and the company by analyzing collected data and using it for process improvement to reduce the cost.

Figure 1 | Iron core automatic stacking equipment

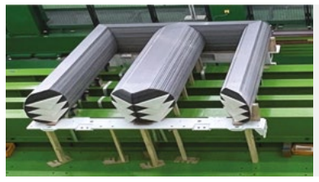


Figure 2 | Finished iron core stacking

Components of automatic iron core stacking machine

The iron core automatic stacking machine consists of a total of 4 units: a servo motor for driving equipment, a pneumatic circuit for adsorbing and transporting the iron core, a visual scanning system to precisely recognize and control the lamination position, and a control panel.

- Gantry system : frame and driving part (servo motor, reducer, etc.)
- Adsorption system : Bridge, gripper and dimension control unit for lifting the iron core (height control unit, visual control system)
- Control unit : control panel and program
- Pneumatic equipment : for vacuum adsorption

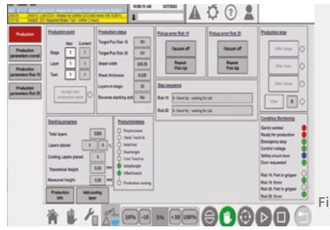


Figure 3 | Iron core automatic stacking equipment UI

Effect of iron core automatic stacking machine

1) Increase productivity through automation

The number of workers has been reduced by automatically transporting/stacking iron cores instead of the method in which workers manually stack iron cores one by one.

2) Quality improvement

By implementing product dimension measurement and error adjustment functions, measurement errors by operators are eliminated by enabling automatic dimension measurement without stopping the machine.

3) Work status monitoring through connection between machine and MES

Through connection between machine and MES (Manufacturing Execution System), iron core stacking data such as the number of stacks, stacked height, etc. are collected and monitored in real time. In addition, it is possible to immediately respond to problems by checking the work progress status, progress rate, and abnormal status in real time. In the future, we plan to analyze the collected data and use it for process improvement.

4) Equipment maintenance and remote diagnosis

We monitor the status of equipment such as motors and sensors in real time and respond immediately when an abnormality occurs to minimize work stoppage due to equipment failure. In addition, an emergency response system is established to enable remote equipment diagnosis and repair support without the manufacturer’s engineer visiting us in the case of a sudden equipment failure.

“The present era demands a change to a new way of working, such as digitalization, automation, and Big Data, away from the manual method of the past in accordance with the urgent change in the manufacturing environment. Although automation of certain processes was realized with the introduction of automatic iron core stacking machine, we will strive to increase utilization by supplementing/improving equipment and improving efficiency by optimizing the entire process.
In order to actively respond to the changing environment and provide the best value to customers, we will continue to promote the DX operation, which is the center of smart factory activities, and the establishment of a high-efficiency production system. Furthermore, we will continue to strive to provide VIU (Value In Use) to customers who use our products.

Klaus-Dieter Hildebrandt
Vice President
Responsible for quality and production innovation of Power PU

Soo-Yong Kim
Performance Manager
Smart Factory TFT

MVDC for Improving the Receptivity of Renewable Energy

MVDC: Medium-Voltage Direct Current

MVDC (Medium Voltage Direct Current) technology is a medium-voltage DC power distribution technology having a voltage level and power transmission capacity between HVDC (High Voltage Direct Current, Transmission of extra-high voltage DC power of 100 kV or higher) and LVDC (Low Voltage Direct Current, Distribution of low-voltage DC power less than 1.5 kV). The need for MVDC technology is emerging. It can promote the spread of new and renewable energy sources, or improve the maximum allowable load rate by controlling the power flow. It can also more efficiently fulfill the increasing demand for large-scale power loads from city centers such as electric vehicle charging stations, ESSs (Energy Storage Systems), and IDCs (Internet Data Centers).

MVDC Policy and Development Trend

In accordance with the government's renewable energy expansion policy, the need for MVDCs is increasing.
In particular, according to the Fourth Energy Technology Development Plan, the Korean government has presented the goal of securing MVDC power distribution operation system technology and AC/DC mixed operation, in order to secure the receptivity of renewable energy. Korea's Ninth Power Supply and Demand Master Plan lays out the application of MVDC to solve the distribution network problem caused by the expansion of distributed power sources and the phased introduction of the micro power grid. Although Korea's market for MVDC is currently in an introductory stage, it is expected to expand in the very near future.

Keeping in line with such a trend, Hyosung Heavy Industries has carried out R&D for 20 MW MMC (Modular Multilevel Converter) HVDC (High Voltage Direct Current) and completed its demonstration in the Jeju demonstration site in 2017.
Using the MMC technology developed through this R&D project, we have successfully commercialized STATCOM, which has been delivered to Korean and international sites and is in operation around the world.
In addition, we have expanded the technology to MVDC and led Korea's first ±35kV/30MW MVDC station development project promoted by the Green Energy Institute. We have finished the installation at the Naju site and attended the celebratory ceremony in March 2023. Currently, we are in the process of commissioning.

Introduction of Naju ±35kV 30MW MVDC Project

MVDC systems can be divided into the PTP (Point to Point) configuration and the MT (Multi Terminal) configuration depending on the composition of the connection line. The current project (Naju ±35kV/30MW class MVDC station development) is an MVDC system of the PTP configuration comprised of two stations (a station for a rectifier to convert AC to DC and a station for an inverter to convert DC to AC).

The MVDC station is largely comprised of a converter valve for power conversion, a C&P System (Control and Protection System) to carry out the converter control and protection function, and various types of yard apparatuses including a transformer and a cooling system (Fig. 1).

The converter valve, C&P system, and cooling system, which are the major equipment of the Naju ±35kV 30MW MVDC Station, have been designed to be loaded on a container to enable the system to be rapidly built without the necessity for any separate dedicated building (Fig. 2).

The converter valve is made up of an ARM comprised of 30 sub-modules built into a container, and each station is made up of 6 containers.

The inside of each container is constructed adopting the method of loading 5 valve sections each of which is comprised of a total of 6 submodules as shown in Fig. 3.

The C&P system is largely comprised of an operation system that performs the function of; interfacing with the operator, a converter control system that performs the function of controlling and protecting the converter in accordance with the operation instructions from the operator, and a protection system that performs AC line protection and CB/DS/ES operation.

As to HILS (Hardware in the loop simulation) for the simulation of the MVDC system, a Nova Core product which is the latest model among the products of RTDS was used. The power system, converter module, switches (CB, DS, ES, etc.) in the station, initial charging register, and yard apparatuses including the phase reactor and interface transformer were modeled using RSCAD. The connection configuration of the RTDS HILS system is as shown in Fig. 5.

Figure 1 | Block Diagram of Naju ±35kV/30MW MVDC System

Figure 2 | Aerial photograph of Naju ±35kV/30MW MVDC Station

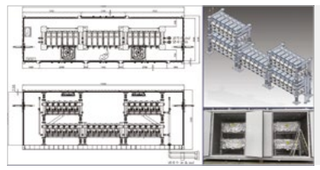


Figure 3 | Converter Valve of Naju ±35kV/30MW MVDC

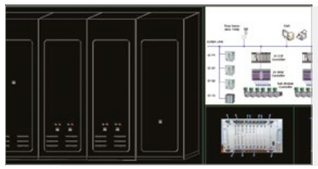


Figure 4 | C&P System

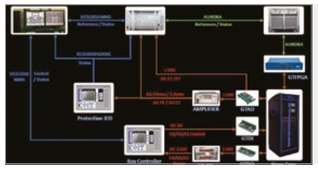


Figure 5 | Connection Configuration of RTDS HILS System

> The need for DC such as LVDC for effective power distribution to consumers, MVDC for grid connection required resulting from the increase in renewable power sources, and HVDC for long-distance transmission and grid connection by region is gradually increasing in power systems. In particular, it is thought that MVDC will become an important solution that enables connections between LVDC and HVDC and connects increasing renewable energy to the existing grid. Hyosung Heavy Industries intends to further develop the current MVDC technology by successfully performing the Next Generation AC/DC Hybrid Power Distribution Network Technology Development Project, which is in progress as a Korean national project. This will help Hyosung expand its business domain for DC solutions worldwide.

Hong-ju Jung
Performance Leader
HVDC Research Team Manager

Jeong-Gon Ryu
Performance Manager
HVDC Research Team

Editor's message

"

Hyosung Heavy Industries will detect market changes from customers and society first, and explore new opportunities through innovation.

Hyosung Heavy Industries is pleased to announce the publication of our third issue of the Power Technology Magazine. Through this magazine, Hyosung introduces our solutions that lead the trends in the power market to our valued customers. Many changes are expected in the sector this year due to diversifying demands from society and customers.
Hyosung will detect market changes from customers and society first, and explore new opportunities through innovation.
Please keep an eye on Hyosung Heavy Industries' activities and achievements this year. We hope the readers find this article helpful.
If you have any questions about the content of this magazine or opportunities to collaborate with us, please feel free to contact us anytime. Thank you for reading Hyosung Heavy Industries' Power Technology Magazine.

Hyosung Heavy Industries Corporation
Executive Vice President **Sung-Hoon Ahn**

Publications Chair : Executive Vice President Sung-hoon AHN

Editor-in-Chief : Senior Vice President MAKOTO HATTORI

Editor : Vice President Hyun-Chul Cho, Vice President Young-Jun Cho, Sun-Dong Kwon Performance Manager, Jin-Dal-Lae Kim Performance Leader, George Ciganik

Technical Advice : Vice President Won-Ho Choi, Vice President Klaus-Dieter Hildebrandt

Assistant Editor : Eun-Jee Ryu Performance Manager, Il-Doo Kim Performance Leader

Publication Place : Hyosung Heavy Industries Corporation

Please click here for any questions.

HYOSUNG HEAVY INDUSTRIES

The Company that Leads the Low-Carbon, Green Growth Era

BUSINESS AREAS

HYOSUNG HEAVY INDUSTRIES

Power Systems PU
- Produces 70% of the core products required for power supply in Korea
- Operates overseas production bases in the United States, India and China
- Power Facilities / Power Systems / Digital Solutions / Welding Solutions

Industrial Machinery PU
- Korea's No.1 electric motor manufacturer and seller
- Performs system engineering business with a wide range of industrial product lineups
- Motors / Generators / Industrial machines / Gear Solusions

Wind Energy Business Division
- Korea's first developer of 750kW, 2MW, and 5.5MW-class wind power generation systems
- Provides total solutions in wind energy such as wind energy core components, wind power turbines, EPC, and O&M

Construction PU
- The first company in Korea to introduce villa-type residential buildings
- Participates in various construction projects such as apartments and office buildings

Hyosung Heavy Industries Homepage

Hyosung Heavy Industries YouTube

Hyosung Heavy Industries Linkedin

Hyosung Heavy Industries Facebook

Hyosung Heavy Industries Instagram