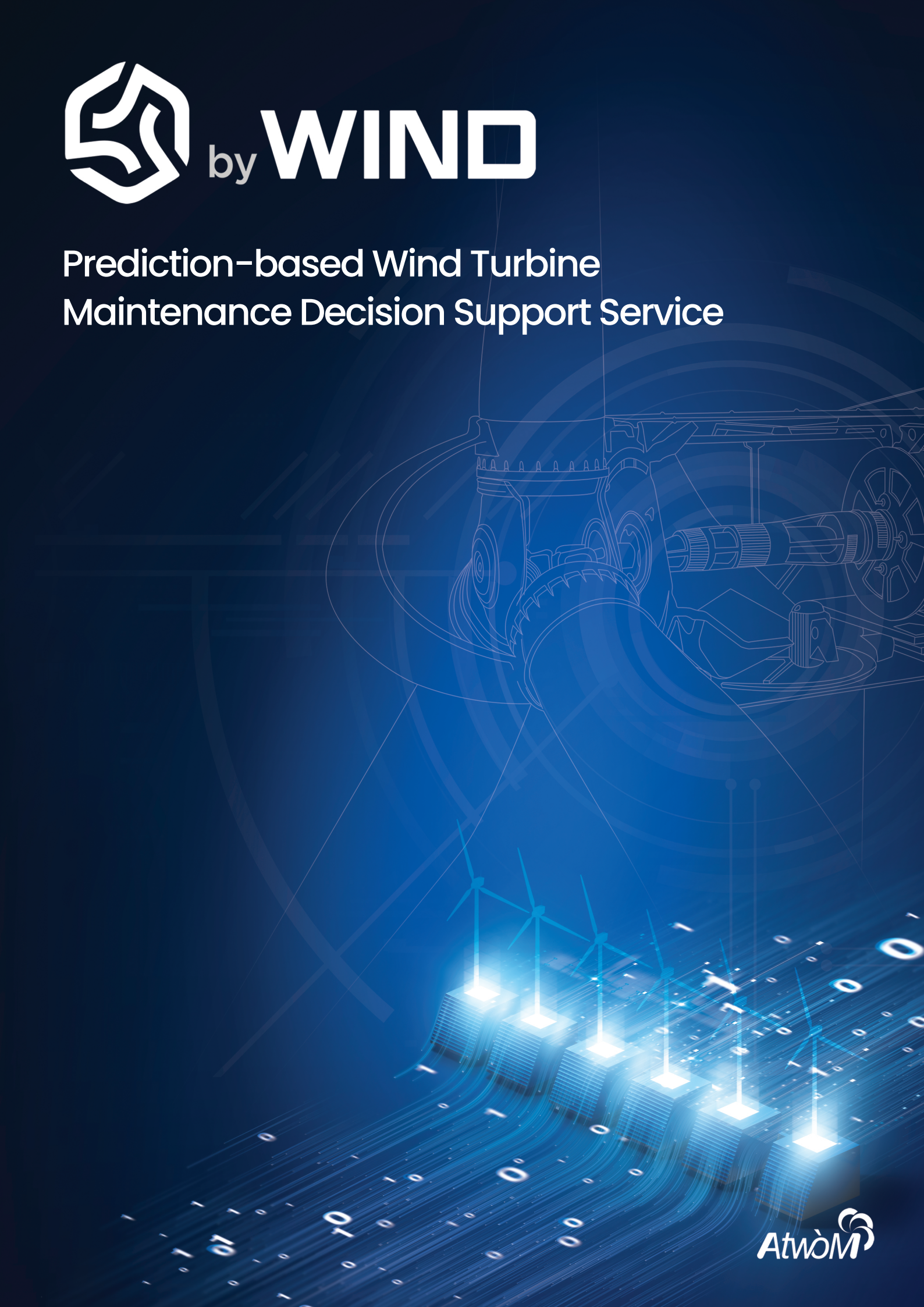
by WIND

Prediction-based Wind Turbine Maintenance Decision Support Service



AtwòM

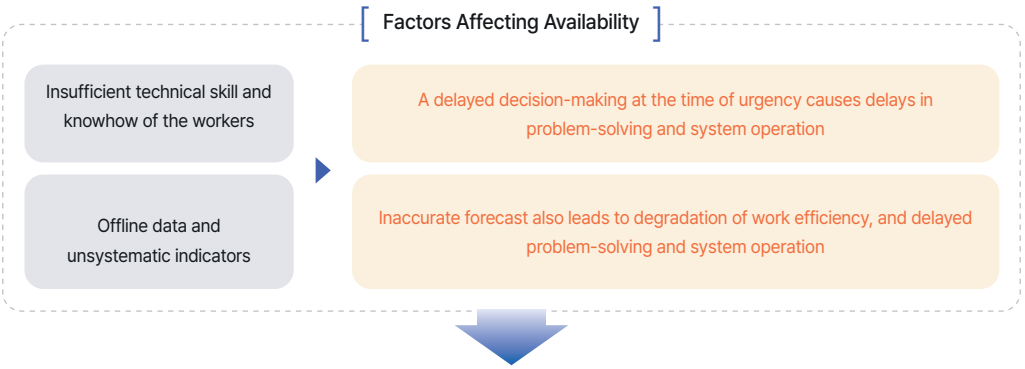
I. byWIND

Through continuous monitoring of wind power generation system,
byWIND prevents the risks of fatal accidents and supports efficient O&M.

byWIND

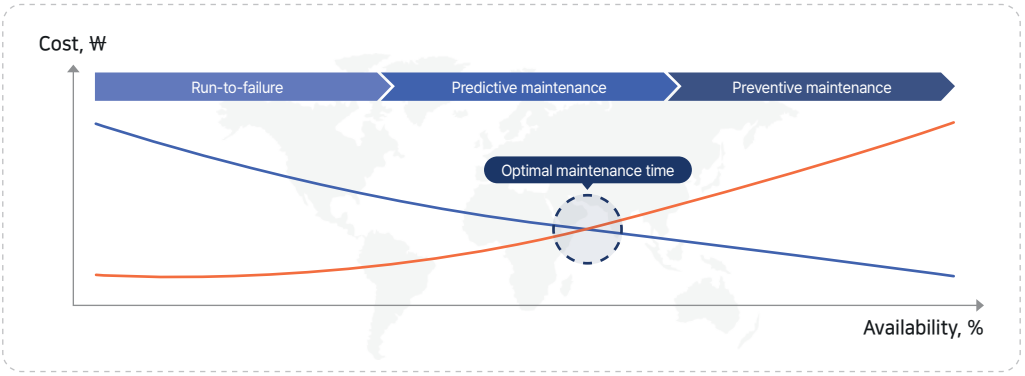
Platform Necessity

To maximize the profitability of wind power generation, it is essential to estimate the O&M costs, which accounts for about 14-30% of the entire life cycle costs, and identify major factors affecting the availability of the generation system. For instance, delays in decision making may have a serious effect on the system operation.



Through continuous monitoring of wind power generation system, byWIND prevents the risks of fatal accidents and supports efficient O&M.

- **Reactive** : Low forecast costs, but increased actual accident costs
- **Predictive** : Optimized cost-effectiveness between forecast costs and sales loss
- **Preventive** : High risk-forecast costs, but reduced actual accident costs



Optimization Features

* For maintenance forecast, we have an energy technology researcher and a machinery researcher ready to serve.

Category	byWIND 2.0*	byWIND 1.0
Custom dashboard	Operator, maintenance service, manufacturer, and shipper	Operator
Report	Daily report, maintenance and repair, operation log, and regular report	3 types of basic report
Forecasting	Wind speed and height, maintenance forecast*	Generation amount
Resources	Ship (Registration, reservation, operation, and accident management) parts/equipment rental	Manpower, parts, and clients
Service contract	Maintenance/Parts management	-
System	Users (advanced), Clients	Wind farms/Individual generators

Essential functions

* Additional functions will be available, if requested (Individual consultation required)

1 Dashboard

Provision of a map API-based location information of a wind farm; integrated monitoring of wind power generators made by different manufacturers; provision of information about the operating state of wind farms/generators and weather information; and display of inventory status with parts demand for each generator and abnormalities in sensor data

2 Condition Monitoring

Monitoring page that shows the integrated condition of wind farm/generators; application of visual tool to show the flow of continuous data, such as chart and map of the sensor data; and provision of information about capacity, availability, number of failure cases, and failure rate

3 Maintenance & Report

Integrated management of failure cases and corresponding response records, which in turn are used as base data for forecasting of generation system failure; and provision of check report, blade check report, and 3 types of checklists, daily report and regular report

4 Management of Parts & Ships

Inventory management of main parts and safety items to ensure smooth maintenance and repair; Notification upon PLM for parts; quotation requesting feature for current and potential clients; and ship registration and operation reservation, and accident control functions

5 Forecast

Provision of predictive information based by analyzing wind speed, wind height, maintenance forecast, generation amount, and LCOE data (* Availability of this function will be determined subject to the range of data provision by the generator manufacturers and operators)

6 Service Management

To assist users' full enjoyment of the platform service, we provide a variety of features, including registration of wind farm and generators, registration of users by authority, access log record, management of authority and menu, and maintenance and parts supply contract management

Operation status

운영 기관	제주에너지공사 JEJU ENERGY CORPORATION	한국해상풍력(주) Korea Offshore Wind Power
운영 단지	5 wind farms	1 wind farm
운영 터빈	40 turbines	20 turbines
설비 용량	56MW	60MW
터빈 제조사	6 different manufacturers, including Vestas, Doosan, and UNISON	Doosan

Key Points

1 We apply government R&D project outcomes, and consider any additional points to the management evaluation conducted by government agencies for procurement from small and mid- sized companies

2 We secure additional profits by participating in the generation forecasting program

Qualification

: Max. 10% monthly average error rate. 4 won/kWh for max. 6% error rage, and 3 won/kWh for more than 6% ~ max. 8% error rate

II. Research Projects

We conduct R&D for system development and technology development for commercialization, sponsored by the Korea Institute of Energy Technology Evaluation and Planning (KETEP) and the National IT Industry Promotion Agency (NIPA) under the Ministry of The Ministry of Trade, Industry and Energy.

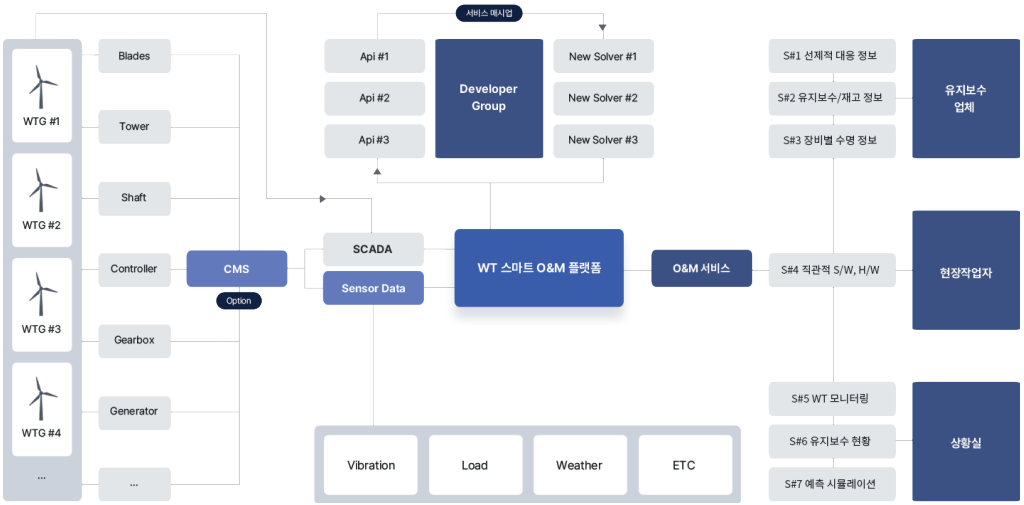
Research Projects

1. Development of Smart O&M Platform for WindTurbine

Research project information

Assignment period	2018.10.01 ~ 2021.12.31 (39 months in total)	Working expenses	KRW 5.78 bil
Organizers	(주)에이투엠		
Objectives	We are dedicated to making a quick response and providing solutions to any on-site needs in maintenance and repair aspect, and aim to establish the best HR and material procurement strategy for maintenance by forecasting the future maintenance cycle.		
Keyword	Wind Power System, BigData, Maintenance, Internet of Things, Artificial Intelligence		
R&D Outcomes	▪ Development and operation of preemptive management service to increase the generators' availability ▪ Establishment of a field-oriented Smart O&M system through a systematic indexation for maintenance ▪ Data acquisition and analysis of wind power generators' condition and operation state, through a linkage with wind power system maintenance platform ▪ Development of user manuals and guidance content to improve on-site workers' expertise		
Participation Institution	한국에너지기술연구원, 윈디텍(주), (주)비주얼라이트		

Service Architecture Diagram



Key R&D Subjects

1. Application S/W-1 : Condition management system by using IoT (CMS: Condition Monitoring System)
2. Application S/W-2 : Development of a blades and tower loads' condition monitoring system
3. Application S/W-3 : Development of maintenance equipment and production of VR-based wind power education materials
4. Provision of solver making tool
5. Provision of solver operation environment (HW + SW + Data)

2. Development and Demonstration of Integrated O&M Service Solution for Digital-Based Offshore Wind Power Plant

Research project information

Assignment period	2020.10.01 ~ 2023.05.31 (32 months in total)	Working expenses	KRW 7.22 bil
Organizers	(주)에이투엠		
Objectives	We aim to develop a digital technology-based integrated O&M solution, which can reduce the levelized cost of energy (LCOE) through efficient operation and management of offshore wind farms, resulting in maximized power generation with minimized maintenance costs, and then to realize on-site application and practical use of the solution.		
Keyword	Offshore wind farm O&M platform, Data analysis, Forecasting and diagnosis, Decision-making support, Cost reduction		
R&D Outcomes	A data-based forecasting platform that allows integrated management of big data information related to the maintenance/repair/safety check of main parts and components in large-scale wind farms, as well as minimizing of the LCOE.		
Participation Institution	한국기계연구원, 윈디텍(주), (주)티에스윈드, 경북대학교 산학협력단, 한국에너지기술연구원, 대한전기협회, 한국해상풍력(주)		

Service Architecture Diagram

Key R&D Subjects

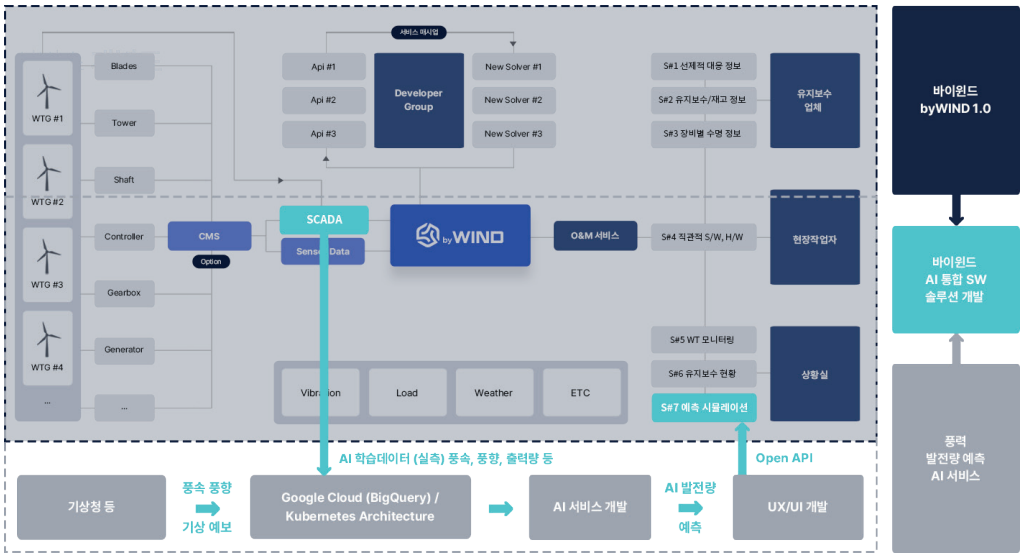
1. Development of a decision support solution by optimizing logistics, inventory, and maintenance planning
2. Real-time simulation technology for wind farms to maximize generation and minimize O&M costs
3. Establishment of offshore wind farm O&M procedure according to the requirements of Global Wind Organization (GWO); and development and standardization of O&M framework
4. Big data and machine learning-based forecasting and diagnosis technology for main parts and components of the farms

3. Development of a SCADA data-based wind power generation forecasting AI service

Research project information

Assignment period	2022.04.01 ~ 2022.10.31 (7 months in total)	Working expenses	KRW 300 mil
Organizers	(주)에이투엠		
Objectives	We are dedicated to developing a wind power generation forecast service by applying AI technology of RETIGRID Co., Ltd. based on SCADA data from ATWOM's own wind farm and weather information, and developing byWIND's own SW integrated solution, ultimately.		
Keyword	Power generation forecast, Artificial intelligence, Wind power, Cloud, ICT		
Participation Institution	(주)에이투엠, (주)레티그리드		

Service Architecture Diagram



Key R&D Subjects

1. Construction of data collection environment for SCADA and weather data
2. Development of API that links SCADA and weather data
3. Development of an AI model that forecasts wind power generation amoun based on KSTM-CNN
4. Development of an open-API for generation amount forecast
5. Development of a UI/UX for generation amount forecast
6. Verification of forecasting error rate through empirical test

4. O&M scheduling technology development for large-scale wind farms optimized in domestic environments

Research project information

Assignment period	2022.11.01~2025.10.31 (36 months in total)	Working expenses	KRW 19.6 bil
Organizers	한국에너지기술연구원		
Objectives	The goal is to develop and commercialize as a service a technology that optimizes a cloud-based maintenance planning for 1.5% reduction of OPEX.		
Keyword	Windfarm, Maintenance, Scheduling optimization, Maintenance cost reduction, Cloud solution		
R&D Outcomes	Predictive maintenance and optimal solution-based offshore wind power O&M service for both domestic and overseas markets : Provision of ISP service for the entire scope of EPC from wind farm consulting and design to installation, operation, and maintenance, with a predictive maintenance based-O&M technology and OPEX reduction model.		
Participation Institution	한국에너지기술연구원, (주)에이투엠, 윈디텍(주), ODSL		

Service Architecture Diagram

Key R&D Subjects

1. Smart platform API
2. Scheduling technology
3. OPEX estimation technology
4. Decision support technology
5. Safety management manual

III. About AtwoM

With the goal of securing the next-generation growth engine through new and renewable energy business, we are currently conducting a research project sponsored by the Ministry of Trade, Industry and Energy. We are also laying the foundation to expand our business to global markets through various endeavors, including patent application and registration, and implementation and commercialization of the patent ICTs.

About AtwoM

AtwoM is

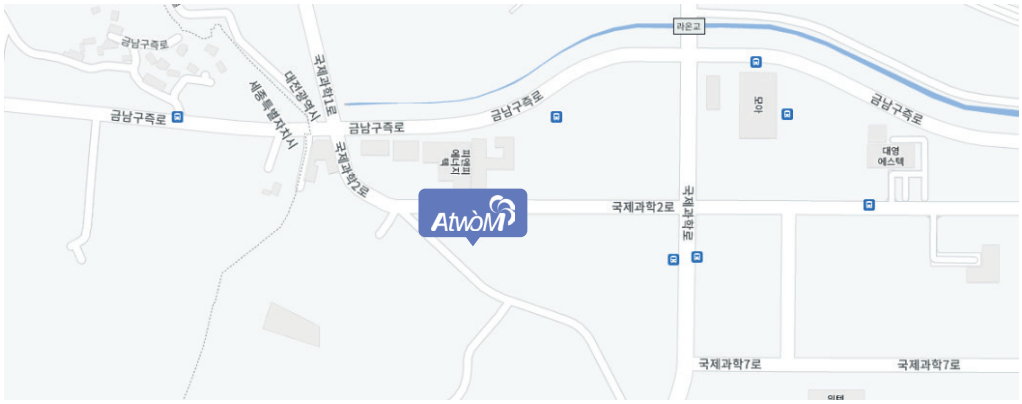
* AtwoM office building

AtwoM Co., Ltd. is a company specializing in information service platform construction for government research institutes and public organizations. Established in 1998, we have been dedicated to technology development and management innovation for the last 24 years, and are expanding our client pool as well as business area to new and renewable energy.

With the goal of securing the next-generation growth engine through new and renewable energy business, we are currently conducting a research project sponsored by the Ministry of Trade, Industry and Energy. We are also laying the foundation to expand our business to global markets through various endeavors, including patent application and registration, and implementation and commercialization of the patent ICTs.

Business establishment

Korea Head office **Daejeon** 27, Gukjegwahak 2-ro, Yuseong-gu, Daejeon, Republic of Korea



Vietnam Branch office **Hanoi** TT3A12 Phung Khoang Nam Cuong UA, Trung Van, Nam Tu Liem, Hanoi

Vietnam Branch office **Taekwang TOC** KCN Long Binh (AGTEX, Đồng Nai, Vietnam

History

2022

- Selected 'Development of O&M scheduling technology for large-scale offshore wind farms optimized in domestic environments' as a project of the Korea Energy Technology Evaluation and Planning
- byWIND trademark registration
- (G)Registration as a member of the Korea Energy Small and Medium Innovation Business Association (Wind Power Support System)
- Selected Development of a SCADA data-based wind power generation forecasting AI service(NIPA)

2021

- Participated in the KOREA SOFTWAVE, SW Quality Products Section
- Awarded the TTA Chairman Prize with byWIND v.1.0 at the Korea SW Products - Quality Products
- Released a wind power system O&M platform, byWIND v. 1.0, for the first time in Korea
- Acquired GS Certification, Level 1, with byWIND v. 1.0
- Released an application source quality verification solution, CodeUp
- Signed an MOU with Jeju Energy Corp., MOU for Empirical Testing of Wind Power Generation O&M Platform
- Registered with K-ICT Cloud Innovation Center, as a cloud-company and service
- Built the company building in the International Science Business Belt
- Acquired Software Process (SP) Quality Certification Level 2

2020

- Signed an MOU of development of an integrated O&M service solution for digital technology-based offshore wind farm, and empirical testing thereof
- Selected by the Ministry of Trade, Industry and Energy as one of the eight promising energy innovation companies, signed an MOU with the Ministry, and attended the meeting
- Registered three patents in wind power generation management area
- Acquired the company building site in the International Science Business Belt

2019

- Developed e-Approval Solution (I'MWARE)
- Developed Messenger Solution (M BOX)
- Selected as a strong S&M enterprise by the Ministry of Employment and Labor

2018

- Developed File Transmission Solution (NERO)
- Selected 'a task to develop exclusive smart O&M platform for wind turbine' as a project of the Korea Energy Technology Evaluation and Planning'
- 'Overseas Proofs of EMS development for Micro Grid of Industrial Complex and Real-time Electricity Market Operation Service'

2017

- Awarded WEB AWARD [Grand Prize for Public Service]

2016

- Established AtwoM Vietnam Branch
- Selected as an employment creation company by Daejeon City
- Registered a patent (Vehicle Antenna)
- Awarded WEB AWARD KOREA [1st Prize for Governmental Agency]
- Awarded WEB AWARD KOREA [1st Prize for Research Institute]

2015

- Awarded WEB AWARD KOREA [1st Prize for Governmental Agency]
- Awarded INTERNET ECO AWARD [Grand Prize for Win-Win Innovation]
- Signed an agreement with the Vietnamese Ministry of Science & Technology
- Applied a patent (Self-directed Learning System using Communication with Parents)
- Registered as a Work and Learning Dual System Company

2013

- Acquired GS certification (Communication Control System via Social Media)

2012

- Selected as an emerging S&M & excellent employment company by Daejeon City

2011

- Certified Technical Innovation S&M Enterprise (INNO-BIZ)
- Selected as a company participating in Smart Grid Integration Project by the Korea Electric Power Knowledge Data Network ('11~'14)

2010

- Selected as a company participating in Local Industry
- Promotion Project by the Ministry of Knowledge Economy Selected as a company participating in Technical Innovation Project by the Ministry of Knowledge Economy ('10~'14)

2009

- Acquired ISO 14001 Certification
- Designated as a company on behalf of military service by the Military Manpower Administration ('09~present)

2008

- Acquired ISO 9001 Certification
- Certified the affiliated Research Institute
- Certified Technical Innovation S&M Enterprise (INNO-BIZ)

2004

- Incubated by Daejeon/Chungcheong Design Support Center(DCDC)

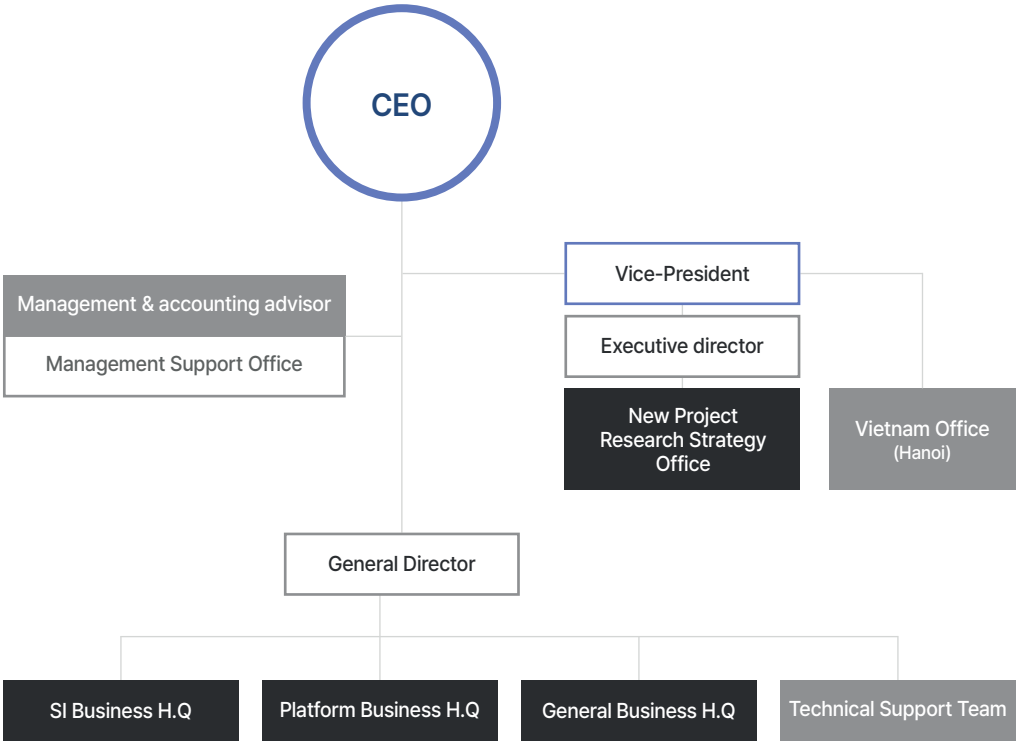
2003

- Registered as Design-specialized company In the Korea Institute of Design Promotion

1998

- Founded Company

Organization



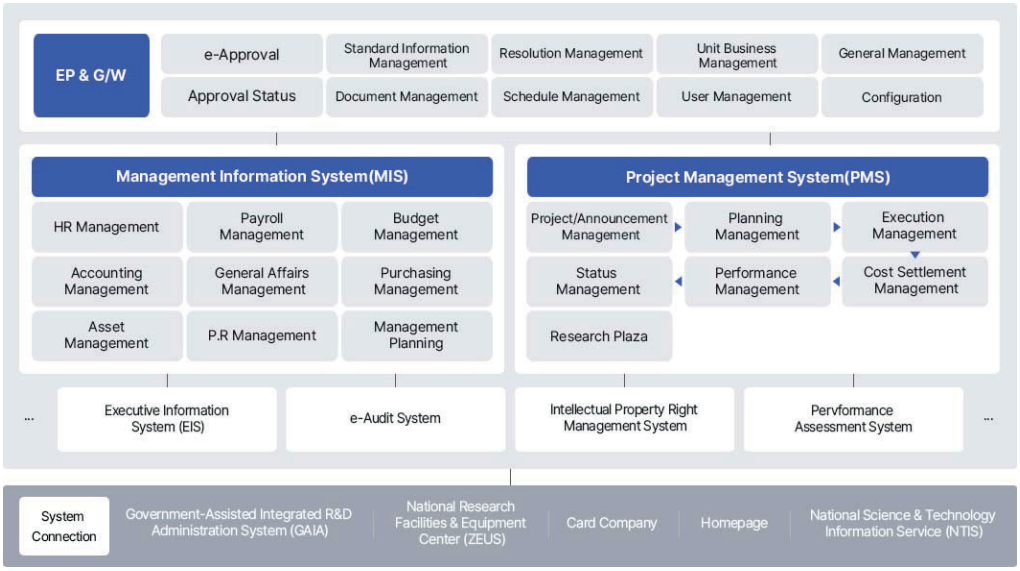
Construction case

Management Information System

It is a system that uses the whole operating information of public agencies to strengthen the efficiency of works such as human resource affairs, payroll, budget, accounting, general affairs, purchasing, assets, etc. and raise reliability of decision making through computerization and systematization of administrative affairs of public agencies and mutual connection of business processes for business management.

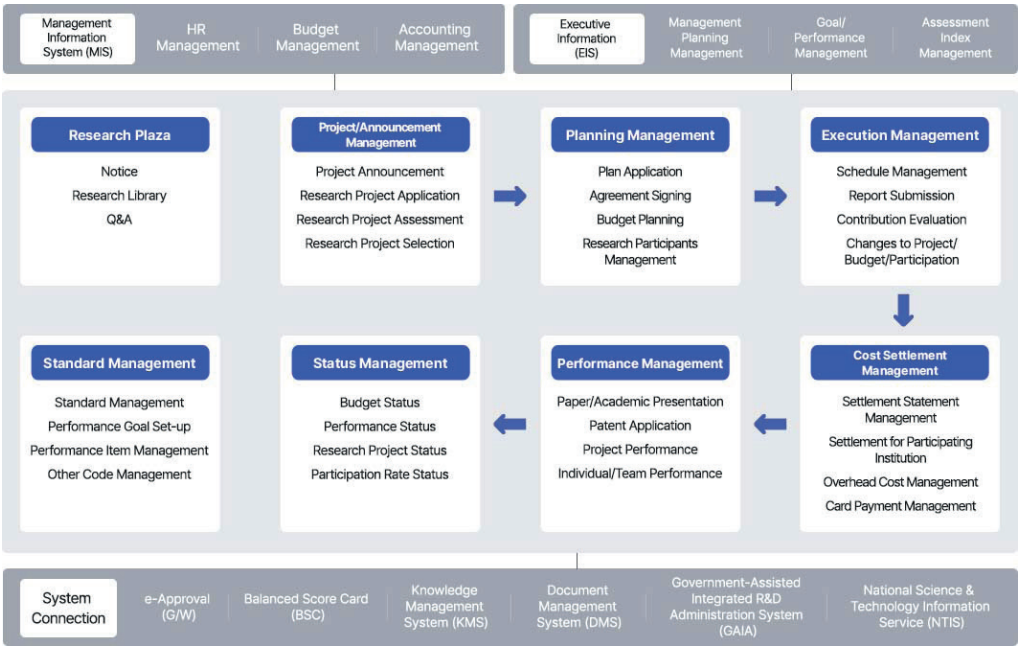
Integrated Information System

It is an integrated system supporting efficient operation of organizations with automation of administrative works due to organic business cooperation between unit systems and smooth connection with external support systems by integrating detailed several systems such as a groupware, etc. including management information system (MIS), research management system (RMS), e-Approval (G/W)



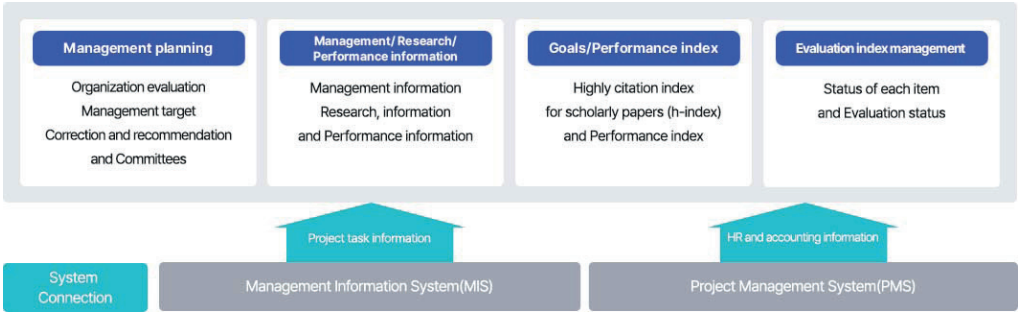
Project Management System

It is a system that maximizes work convenience by systemically managing the whole period of project management process from announcement of research tasks to application, receipt, selection, signing an agreement, execution, expense settlement, and performance management and that provides smooth connection with internal and external systems for the purpose of settlement of research costs and equipment management, etc.



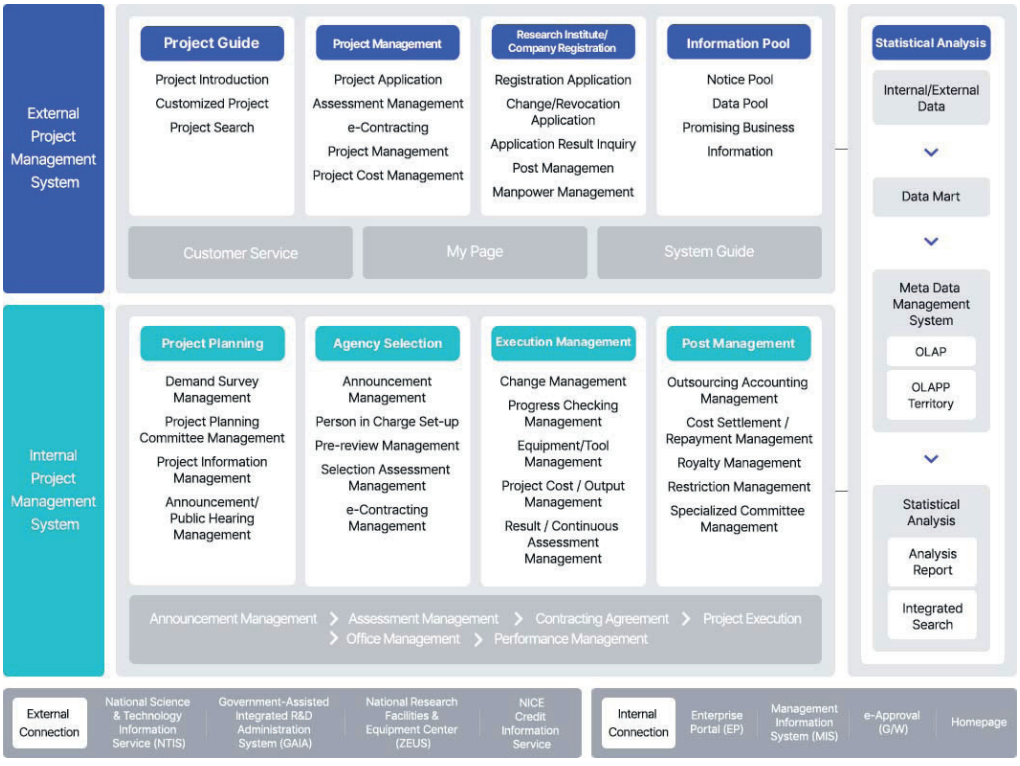
Information System for the Management

This system provides real-time monitoring and download service through data extraction of key information, such as management planning, management status, and research/outcome data, and manages performance factors, and thereby supports the managers and executive level to make decisions and public release accurately and in a timely manner based on the data.



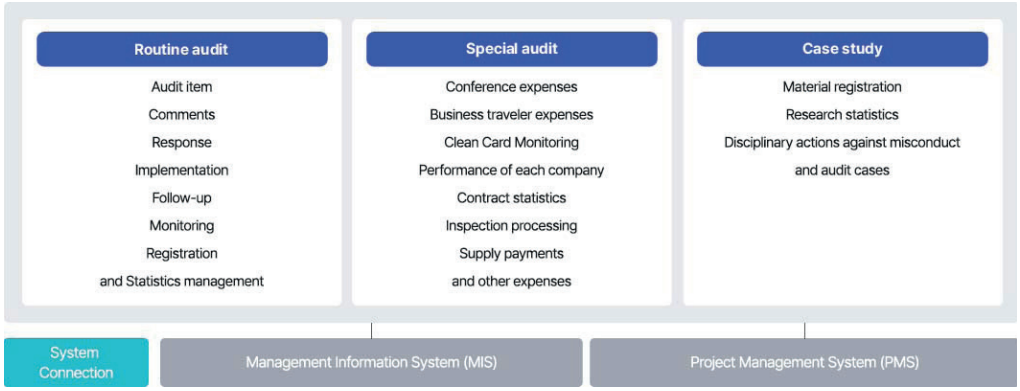
Business Management System

It is a system that constructs online business management system for whole period from project announcement by the organization in charge of the project to post management by analyzing the BMS in progress according to the characteristics of the organization and supports the works based on business management by providing connected service such as project cost management, equipment management, etc. and standardizing documents forms.



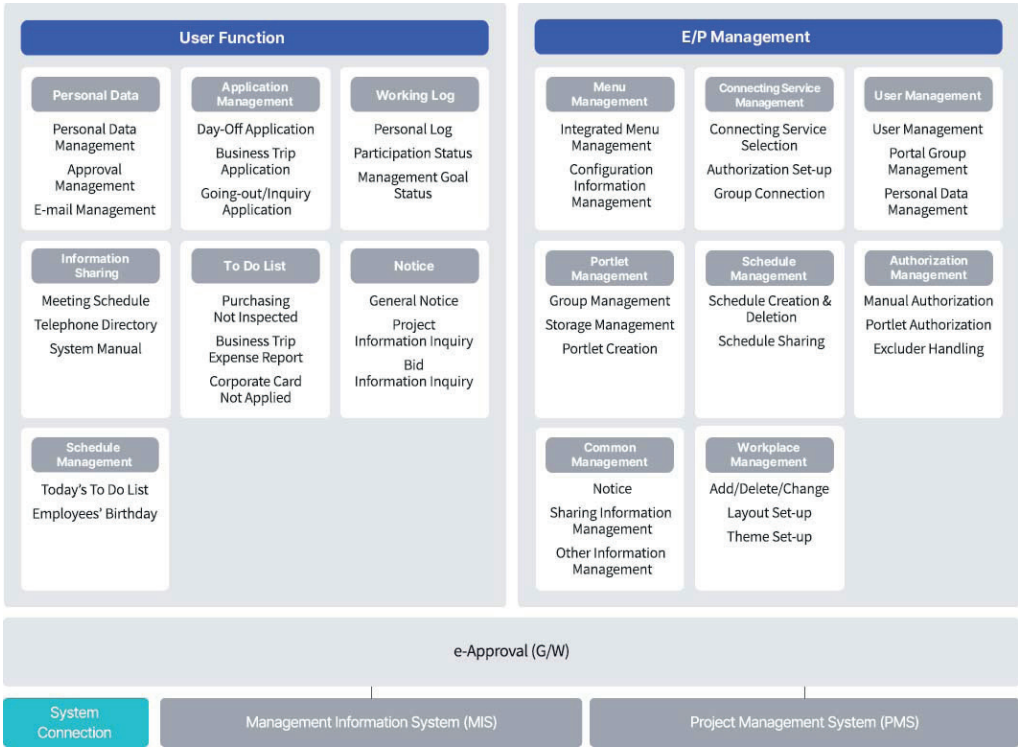
e-Audit System

It is an information system that implements correction requirements and feedback from regular audit, and manages the details concerning internal and external audit datafication, in order to strengthen the routine audit function necessary to operate business based on transparency and integrity.



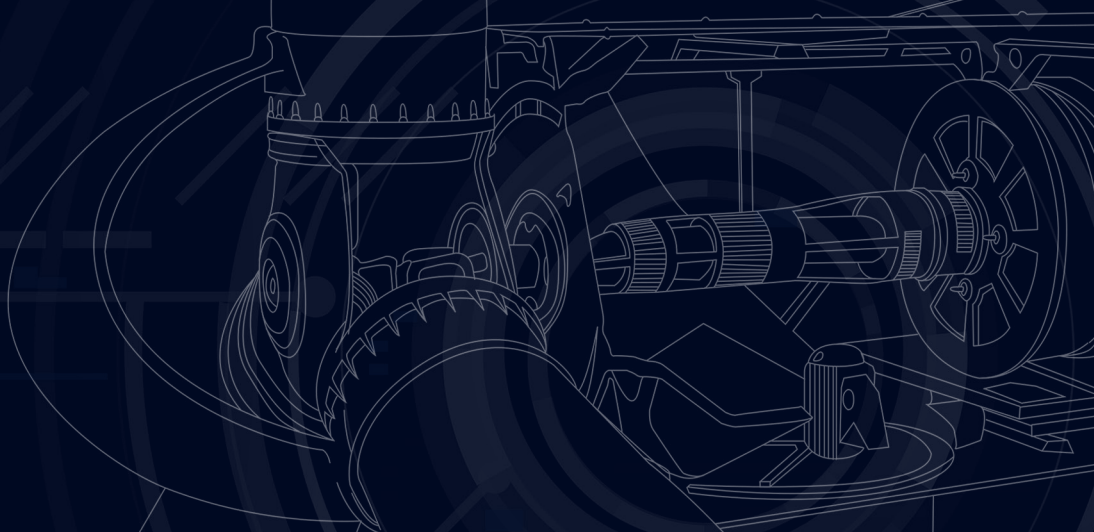
Enterprise Portal

It is an user-oriented portal system, for the purpose of convenient business support, that shares the progress of business such as all kinds of application works, the progress status, schedule management, etc., provides services to manage status in progress, and is possible for flexible application of user environments such as portlet management, authorization administration, menu administration, etc. for user convenience.



IV. About technology

O&M takes approximately 14-40% of the entire lifecycle of wind power generator. Therefore, technology that can assist decision-making is essential for operators to maximize their profits.



4-1. Dashboard

byWIND provides custom-dashboards for each entity, operators, maintenance service, and manufacturers.

Integrated monitoring of wind power generators made by different manufacturers

Provision of generator operation status and weather information

Provision of information concerning current generation amount and generation profits

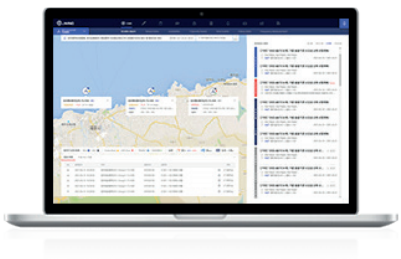
Screen Display

byWIND provides a dedicated screen for operators to manage multiple wind farms composed of various models of generators. Features also include real-time update of issue occurrence and generation status in each wind farm and provision of detailed location information based on Google-map.

Operator-dedicated feature

- Real-time update of issues occurrence and generation status in each farm

Maintenance service-dedicated feature



- Checking generator alarm notification, and grasping the maintenance work status and the progress

Maintenance worker-dedicated feature

- Maintenance schedule management, and grasping the details of each schedule

Turbine manufacturer-dedicated feature

- Checking generation system information, product registration and inventory management

Additional Feature

We can make additional features in the dashboard as required by operators.
In the bottom of the screen, you can see the application images in A complex.

Wind farm monitoring

Checking any anomaly in telecommunication service and operation state, and making a proper response to any need in generation conditions

Generation amount forecast

Forecast of wind speed, generation amount, and sales revenue

Flow Diagram

Monitoring of power supply by each resource type and SMP monitoring

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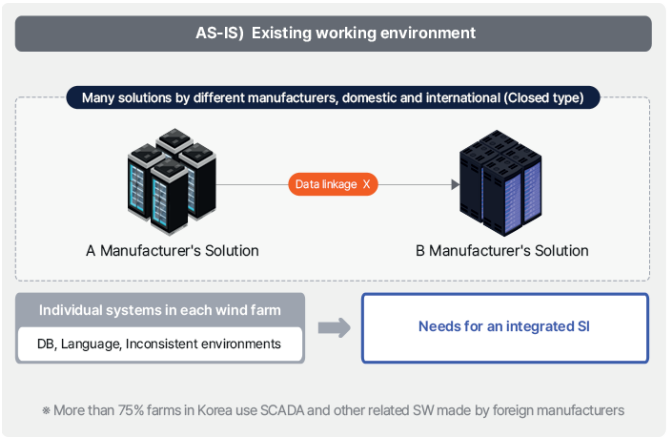
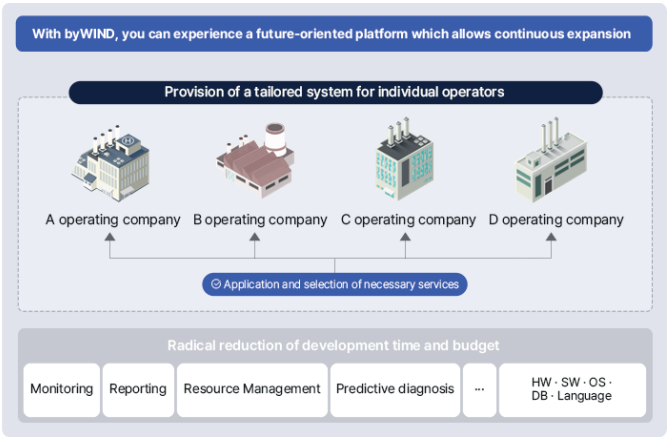
4-2. Operating environment





4-3. Monitoring

Functions include checking the SCADA notification and generator's operation condition.

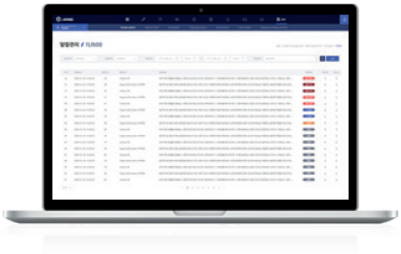
Checking the sensor list by main components and relevant data

Comparison of the sensor data of the same generator models

Provision of detailed information page for SCA notification

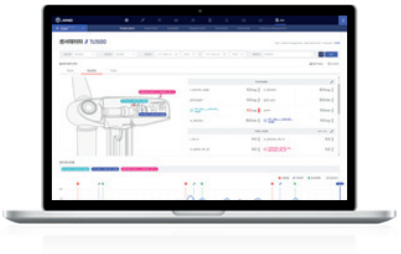
Screen Display

Alarm notification management



- Checking the alarm code record of each tribune and making suggestions to handle relevant code, and provision of the confirmation page showing the relationship between a specific event and the sensor data

Sensor data monitoring



- Checking the data of sensors installed in the turbines with time series-based graphs and numeric values, and alarm detail setting for relevant sensor values

Data analysis

- Provision of information concerning capacity, availability, failure frequency, and failure rate, based on the checking period of subject wind farm and/or turbine

4-4. Forecasting

By forecasting generator's condition, byWIND prevents fatal accidents and minimizes the risk of loss in sales.

* For maintenance forecast, we have an energy technology researcher and a machinery researcher ready to serve

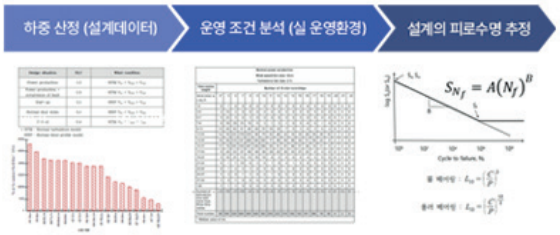
Tower and blades load analysis

Drivetrain and bearing vibration analysis

Machine learning-based forecast of generation amount and maintenance need

Screen Display

Fatigue Life Assessment & Forecast Technology



- Parts life forecast by fatigue life assessment on combined load structure and bearing, and statistical forecast of external loads
- This study was performed by the Energy Technology Research Center.

Generation Amount Forecast

- Provision of daily error rates indicating the discrepancy between actual generation and forecasted generation amounts for subject wind farms and individual generators

Forecast error rate = (|Forecasted generation amount − Measured generation amount| ÷ Facility Capacity) × 100(%)
* Time slots that have less than 10% capacity are disregarded in this calculation.

Trends and Remaining Useful Life Forecast

- Remaining useful life forecast based on the loads and data subject to the condition of gear box and main bearing operation state)
- This study was performed by the Energy Technology Research Center, and has been provided to byWIND as a useful forecast service.

4-5. Reports/Scheduling

byWIND analyzes the cause of issues with the generation system, and provides the decision-making index to optimize customers' maintenance planning.

Provision of materials to decide the best timing to inject O&M, based on database

Maintenance scheduling, on-site report, and online environment provision for maintenance record management

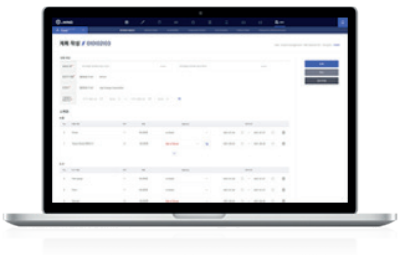
Print-out of registration details in PDF format

Screen Display

Turbine Operation History

- Provision of full lifecycle DB from the occurrence of a failure or issue case to the completion of the repair, with sensors in each stage of the issue, CMS and SCADA data-based alarm and notification, and details of parts use and repair, etc.

Data based-Planning



- Assisting operators and maintenance service providers in their establishment of data based-decision and optimal maintenance plan; and extracting data concerning future annual operation costs of each generator, such as operation suspension time, availability of parts and tools, and labor input data

Standard service includes the provision of various reports

Operation · Inspection · Blade check · Regular inspection report / Ship operation log
(expand the report type)

- We support various report formats satisfying specific operation system of individual wind farms. All reports can be prepared online, without relying on the traditional method using Excel and/or Word program
- We provide customized reports to meet the specific needs of individual operators.

Support of various print file format

XLS · PDF · IMG · ZIP
(expand the output type)

- For user convenience, registered, stored, and record data are provided in various file formats

4-6. 자산관리

We support rational decision-making on asset management through demand forecasting based on material reserve rates.

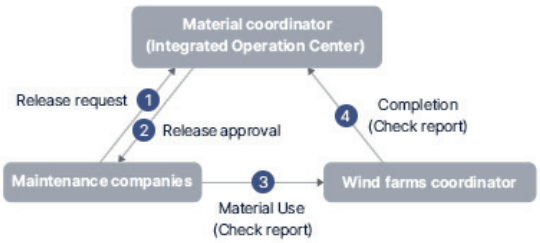
Material warehousing (both incoming and outgoing) management based on safety checking process

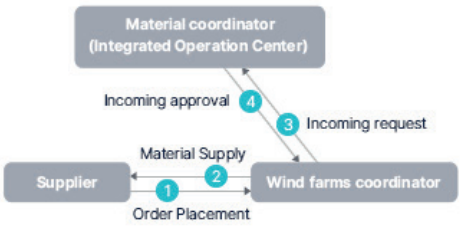
Automatic calculation of material reserve rate

Real-time material warehousing management by using QR code

Screen Display and technology

Setting up a material management system

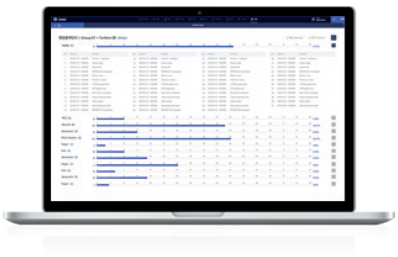




Release Procedure | Incoming Procedure

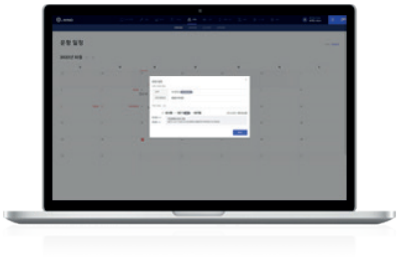
- Provision of material management service based on warehousing procedure
- Our material management system will be based on each operator's material management process.

Identification of Use Material based on the Failure Type



- Provision of statistics on the use materials (parts and tools, etc.), based on the statistics on the failure types of turbines in operation

Ship Operation Management



- Provision of ship registration and operation management service for smooth maintenance and routine check of offshore wind farms

4-7. 안전

We provide core technologies to ensure the workers' safety in the wind farm operation.

Provision of risk assessment model and supporting tools

Management of business places and work permits

Provision of website and mobile service environments

HSE operation support system

When working on maintenance planning, we can check and identify risk factors in the entire processing (work) at relevant business places, by conducting a preliminary risk analysis. The most significant role of risk assessment is to prevent potential accidents. In this context, documentation and continuous updates of risk factors and giving feedback are essential.

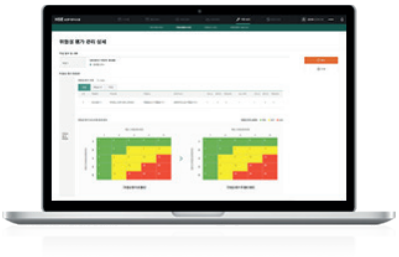
We are developing HSE operational support system in collaboration with WINDETECT Co., Ltd., and the Institute for Advanced Engineering.

※ Legal Basis of Risk Assessment ※

- The Occupational Safety and Health Act, Article 41-2 (Risk Assessment)
- The Enforcement Rules of the Act, Article 92-11 (Risk Assessment Performance, and Record and Preservation of the Results)
- Article 13 (Persons in Charge of Safety and Health Management), and Article 14 (Supervisors) of the Act
  : Monetary penalty of not more than 5 million won, in case of failure to perform risk assessment
- Ministry of Employment and Labor, Announcement No. 2017-36 [Guidelines for Risk Assessment in Business Places]

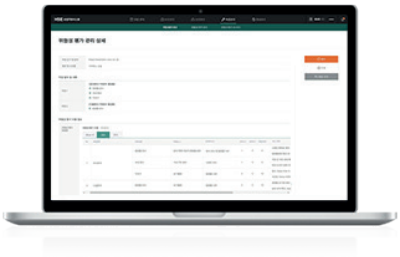
Screen Display and Risk Assessment Model (3 Types)

Job Safety Analysis(JSA)



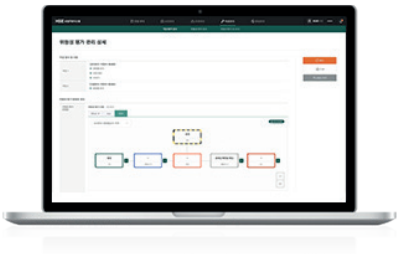
This method divides a subject task into key steps, and identifies hazardous factors and risks of potential accidents in each step. Using the information, it then develops a measure to remove, minimize, and/or prevent such risks

What-If Questions



It is a method to recommend a proper measure to minimize risks by identifying and forecasting potential accident risks and hazardous factors in a given processing by way of a series of preliminary safety questions. It is particularly useful to examine new risks due to change or modification of existing processing

Bow Tie Analysis(BTA)



It is a method to examine the propriety of risk treatment planning by describing the proper measures to each cause and effect of relatively large-scale and frequent accidents. It can explain risk prevention and reduction measure according to each risk path

4-8. Safety Content(VR)

We provide mandatory safety education for site workers by using virtual reality (VR) technology.

We collaborate with Visual Light Co., Ltd. for safety content development.

Provision of Oculus Quest-based application (For convenience)

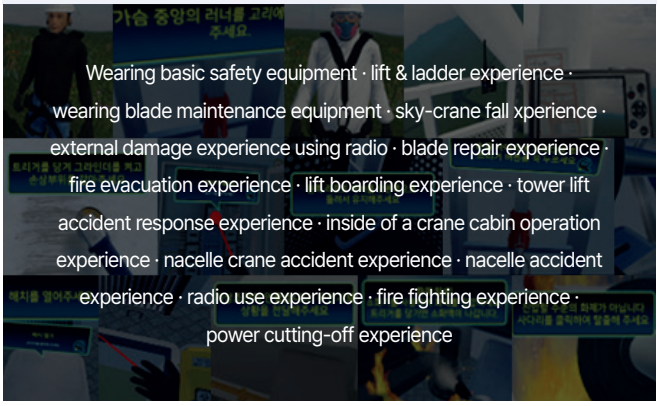
VR experience of different risk situations that can occur in work sites.

On-Site based Content Composition

Content Title Screen

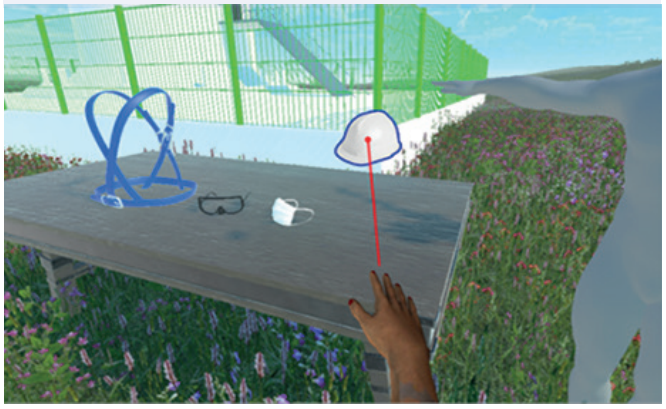
Screen to Select Internal Experience

15 Types of Experience Contents



Wearing basic safety equipment · lift & ladder experience · wearing blade maintenance equipment · sky-crane fall xperience · external damage experience using radio · blade repair experience · fire evacuation experience · lift boarding experience · tower lift accident response experience · inside of a crane cabin operation experience · nacelle crane accident experience · nacelle accident experience · radio use experience · fire fighting experience · power cutting-off experience

Educational Content Screen



Visit to Safety Education Classes

4-9. Mobile

byWIND guarantees business continuity based on service functions and characteristics.

Provision of same service through a web browser open to everyone

Easy additional development and maintenance, compared to native app.

Screen Display

byWIND mobile

Mobile QR code recognition

Wearing a Smart Watch

4-10. Intellectual Property (IP) Rights

[Patent]

Integrated management platform system for wind power generation

Maintenance system and method for preemptive forecast based-power generation facility, by using data analysis indicators

Web-based wind power generation blade management system

Scheduler-based maintenance supporting O&M platform device for wind power generators

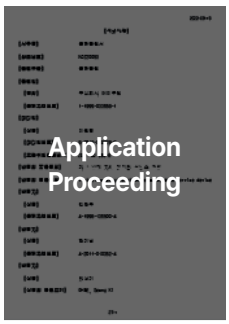
Wind farm simulator in consideration of environmental impact assessment

Smart watch-based integrated safety management system for field workers

Digital technology-based integrated O&M service platform devicefor offshore wind farms, by using an analysis of wake effect and farm control simulation

Service provision system that supports the decision of vessel navigation for wind farm maintenance

Preemptive maintenance system for wind power generation



(Application filed)
Data service device for virtual power generation resources

Power transaction pricing information system

Platform device that performs big-data based integrated data service in integrated micro-grid environment

Solar heated hot water circulation system

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