

**Ingeteam**



## Yaw Backup System

An Emergency Power Supply to Protect  
Wind Turbines during Extreme Weather Conditions

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# 1. Introduction

The unprecedented twin challenges of ensuring secure and affordable energy supplies and meeting climate targets have propelled wind power development into an extraordinary new phase of ever-faster growth. After a challenging year, the global wind market is ready to bounce back in 2023, exceeding 100 GW for the first time. With a double-digit growth rate of 15%, the mid-term outlook for wind energy looks very positive. GWEC Market Intelligence expects that 680 GW of new capacity will be added in the next five years.

Also, the increasing demand for renewable energy has resulted in manufacturers increasing the wind turbine dimensions and capacity, which implies the installation of increasingly larger blades and towers that are significantly more sensitive to adverse weather conditions, therefore, there is a greater risk for component major damage. Stresses can be reduced by aligning the rotor to track the incoming wind. During extreme weather conditions, power outages can suddenly happen.

In this regard, the existing power backup solutions are based on a generator with a reciprocating engine (genset). Although the Genset machine is capable of starting autonomously and supplying hard loads for a long time, it starts working a few seconds after a failure, thus exposing the system to costly damage. Summarizing, this technology presents low efficiency, as well as low commitment to sustainability.

In this context, Ingeteam has developed a Yaw Backup System product range, a sustainable solution which ensures an instant response in hazardous weather conditions, to reduce the mechanical stresses of the wind turbine through fast feeding of the Yaw System, thus, keeping the components safe and avoiding financial losses. Furthermore, the Yaw Backup System also provides an emergency electric power source to support essential loads such as control, communications, and thermal, among other systems.

The Yaw Backup System's technology is based on an electrical storage system which is capable of reacting immediately in the hardest conditions of voltage drops, as well as adapting its operation to demanded energy.

Ingeteam's ethos is to be technology agnostic in developing power conversion solutions for the industry. Our goal is to provide customers with the solution that works best for the turbines they are developing.

Our offering is a reliable, efficient and sustainable Yaw Backup System comprised of a Power Conversion System (PCS) and a unique batteries storage system (ESS) based on our 50 years of experience developing and supplying power conversion solutions for wind and other renewable energies and industries.

This innovative technology will provide the power required to control the Yaw Systems, to protect the structural integrity of the wind turbine during a power failure, contributing to the challenges of the wind sector in terms of security, sustainability, and efficiency.

A sustainable solution  
which ensures an instant response  
in extreme weather conditions.

## Benefits at a Glance

- Improves wind turbine performance in hostile conditions.
- Ensures a safe and reliable operation.
- Reduces maintenance costs and longer plant life, resulting in productivity growth.
- Enables early profits through the high Return on Investment.
- Prevents great damages on wind turbines and other assets resulting in serious consequences for the energy sector and financial losses.
- Avoids the use of diesel generators, except as a last resort in emergency situations.
- Contributes to the massive penetration of wind energy into the grid to enable the clean energy transition.
- Offers real-time operation monitoring and control, including alarm event captures.

In this whitepaper, Ingeteam covers the description of the new product range including the key areas of technological innovation for sustainable solutions based on power electronics and designed specifically for providing emergency power for wind turbine Yaw Systems.

Emergency power  
for wind turbine yaw systems

## 2. System Overview

Ingeteam's Yaw Backup System product range has been designed to ensure power supply in case of grid losses. The Yaw Backup System is a key element for safeguarding the reliability and availability of wind turbine farms, specifically the Yaw System and other single-phase critical loads that constitute each wind turbine. This system is available in a wide range of both power and voltages, adapted to the standards of each country or adapted to the application requirements.

The system is composed of two enclosures: One of them contains the Power Conversion System (PCS) and the other one contains the Energy Storage System (ESS).



Fig. 1 Yaw Backup System (YBS)

The Yaw Backup System is characterized by its great capability to be customizable, allowing configuration according to the desired power converter topology and load type.

The power converter system can be configured using a unique conversion line that works as both a rectifier and an inverter. Alternatively, it can include a Back-to-Back converter to connect the DC Bus at any voltage and frequency input.

On the other hand, it can also incorporate a DC/DC converter to improve the operating voltage of the batteries, and thus overcome voltage limitations of the batteries.

Regarding the output configuration, it is capable of supplying three-phase loads (3p and 3p+N). Additionally, it can incorporate single-phase loads (1p+N).

The system uses advanced modulation techniques to synthesize any type of voltage or current waveform to the output, leveraging the fast-switching speed of the IGBTs controlled by the Converter Control Unit.

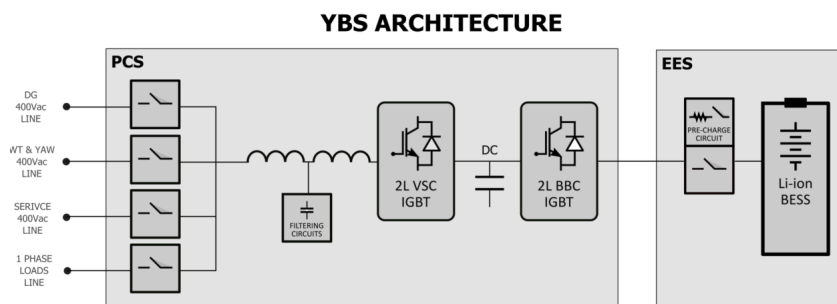


Fig. 2 Yaw Backup System (YBS) Architecture

Also, Ingeteam guarantees the repair service of the Yaw Backup System product range for 25 years after the date of purchase of the equipment. It should be noted that the Yaw Backup System range complies with the main codes and standards according to safety, and grid performance, among others.

Main characteristics of the equipment:

- Full front access for easy access to maintenance and replacement
- EMC certified (IEC 60092 / IEC 61800)
- Protection against dust, humidity, and water splash resistance, IP54
- Protection against high rust, CH4
- Highly efficient design
- Variable speed fans
- Low noise level
- Air input filters

MAIN TECHNICAL FEATURES	
Efficiency	>96.0 %
Power Factor (PF)	0.8– 1.0
Output voltage THD	< 8 % (IEC61000-2-2)
GENERAL INFORMATION	
Operation Temperature	-15...+45 °C
Life Time	25 years
Certifications	CE / UL
PCS Weight (With batteries/Without)	650 kg
PCS Dimensions (DxHxW)	650x2276x1500
ESS Weight (with batteries)	1500 kg
ESS Dimensions (DxHxW)	1110x2398x2743

Table. 1 Yaw Backup System (YBS) characteristics

### 3. Power Converter System (PCS)

The main objective of the Power Conversion System (PCS) is to transform the continuous energy of the batteries into alternating current to supply the system loads.

It is materialized as a cabinet which is composed of a Power Stack in charge of adapting the energy, a harmonic filter to improve the signal quality, protections against shortcircuits and overvoltages and a general control device (CCU).

Furthermore, it has been configured to respect demanded grid codes and keep the batteries healthy in a good term.



Fig. 3 Power Converter System (PCS) cabinet

Main benefits of the Power Conversion System:

- High customization of power converter topology
- Multiple power source connection points capability to charge batteries from different power supplies
- Dedicated three-phase and single-phase output
- Capability to connect linear and non-linear loads
- HMI to be easy maintenance operations locally
- Field bus connectivity via Profinet communication protocol for monitoring, control and data storage via a WebApp SCADA tool
- High cybersecurity level
- Guarantee fulfilment of the most demanding grid codes and standards
- Guarantee fulfilment of Electromagnetic Compatibility (EMC) standards
- High road & sea transport

PCS OVERVIEW	
Grid rated voltage ( $V_{\text{nominal}}$ )	400 Vac $\pm$ 10 %
Grid voltage range ( $\Delta V$ )	$\pm$ 10 %
Grid rated frequency ( $F_{\text{nominal}}$ )	50/60 Hz $\pm$ 10 %
Rated load power ( $P_{\text{RMS}}$ )	up to 75 kW
Peak load current	up to 125kVA

Table. 2 Power Converter System (PCS) overview

## 4. Energy Storage System (ESS)

The Energy Storage System (ESS) is in charge of basic tasks of batteries control and maintainability to guarantee the health and use efficiency of the storage system. The battery cells are assembled with LFP technology (Lithium Iron Phosphate) which is characterized for its high energy density. This type of cell provides great durability in the long term. Besides, the device has a Compact design for easy future upgrades thanks to its form factor and cell dimensions.



Fig. 4 Energy Storage System (ESS) cabinet

Main Benefits of the Energy Storage System:

- Unique storage system
- Lithium Iron Phosphate chemistry as battery technology
- High performance and excellent thermal dissipation by stacking plates and aluminium cases
- High mechanical protection thanks to the Prismatic Cell structure
- High lifetime performance
- Scalable energy storage
- Active or Passive Balancing
- Full Protection Function
- Wildly Application & Experience
- Easy Installation
- Consideration for Containerized Arrangement
- Automatic fire extinguishing system
- Tested and Listed to UL and IEC Standards for Safety

ESS OVERVIEW	
Chemistry	LiFePO4 [LFP]
Installed Energy at the Beginning of Life	Up to 165kWh
DC voltage range	580– 750 Vdc
Maximum discharge current ( $I_{MAX}$ )	350 A
Maximum discharge rate	1C
Maximum charge rate	0.5C

Table. 3 Energy Storage System (ESS) overview

The architecture of the ESS control is divided into three levels. The most basic module in the structure is the BMS which is connected to each battery, therefore, there will be as many BMS units as the number of batteries. Subsequently, all BMS units are governed by a Power Distribution Unit (PDU) which is responsible for obtaining voltage, and temperature measurements, among other tasks.

At the highest level of the hierarchy, there is the Battery Administration Unit (BAU) which acts as a gateway between PCS and ESS. In this connection, the BAU manages the sending and receiving of data with the PDU. On the other hand, it is responsible for the main connection between CCU and BAU.

BMS Functionalities:

- Conditions Monitoring
- State of Charge
- Discharge Control
- Thermal Management
- Fault Alarms
- Balancing tasks
- Protection device

<b>SAFETY STANDARDS</b>	
ANSI/IEEE C -2	National Electric Safety Code American National Standards Institute Institute of Electrical and Electronics Engineers
IEC 61508, 60812, 61025, 62281	International Electrical committee
UL 9540, 9540A, 1973, 1642, 991, 1998, 60760-1, 60950, 60812, 61025, 1778, 1598, 8750, 1012, 1995.	Underwriters Laboratories
NFPA 70E, 70, 551, 550	National Fire Protection Association

Table. 4 Safety standards

<b>PERFORMANCE AND GRID INTERCONNECTION STANDARDS</b>	
IEC 61427-2 2015, 62620, 60529	International Electrical committee
IEEE 1547, 693-2005	Institute of Electrical and Electronics Engineers
NEMA 250	National Electrical Manufacturers Association
UL 50E, 1741 (SA)	Underwriters Laboratories

Table. 5 Performance and grid interconnection standards



## 5. Control, Monitoring and Control

### Control

The Yaw Backup System is managed by the Converter Control Unit (CCU), a programmable electronic device designed and manufactured by Ingeteam, which is in charge of governing the power conversion system (PCS), as well as, the energy storage system (ESS).

Within the CCU, the programmed Firmware can autonomously manage the charging and discharging of batteries, and various operation modes dictated by the wind turbine control, among other functions.

Main characteristics:

- Powerful CPU for regulation and control
- Reliable hardware based on standard modules
- Modular and scalable control topology
- Robust and certified control design, validated in different applications for various sectors

### Monitoring and Communication

The CCU is a core element of the power converter both in control and communication. It communicates with the turbine's PLC through the Profinet communication protocol, and on the other hand, with the power storage supervisory elements, the BMS, through multiple serial communication protocols such as Modbus, CAN, or RS485. This shows the great versatility of the system to make use of multiple field buses.

Each battery is equipped with its associated Battery Management System (BMS), allowing it to know voltage, temperature, state of health, and state of charge, among other parameters of the cells. This ensures optimal operation and maximizes their lifetime through the latest control strategies and algorithms developed by Ingeteam.

The Web Application Manager is a user-friendly software SCADA tool used to monitor, control and acquire data on real-time operation of the equipment locally or remotely. It offers a wide set of diagnostic and service tools embedded in the CCU that allow it to carry out monitoring, configuration, diagnostics, control, data recording, and commissioning tasks locally.

The software only requires a web browser, and it runs as a Web application without any special requirement for your PC. This technology allows you to connect the power converter control and your PC locally or remotely via an Ethernet link. Additionally, it is essential to use its different security levels to work with greater comfort and control.

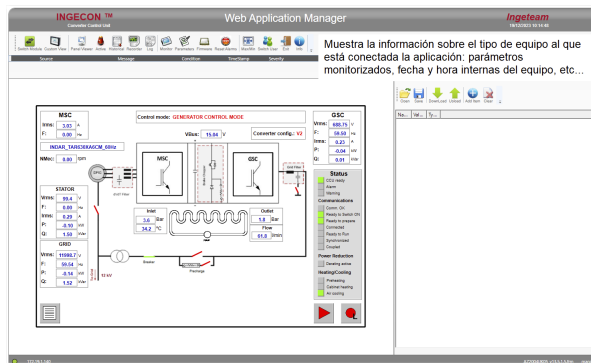


Fig. 5 Web application manager user interface

Web Application Manager main features:

- Monitor signals
- Save and compare data
- View and set up parameters
- Event and historical alarms
- Custom and user-friendly interface adapted to client requirements

One of the most important functions offered by the WebApp is the Troubleshooting module, which optimizes and facilitates corrective and preventive maintenance tasks through the HMI or PC panel.

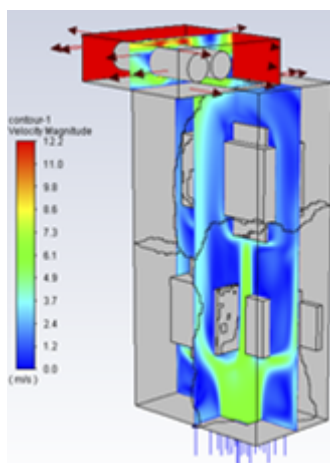
## 6. Heating and Ventilation Efficiency

Regarding the grid loss scenario, the main objective of the YBS is to maximize the energy supply time during grid outages when the YBS is in operation. Therefore, it is of vital importance to develop an air-cooling system that maximizes the cabinet's efficiency.

On the one hand, the PCS employs a single fan that regulates the airflow based on the losses of the semiconductors and evacuates all system losses at the same time.

On the other hand, the ESS employs an insulated enclosure, to preserve a constant battery temperature and reduce the energy demanded of the heating system.

To achieve this, a detailed analysis has been carried out using CFD (Computational Fluid Dynamics) based models.



*Fig. 6 Thermodynamic model of the PCS*

The temperature is a variable that has a direct impact both on the capacity and lifetime of the electrical storage. For that reason, BMS devices are used to supervise the voltage of the cells, the State of Charge, the State of Health, and the self-temperature, among others.

Therefore, within equipment firmware, the thermal control logic plays an important role in managing the equipment's cooling and heating system. These logics are composed of mathematical algorithms that use the extracted data from the BMS devices. Thus, the maximum efficiency of the operation and the maximum battery storage lifetime are guaranteed.

## 7. Algorithms

Ingeteam has developed algorithms and control strategies to comply with established requirements, manage the process of charging and discharging batteries, control the cooling system, and maintain the batteries in good condition, among other tasks. Therefore, the design of the algorithms must integrate all elements that compose the system, such as a grid, main converter, DC/DC converter, and batteries, thereby guaranteeing reliable and efficient operation.

The development of the Firmware has been carried out using a Software-In-the-Loop model in Matlab, considering the PSC, ESS, and the modelling of linear and non-linear loads. Additionally, the Hardware-In-the-Loop model has enabled the computational optimization of the system and the validation of the Firmware through a test bench.

Worth highlighting, the product undergoes testing protocols during its production to ensure the correct performance of the equipment.

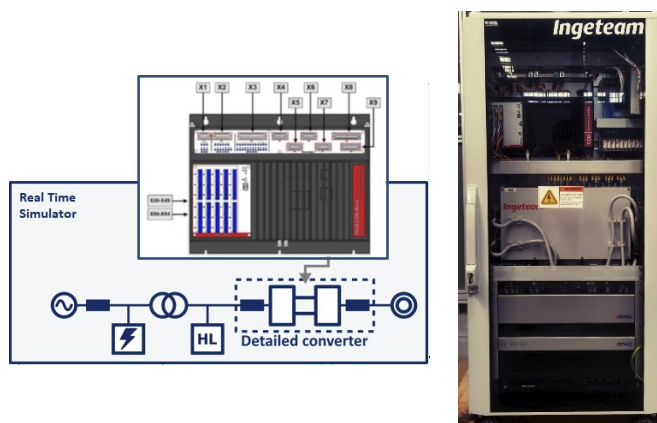


Fig. 7 Yaw Backup System model in Matlab

## 8. Conclusion

Ingeteam's Yaw Backup System product range has been designed to ensure power supply for the Yaw System and critical loads, ensuring operational continuity in case of grid losses. This, in turn, helps safeguard wind turbine components and prevents financial losses.

The full range of Ingeteam's Yaw Backup System allows satisfaction of specific requirements for each client, thanks to its high capability for customization. This enables the configuration of inputs, outputs, and conversion topologies as desired.

On the other hand, the product incorporates a WebApp SCADA tool that allows the monitoring of the operation using real-time data to make informed decisions and enhance the availability of wind turbines. Additionally, the mechanical design and troubleshooting software module facilitates easier corrective and preventive maintenance, thereby reducing operational expenditures.

The Energy Storage System is characterized by a compact design conceived for easy future upgrades, providing a scalable energy storage solution.

Ingeteam, as a recognized leader in renewable generation with more than 57 GW installed worldwide, focuses on delivering both maximum performance and the fulfilment of the highest quality standards. The company provides multiple functionalities aimed at supporting operation and maintenance activities to enhance the Levelized Cost of Energy.

### **WHY INGETEAM?**

Flexibility to adapt the final product to comply with each client's specific requirements, with the highest standards of quality and guaranteeing the fulfilment of the most demanding grid code, to provide competitive, reliable and robust products.

Ingeteam offers a 360° CRS (Customer Relationship Service) with all of its product range, providing direct technical support, training and maintenance service throughout the lifetime of products. In addition to, assistance and advice during the initial stages and from the project definition to the commissioning of the equipment.

The Yaw Backup System commissioning is carried out by highly qualified, multidisciplinary staff with experience in a wide range of sectors, to assure the best performance.

## 9. Authors



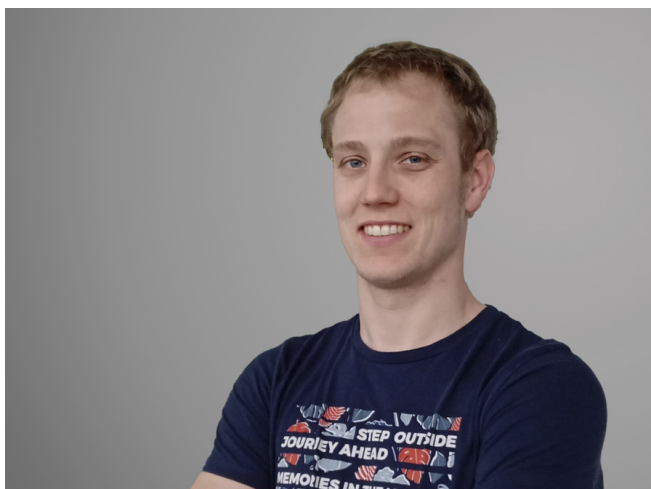
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