ABB Power Generation

Wind Automation
Customer Presentation

Power and productivity
for a better world™

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Introduction

Wind Market
Onshore stable, Offshore expected to grow

Onshore Wind Capacity Outlook CAGR 2013-2023: 5.8%

GW — years 2011, 2012, 2013, 2014e, 2015e, 2016e, 2017e, 2018e, 2019e, 2020e, 2021e, 2022e, 2023e

■North America ■Latin America ■Total Europe ■Asia Pacific ■Middle East & Africa

Offshore Wind Market Outlook CAGR 2013-20: 20.6%

GW — years 2011, 2012, 2013, 2014e, 2015e, 2016e, 2017e, 2018e, 2019e, 2020e, 2021e, 2022e, 2023e

■North America ■Latin America ■Total Europe ■Asia Pacific ■Middle East & Africa

- Traditionally strong Onshore markets forecast to have a moderate growth
- Favorable Onshore sites drying up
- Europe sustained by RES policies in UK and Germany
- China challenged by overcapacity and grid access
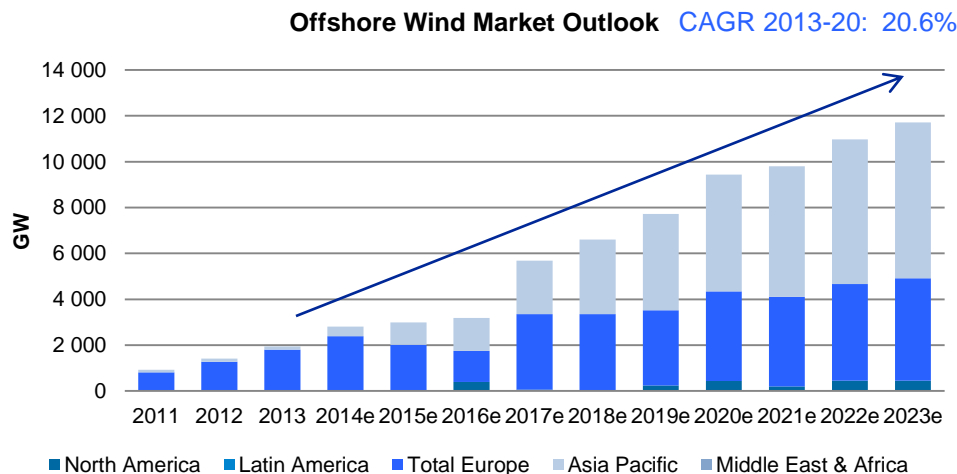
- Offshore market forecast to grow at 20% CAGR from 2013 to 2023
- Offshore presents increasingly attractive opportunity
- UK and Denmark pose largest global markets; Europe accounts for 72% of installations and 89% of pipeline
- China forecast to pick up with resolution of regulatory and infrastructure complications

Source: Make Consulting Q1 2014 Wind Power Market Outlook

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Wind Market
Challenges, Situation, Trends

| **Challenges**	General trend to reduce or eliminate the subsidies for renewable energies across the globe Cost of renewables to reach grid parity
Situation	Slowdown in new installed capacity – economic challenges for some of the WT OEMs Market consolidation on ownerships side - larger utilities acquire projects and assets from smaller owners
Trends	Operations and maintenance in focus - make assets more profitable Offshore sector asks for improved remote management and better reaction to field problems

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ABB delivers from A to Z into wind industry
Wind Power Generation, Transmission, Integration & Control
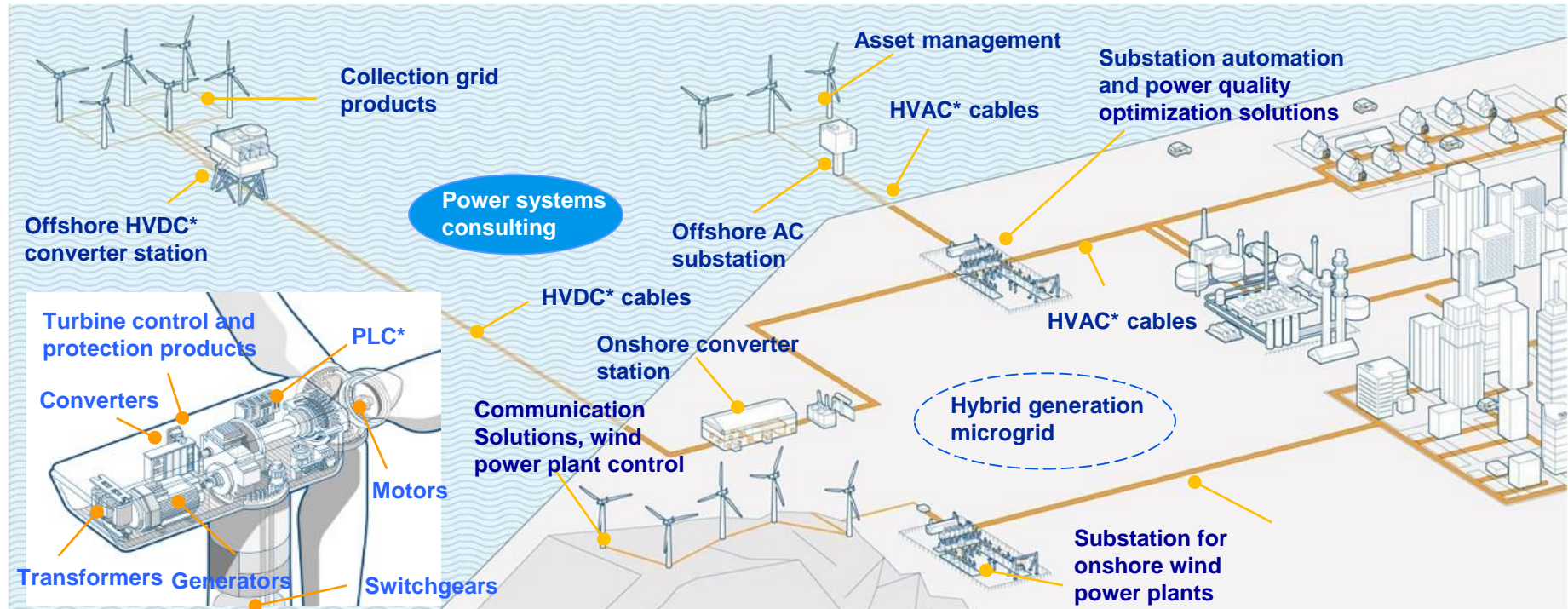
EMS: Energy Management System
GMS: Generation Mangement System
HVAC: High-voltage Alternating Current
HVDC: High-voltage Direct Current
PLC: Programmable Logic Controller
SCADA: Supervisory Control And Data Acquisition

Value Proposition

Customer Value Proposition
Why ABB?

Trusted partner	ABB is a leading provider of automation and power solutions to the wind industry, covering all areas from wind turbines, to farms to grid connection and operation of assets.

ABB is a strong technology leader committed to long term developments for bringing wind power on par with other generation technologies |
| **Reliable & proven solution** | Symphony Plus, ABB's leading automation system for power & water industry, provides the necessary flexibility and scalability demanded by wind farms to large fleets |
| **Focus on customer values** | Symphony Plus Wind specific applications improve control, operations and diagnostics of wind power plants, increasing the efficiency and uptime of turbines, and therefore maximizing owner's benefits |

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Wind Automation
Customer Benefits

Reduce Costs, Improve Efficiency

- Effective operations of fleet of plants with scalable and versatile remote control center solutions

- Improved efficiency of the wind turbines based on a range of diagnostic solutions, from high level KPIs to detailed Condition Monitoring analysis of relevant components

- Reduced costs of operations using a single automation system to mange all assets
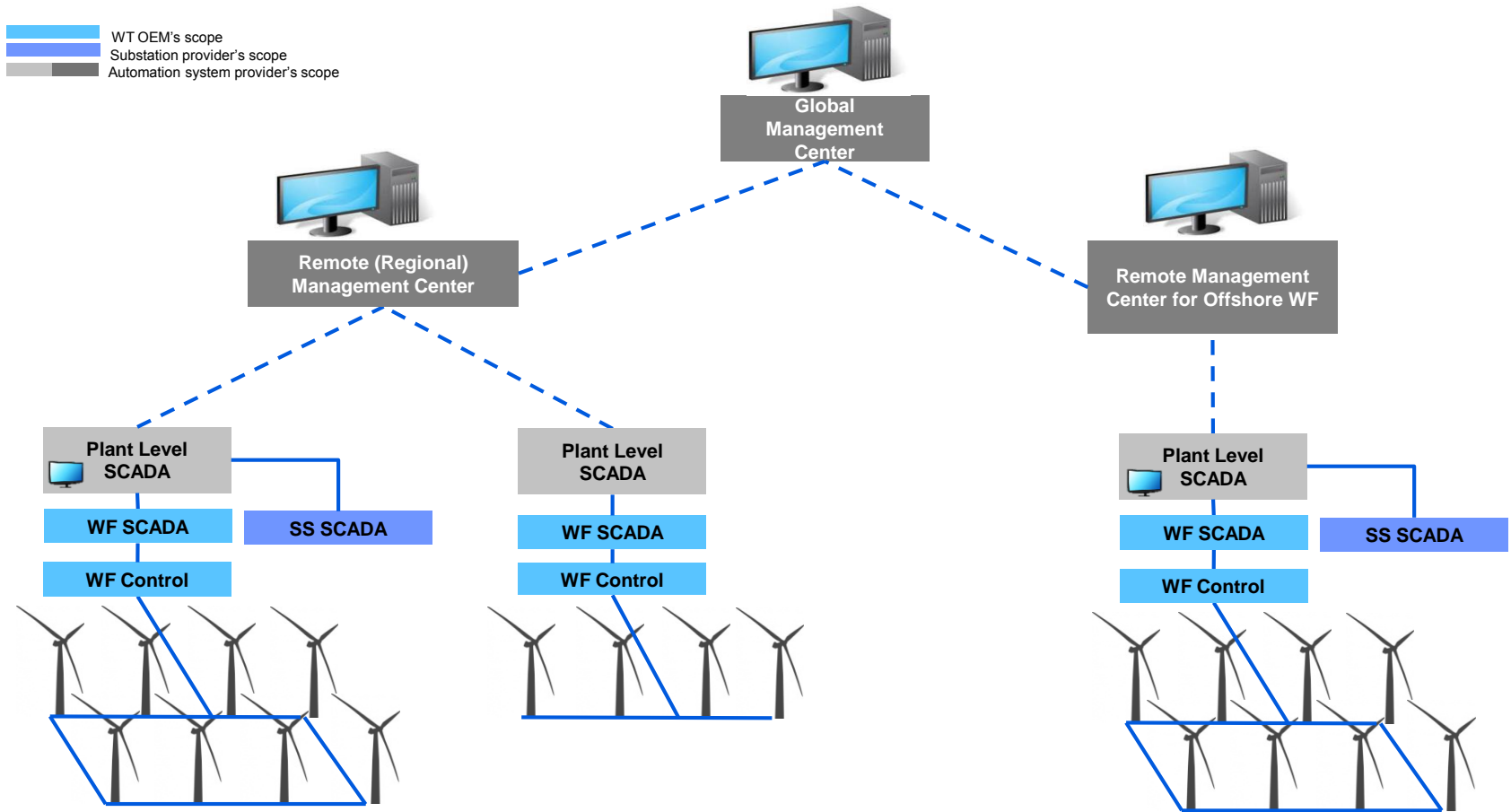
Sustainable Business, Trusted Partner

- ABB's wind automation system helps our customers expand their business in the renewable sector

- Highly competitive solutions and strong partners needed for successful renewable business in the long run

- ABB's vast experience and expertize in wind industry helps our customers to always stay on top of their business

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Solution Overview

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Wind Automation
Solution Architecture

Legend:
- WT OEM's scope
- Substation provider's scope
- Automation system provider's scope

Global Management Center

Remote (Regional) Management Center

Remote Management Center for Offshore WF

Plant Level SCADA
- WF SCADA
- SS SCADA
- WF Control

Plant Level SCADA
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Plant Level SCADA
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Automation of renewables relies on remote control centers due to plant sizes and their geographical dispersion.

SCADA = Supervisory Control and Data Acquisition
WF = Wind Farm
SS = Substation

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Wind Automation
Key Offerings from ABB Power Generation

Provide automation solutions for the wind sector	**Monitor and diagnose the wind farms**
	Provide automation solutions for wind farms (at farm and at remote levels) using Symphony Plus platform
	▪ S+ Operation as SCADA solution for the remote control center
	▪ S+ Operations and PLC for SCADA and control system at the farm level
	Monitor relevant signals and diagnose the wind farms to minimize downtime of turbines and improve their efficiency

Provide software solutions to increase the value of renewables	**Turn renewables into a reliable generation source**
	Provide control capabilities and aggregation in (larger) virtual power plants to facilitate the integration of renewables into the power system planning and operations through flexible control and forecasting of power production
	Provide optimized control, predictive service and maintenance solutions to reduce the cost of renewable energy

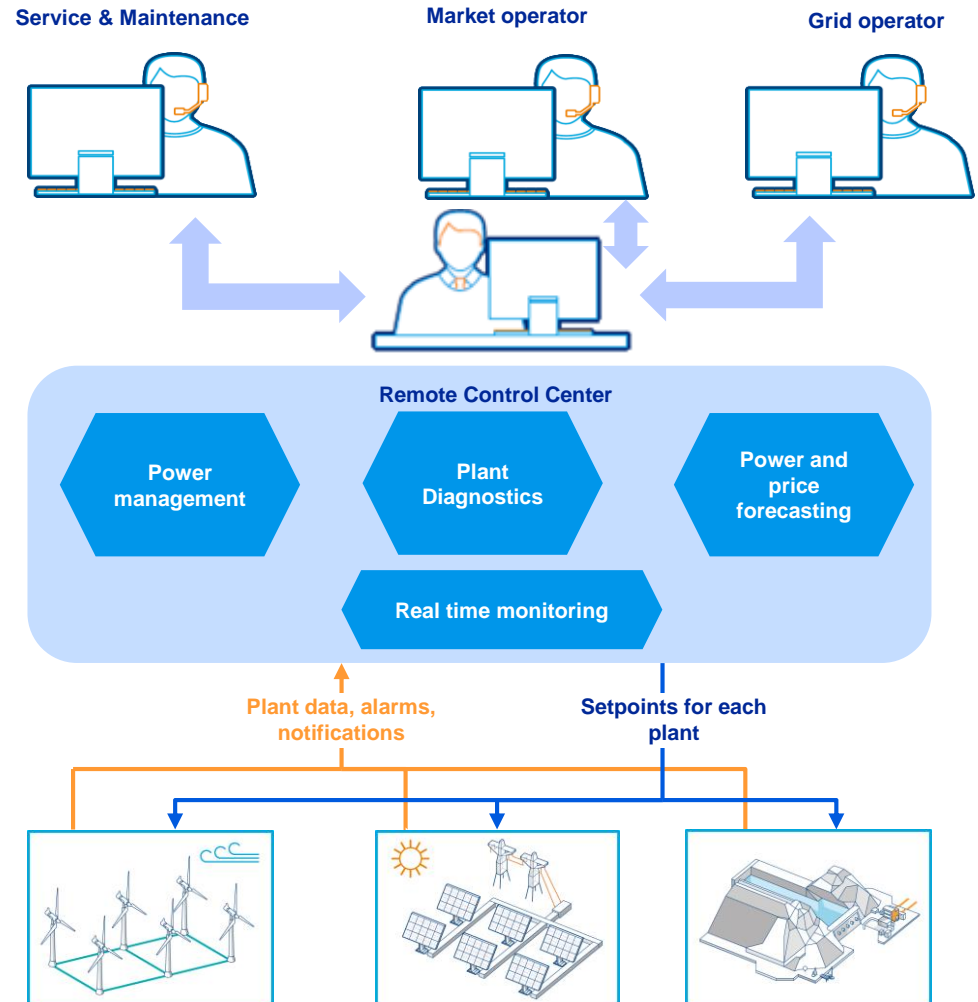**ABB**

Solution Overview
Focus on Awareness, Effectiveness & Optimization

Architecture and Interfaces

- Hierarchical architecture with Plant Level and Remote Center Systems using the same technology (S+ Operations)

- Standardized protocols to connect all relevant assets into a single system

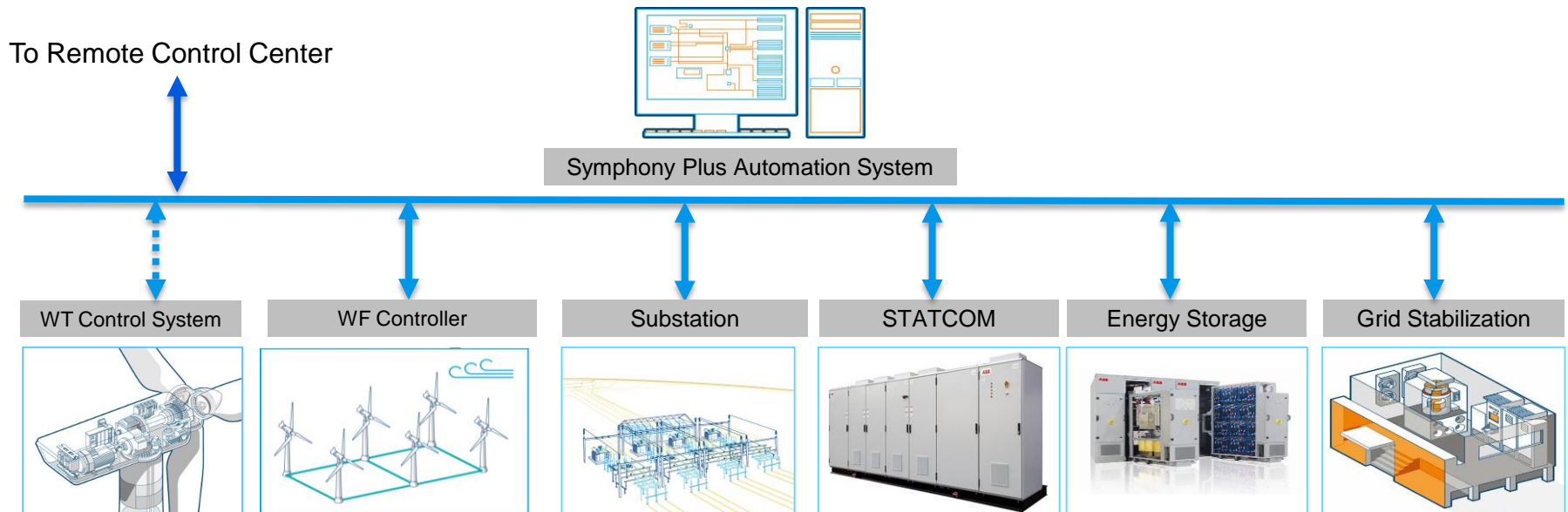- Interfaces with other systems for effective operations of renewable plants

Key Features

- Monitoring and diagnostics of the generation fleet through dedicated applications

- Power Management function to turn renewable plants into reliable generation

- Forecasting of power production and energy prices

- Optimization power production based on diagnostics and forecasting

Service & Maintenance　　　　**Market operator**　　　　**Grid operator**

Remote Control Center

- **Power management**
- **Plant Diagnostics**
- **Power and price forecasting**
- **Real time monitoring**

Plant data, alarms, notifications　　　　**Setpoints for each plant**

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Plant Level System
Single Point for Monitoring & Control

To Remote Control Center

Symphony Plus Automation System

WT Control System	WF Controller	Substation	STATCOM	Energy Storage	Grid Stabilization

| SCADA Functionality	Control Functionality

SCADA Functionality

- Data acquisition from Wind Turbines and/or Wind Farms SCADA systems through various protocols

- Data acquisition from the Substation SCADA and/or RTU or direct connection to the IEDs through 61850

- Supports connection to any other device/system, e.g. STATCOM, Capacitor Banks, Energy Storage

- Supports a broad ranges of communication protocols, e.g. IEC 60870-5-101/104, DNP3, OPC, Modbus, IEC 61850

- Measurements acquisition (e.g. power, current, wind speed/direction, temperatures)

Control Functionality

- Integrates the operations of generation and electrical equipment into a single system

- One point of control for the entire plant, one point of connection with the upper level systems (plant and grid operators)

- Coordinates the control of active and reactive power at the plant level, integrating reactive power compensation devices and/or energy storage into the control logics of the plant

- Dispatches the individual wind turbines in case the wind farm SCADA controller is missing or not desired

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Remote Control Center
Monitoring & Diagnostics
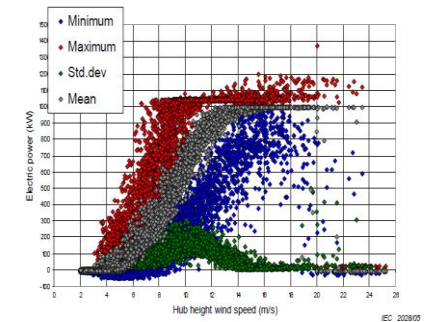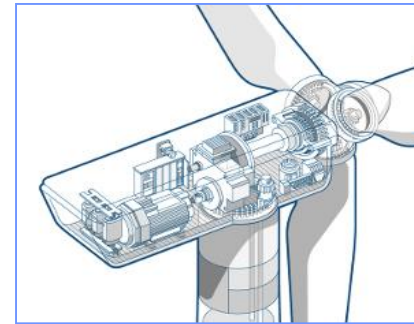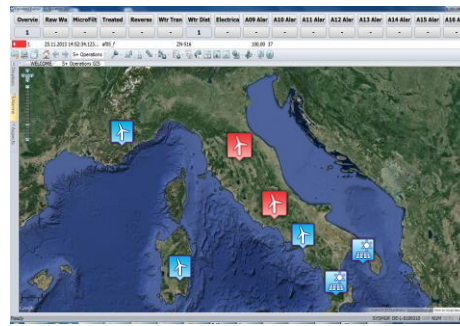
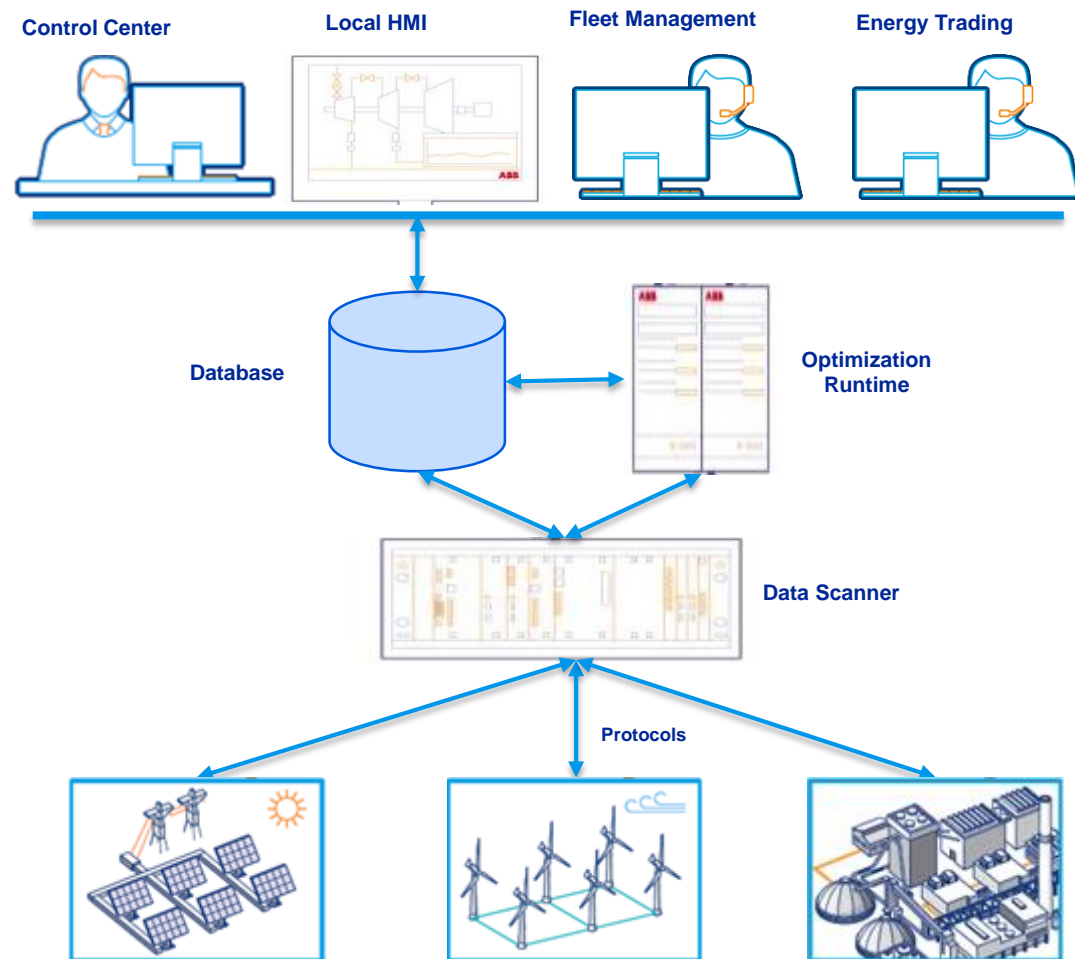| Greater Awareness	Effective Operations	Remote Management	Data Analysis and Reporting
• Intuitive HMI to visualize all relevant process data from the plant, grid connection and/or weather stations • Visualization of critical data in a high level displays based on GIS • Effective navigation from the GIS displays to the plant and vice-versa	• Alarm Management system for greater awareness and faster response • EEMUA191-compliant alarm analysis tools help users categorize occurring alarms with focus on effectiveness and safety operation	• Commands to remotely or locally control the substation equipment • Remote set-point settings to the power plant such as active and reactive power or power factor angle set-point • Remote diagnostic and handling of errors, alerts, or alarms	• Wind Turbine Power curve and Power coefficient analysis • Energy Production and production loss • Standardized Key Performance Indicators based on the IEC 61400-12 • Customer specific Performance Indicators

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Remote Control Center
Power Management

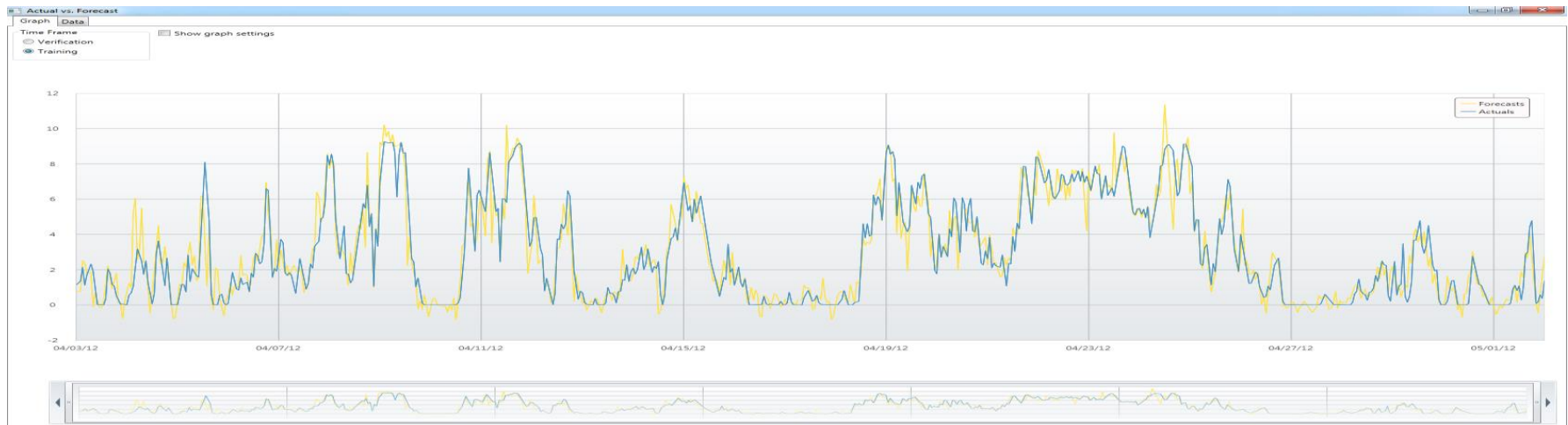## Features of OPTIMAX PowerFit

- Real Time Optimization of generation fleet due to new system layout with online optimization connected directly to automation networks (either physically or through VPN)

- Use of power and price forecasting for intraday optimization

- Mathematical optimization running in control loops with simple engineering

- Increase flexibility of power production, including: secondary control, minute reserve, direct trading

- Running on ABB Dynamic Optimization platform

Benefits of OPTIMAX PowerFit

- Always run at economic best point, the plant and fleet efficiency is maximized

- Provides capability for the operator to participate in the secondary and tertiary control

- Intraday optimization

- Direct trading of renewable power

- Planned production of generation assets

- Human operators take supervisory role

Control Center **Local HMI** **Fleet Management** **Energy Trading**

Database **Optimization Runtime**

Data Scanner

Protocols

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Remote Control Center
Power Production & Energy Prices Forecasting

Features	Capabilities
• **Neural Network Technology** – which recognizes relationships and applies this knowledge to produce accurate daily and hourly demand and price forecasts.	• **Flexible Data Integration** – for creating a customized model set-up, forecast execution, and results processing.
• **Rules-based Error Handling** – to identify, cleanse, and manage data in a way that can still produce accurate forecasts.	• **Profile Manager** – for creating, adjusting and maintaining similar models to allow for easier use.
• **Error by Time-Frame** – can indicate outlying months, days, or hours, as well as isolate where adjustments need to occur.	• **Sensitivity Analysis & Comprehensive Statistics** – to track changes in data for a better understanding of relevant inputs and more accurate capture of forecast peaks and valleys.
• **A Scatter Plot** – of actual data versus forecasts can depict outer points immediately	• **Customized Reports/Graphs** – which analyze specific data areas and present them in Excel, Access, and/or HTML using the Ventyx Report Agent.

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Condition Monitoring for Wind Turbines

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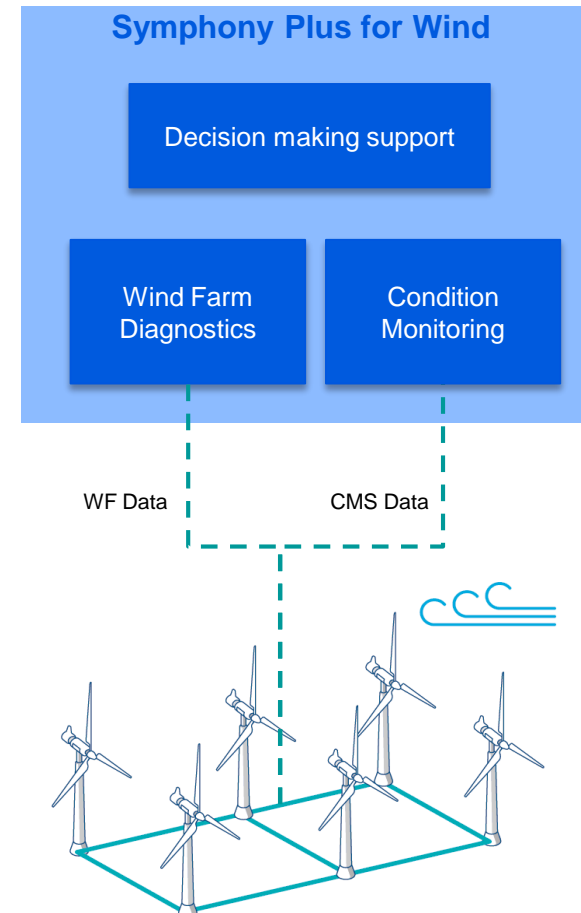# Diagnostics for Wind Farms
Condition Monitoring of Wind Turbines

Why?

- Breakdown of critical assets affects negatively the uptime of the turbines and their capacity factor

- Understand the condition of the assets and better plan maintenance and service activities, particularly for offshore projects

- Reduce costs and risks associated with breakdown of components

How?

- Condition Monitoring System to monitor critical components such as gearbox, main bearing, main shaft, generator shaft

- Dedicated algorithms for asset condition estimation to support the decision making of operations and maintenance personnel

Symphony Plus for Wind

Decision making support

Wind Farm Diagnostics

Condition Monitoring

WF Data

CMS Data

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Diagnostics of Wind Farms
Solution for vibration & temperature monitoring

Symphony Plus for Wind

Predictive Maintenance

- Uses Analyst results and other relevant process data to estimate the remaining life of the components

Predictive Maintenance

Analyst

- Software solution that monitors and analyses MCM data along with other relevant process variables necessary to determine the condition of the equipment

- Provides Key Vibration Indicators (KVI), Key Diagnostics Indicators (KDI) and Key Performance Indicators

Analyst

CMS Data

Machine Condition Monitoring (MCM800)

- Hardware & software platform to acquire and process vibration and temperature data from relevant sensors (ABB and non ABB)

- Used in thermal and hydro generation, marine and other applications where large machines are involved

MCM 800

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Customer Benefits

Customer Benefits
Reduce Investment due to Strategy Shift

Same operators can easily manage renewable plants

Operator

Renewable Plants Control Center
Symphony Plus

Thermal Power Plant Control
Symphony Plus

Hydro Power Plant Control
Symphony Plus

Solar Plants

Wind Plants

Small Hydro Plants

Thermal Plants

Large Hydro Plants
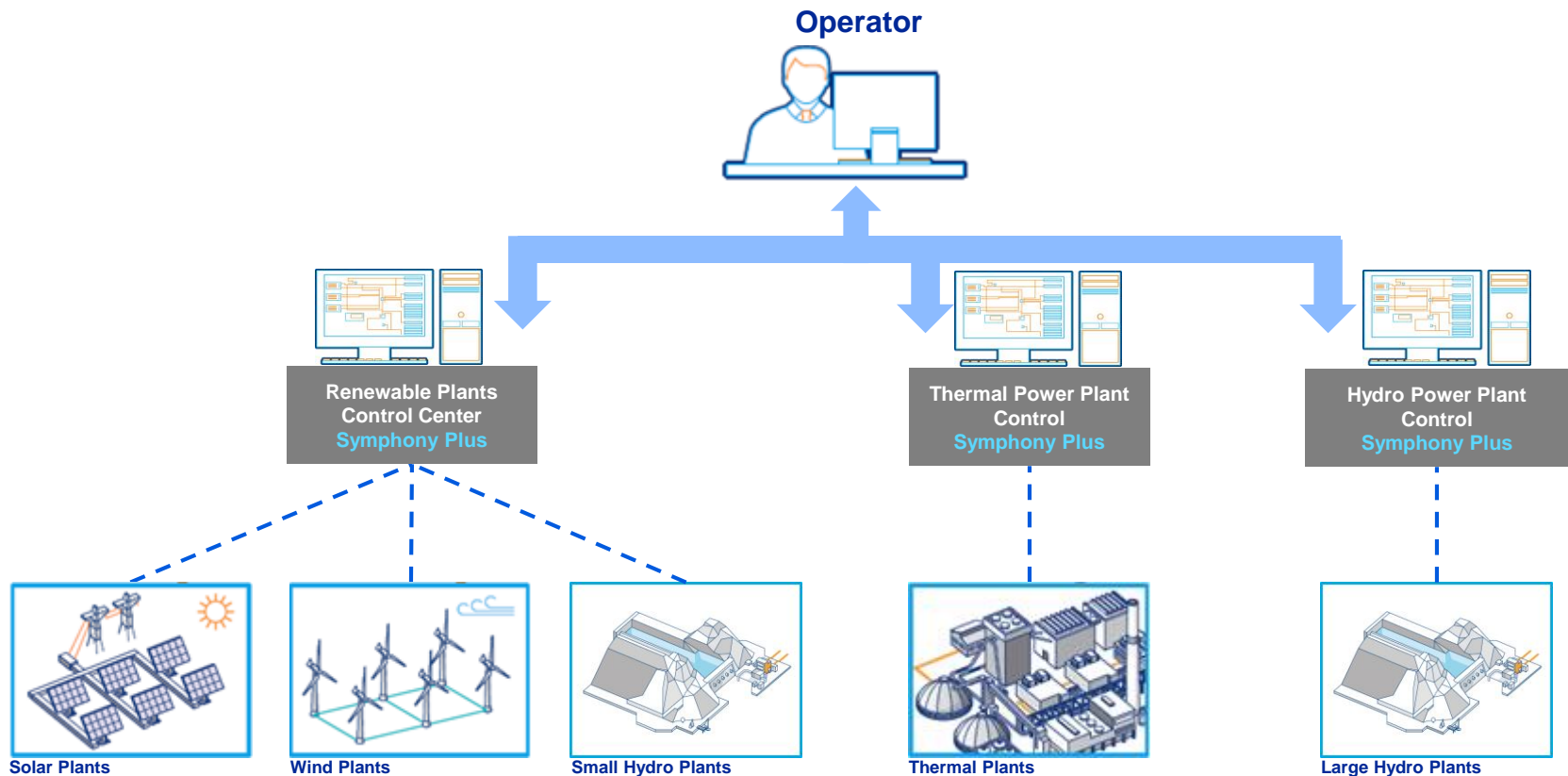
Customer Benefits
More Value from the Assets

Maximize benefits with optimal power dispatching ▶

Historical and Real Time Asset Data	Power forecasts

Optimal Power Dispatching

Real Time Operation & Control	Intraday Operation & Planning
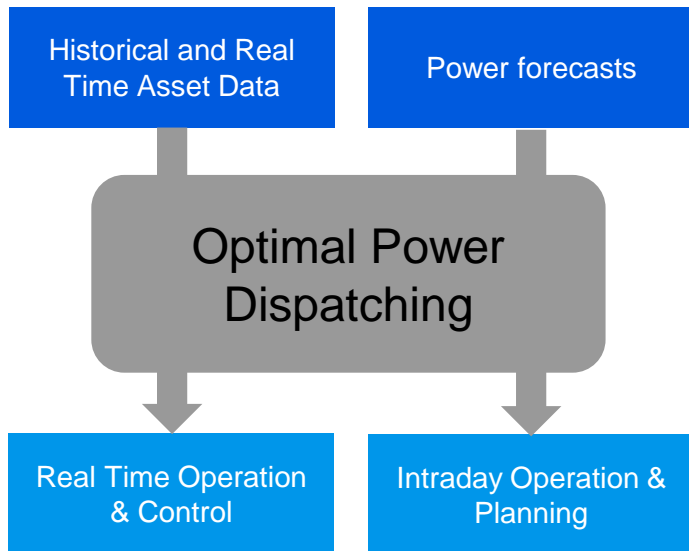
- Real time control loops optimize the setpoints for each plant considering customer objectives and asset constraints

- Intraday optimal planning taking in consideration the forecasts of power production and energy prices

- Diagnostic results are accounted for in the optimization

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Customer Benefits
Increase Efficiency with Newer Technologies

Improve the efficiency of wind farms ▶		
	Spinner Anemometer (from ROMO Wind)	▪ Accurate wind speed measurements using sonic sensors **placed on the spinner of each wind turbine** ▪ Possibility to **accurately determine the power curve** (efficiency) of the wind turbine by correlating wind speed and produced power ▪ Identify the **reasons for efficiency loss** (e.g. yaw misalignment) and correct it
	LiDAR Technology (from Pentalum)	▪ Accurate wind speed measurements using LiDAR (Light Detection and Ranging) sensors placed **on the ground, in front of each wind turbine** ▪ Possibility to **accurately determine the power curve** (efficiency) of the wind turbine by correlating wind speed and produced power ▪ Identify the **reasons for efficiency loss** (e.g. yaw misalignment) and correct it
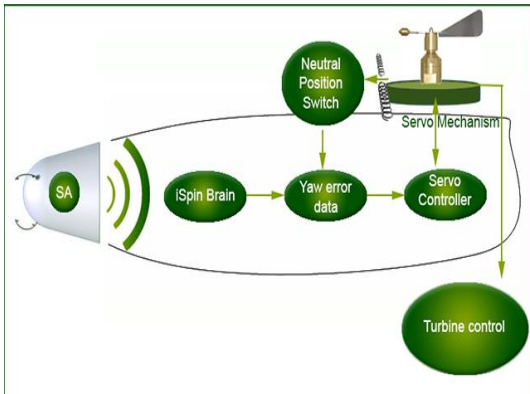
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Know and understand the process
Wind flow analysis and influence on WF performance

Technology

- LiDAR* technology to sense the wind speed and direction within and around the wind farm
- Accurate measurements at different high levels across the wind turbine rotor plane

Strengths

- More precise wind speed and direction measurements as compared to the traditional nacelle anemometry (anemometer cups and wind vanes)
- Cost effective technology based on Spidar from Pentalum
- Easy to handle, mount and monitor due to its minimalistic requirements to setup
- Sensor data can be wirelessly transferred to the control center or can be integrated in the existing wind farm communication infrastructure

Added Value

- Independent measuring devices to be used as alternative to existing nacelle anemometry
- Wind flows in the wind farm and its surroundings can be better understood
- Wind turbine performance and loads can be calculated in a more accurate way

*LIDAR = Light Detection and Ranging

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References

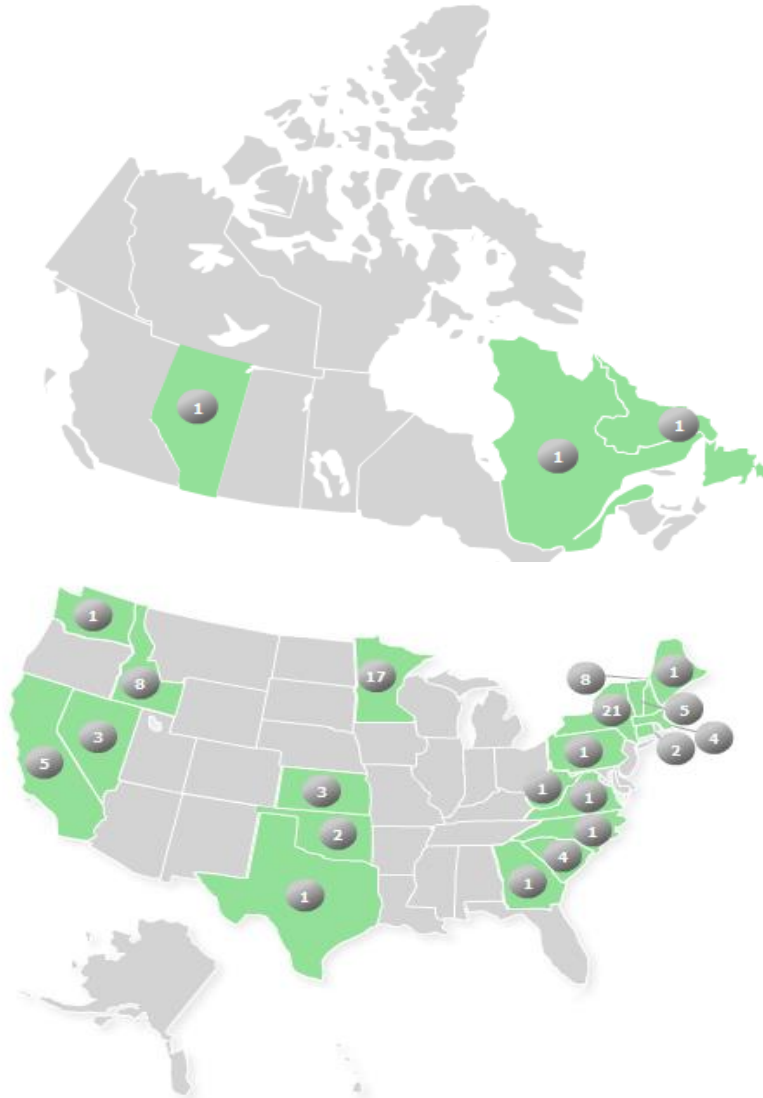# Remote Renewable Management System
Example of Installation in Italy

ITALY

Total 3068 MW	Total plants 403

- 1512 MW
- 723 MW
- 112 MW
- 720 MW

- 6 Remote Control Centers distributed on regional and macro-regional basis (PGP based)

- 1 Disaster Recovery Control Center ready to take over any of the 6 in case of faults or malfunctions

- The Remote Control Centers manage all wind, solar and hydro plants in the region

- 1 dedicated Control Center for managing the geothermal power plants

● Monitoring and Control Center for Wind, Solar & Hydro plants

● Disaster Recovery Control Center

● Control Center dedicated to Geothermal plants

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Remote Renewable Management System
Example of Installation in the US

NORTH AMERICA

Total 1673 MW	Total plants 93

- 21 MW
- 313 MW
- 47 MW
- 26 MW
- 1266 MW

93 renewable energy plants of multiple types: Wind, Solar, Hydro, Biomass and Geothermal

PSPG provides Plant Level Automation Systems

- S+ Operations

- Ventyx provides the Remote Management System

  - AGC for Power Management and coordination with SPP and other ISOs

  - Nostradamus for Production Forecasting

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Summary

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Customer Value Proposition
Key Points to Take Away

Trusted partner	ABB is a leading provider of automation and power solutions to the wind industry, covering all areas from wind turbines, to farms to grid connection and operation of assets. ABB is a strong technology leader committed to long term developments for bringing wind power on par with other generation technologies
Reliable & proven solution	Symphony Plus, ABB's leading automation system for power & water industry, provides the necessary flexibility and scalability demanded by wind farms to large fleets
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