System services
ENERCON technology in the grid support

ENERCON Sales - Grid Integration

Nuno Taveira / Salvatore Stanco

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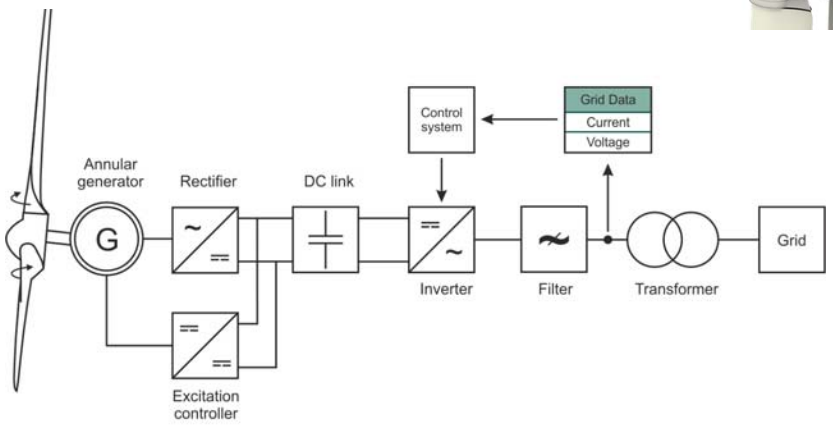
Agenda

1. **ENERCON electrical design**
2. **Drivers for System services**
3. **How to keep the system running?**
   - **Grid Codes vrs System services**
4. **Delivery of System services by ENERCON**
5. **Reactive power capability & voltage control**
6. **System Services in Europe**

Basic Electrical Design

Key characteristics

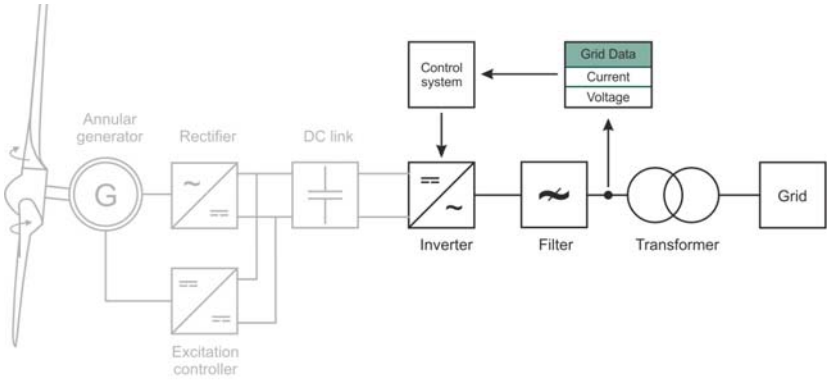
- Type 4 Wind Turbine Generator (WTG), with no gearbox
- Full scale power converters decouple annular generator from the grid



Basic Electrical Design

Key characteristics

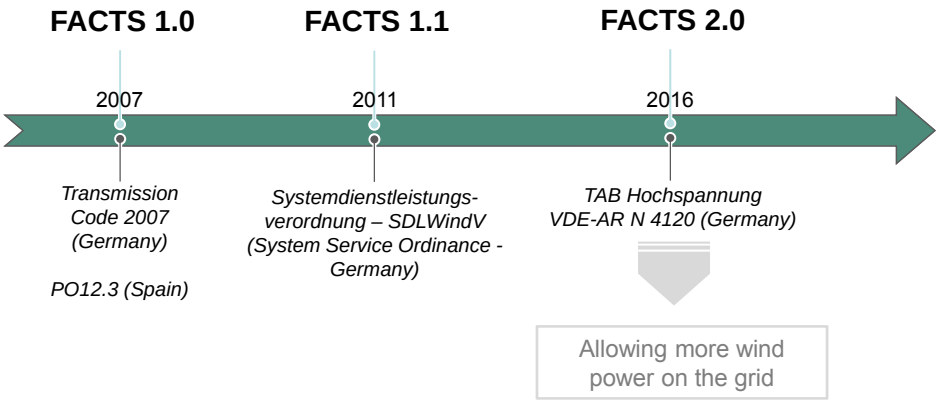
- Type 4 Wind Turbine Generator (WTG), with no gearbox
- Full scale power converters decouple annular generator from the grid
- Performance on grid mainly determined by inverter(s) (current source)



Basic Electrical Design

ENERCON ENERGY FOR THE WORLD

History of FACTS (Flexible AC Transmission System) at ENERCON

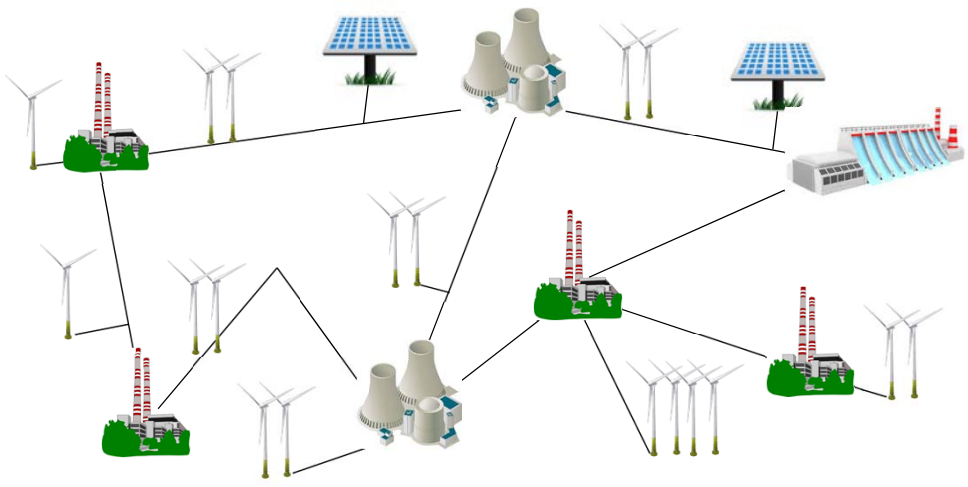


Securing compliance with future grid codes & market requirements

Drivers for System Services

ENERCON ENERGY FOR THE WORLD

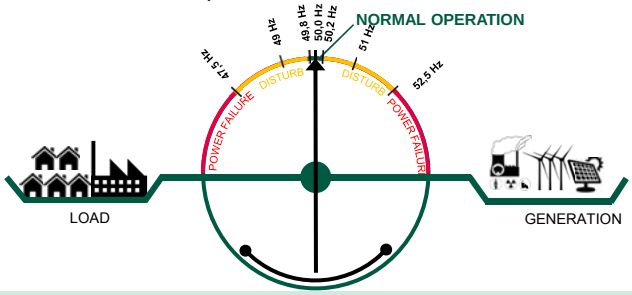
Paradigm Shift in Power System Operation



Drivers for System Services

Challenges With Performance Characteristics of Renewable Generation

- **Reduction in system inertia**
  - RoCoF
  - Frequency containment
- **Voltage management**
  - Reduced voltage support in case of short circuits
  - Voltage control induced dips
- **System strength**
  - Fault current for protections
  - Fault level for converter stable operation
- **Need for flexibility**
  - System balancing



How to keep the power system running?

Mandatory Grid Code Requirements

vs.

System Services Market

Physical System Needs

How to keep the power system running?

Grid Code Requirements Vs. System Services

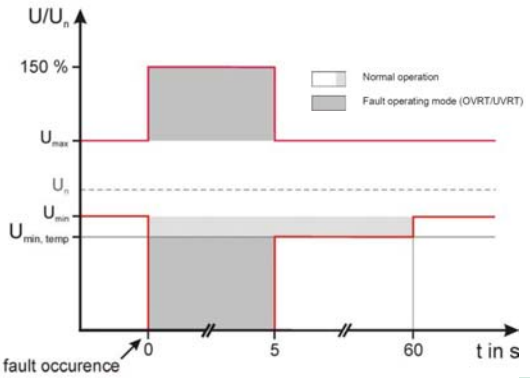
- Grid codes set out the minimum **system requirements** that a generator must be capable of when connecting to the transmission / distribution grid
- System services are **additional system supports** that the system needs to maintain security of supply

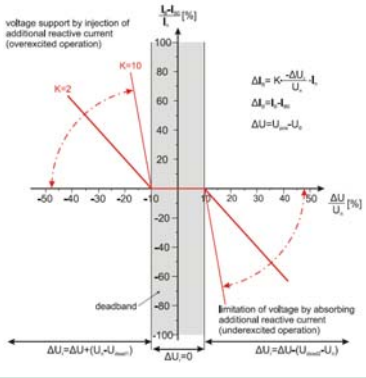
	System Requirement	Additional System Support
Frequency Control	Shutdown by protections or P-limitation @overfrequency	Control Reserve (FCR, mFRR, aFRR, RR ..)
Voltage Control	Provision of Q to compensate own injection	Provision of Q to optimize grid operations
Fault Ride Through	Remain connected during grid fault	Provide P and Q in required timeframe during grid fault
Power Quality	Injection with very low level of Harmonics	Filtering / Damping of existing harmonics in the grid
Voltage Asymmetry	Injection of a symmetrical current	Reduction of asymmetries by asymmetrical injection

Delivery of System Services by ENERCON (1/2)

Fault Ride Through

- All current ENERCON WEC types can ride through:
  - Symmetrical and asymmetrical faults
  - Under- and overvoltage events for up to 5 seconds per event
  - Optionally with reactive current injection during the fault

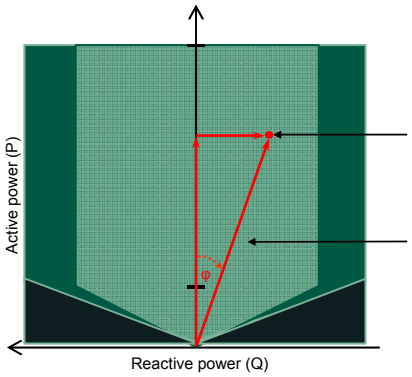




Delivery of System Services by ENERCON (2/2)

Reactive power capability

- Active power output depends on wind
- Reactive power output depends on inverter number and control type
- Basis for the Voltage control by the wind farms
- Optional STATCOM → reactive power output independent of the wind conditions



Operating point

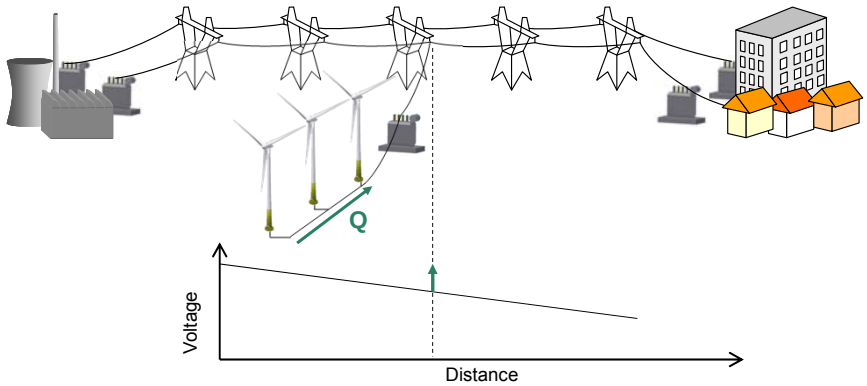
Apparent power "S": important for inverter, physical current limit of IGBTs

Standard
+
Q+ Option
+
STATCOM Option

Reactive Power and Voltage Controls

Power system voltage

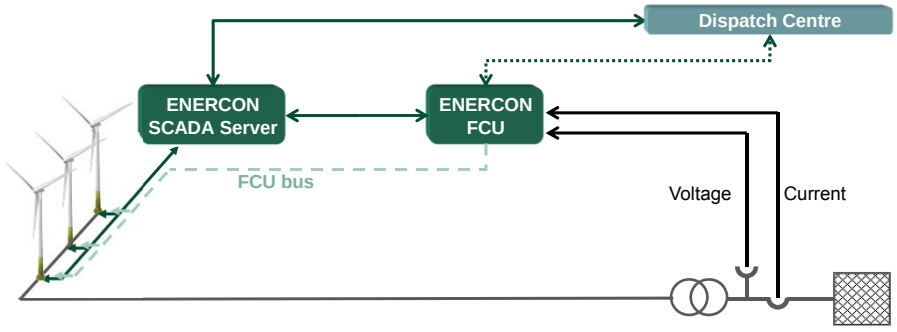
- Wind Farms can provide reactive power to contribute to grid voltage control
- Voltage decreases over length of power line



ENERCON Farm Control Unit (FCU)

Key characteristics

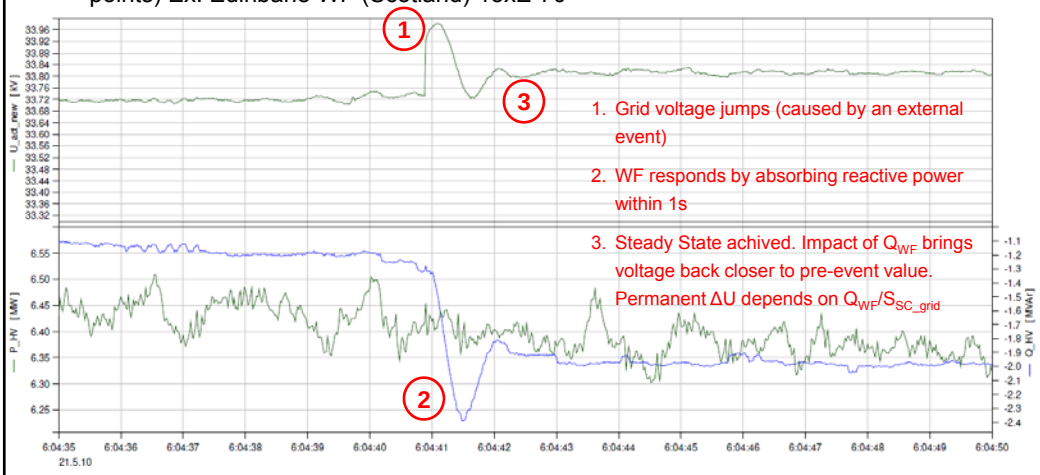
- Advanced, flexible controller for Wind Farms
- Can be very fast due to dedicated data bus for set points to WECs
- High dynamic performance with rise times as low as 1s
- Project specific simulations and on-site compliance testing (fine-tuning) required



Voltage Control example

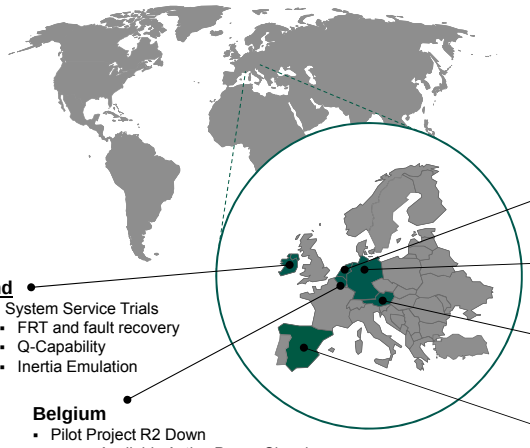
Voltage control by the WF (ENERCON Farm Control Unit)

- Fast voltage control by the WF → stabilize the grid (specially in weak connection points) Ex: Edinbane WF (Scotland) 13xE-70



Delivery of System Services by ENERCON

Active System Services Markets for ENERCON



Ireland
- DS3 System Service Trials
  - FRT and fault recovery
  - Q-Capability
  - Inertia Emulation

Belgium
- Pilot Project R2 Down
  - Available Active Power Signal

The Netherlands
- Frequency Containment Reserve (FCR) R1
  - Available Active Power Signal

Germany
- Frequency Containment Reserve (FCR) R2
  - Available Active Power Signal

Austria
- Frequency Containment Reserve (FCR) R3
  - Available Active Power Signal

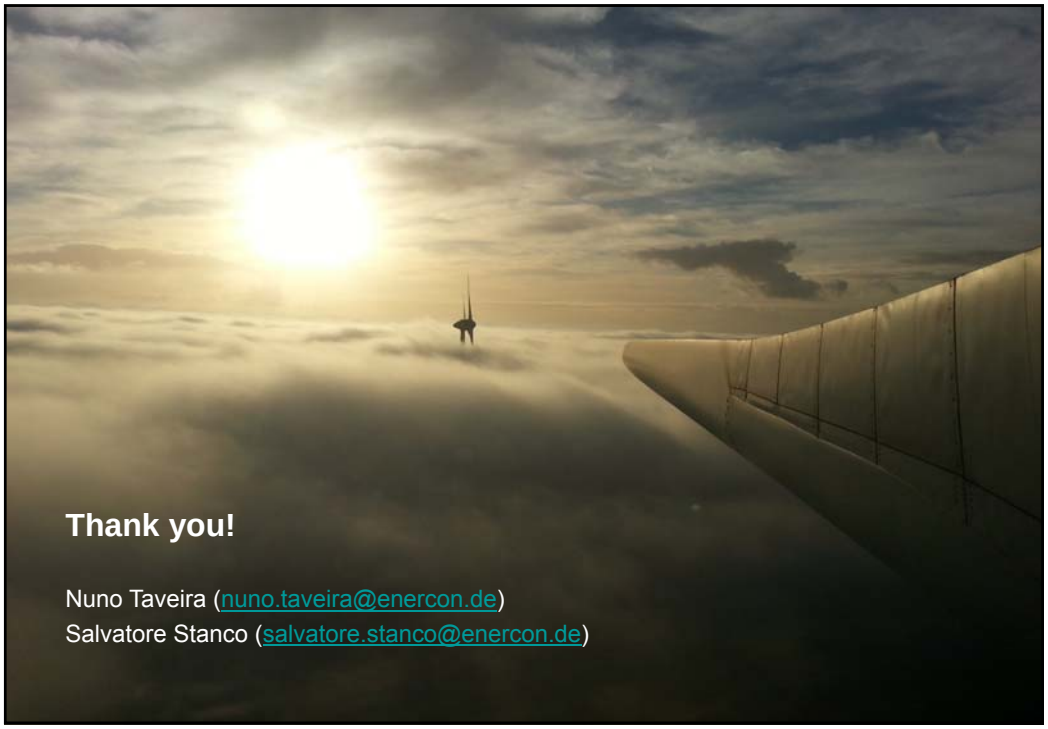
Spain
- "Servicios de Ajuste"
  - Mercado de operaciones (d+1)

DS3 System Services (Ireland)

SIR	Synchronous Inertial Response	**SRP**	Steady-state reactive power
FFR	Fast Frequency Response	**POR**	Primary Operating Reserve
DRR	Dynamic Reactive Response	**SOR**	Secondary Operating Reserve
RM1	Ramping Margin 1 Hour	**TOR1**	Tertiary Operating Reserve 1
RM3	Ramping Margin 3 Hour	**TOR2**	Tertiary Operating Reserve 2
RM8	Ramping Margin 8 Hour	**RRD**	Replacement Reserve (De-Synchronised)
FPFAPR	Fast Post-Fault Active Power Recovery	**RRS**	Replacement Reserve (Synchronised)

- **Four key products (marked in green):**
  - **FFR & POR:** Inertia Emulation (option)
  - **DRR**
  - **FPFAPR**

  (Fault Ride-Through (standard)) — **(DS3 Trial in Process)**
  - **SSRP**: Reactive power (standard & option) ✓
- **DS3 System Services Contracts**: competitive process with detailed technical submissions
- **ENERCON** acts as a **partner** to help customers win System Services contracts:
  - ***High-performing, reliable*** *technology; strong* ***in-house*** *know-how*


Thank you!
Nuno Taveira (nuno.taveira@enercon.de)
Salvatore Stanco (salvatore.stanco@enercon.de)