The TWENTIES project aims at: "demonstrating by early 2014 through real life, large scale demonstrations, the benefits and impacts of several critical technologies required to improve the pan-European transmission network, thus giving Europe a capability of responding to the increasing share of renewable in its energy mix by 2020 and beyond while keeping its present level of reliability performance."

To this extent it will be focused in removing several barriers which prevent:

• pan European electric system from welcoming more renewable generated electricity.
• renewable-generated electricity from contributing more efficiently to the single European electric market.
Project objectives

**Task force 1:** What are the valuable contributions that intermittent generation and flexible load can bring to system services?

**Task force 2:** What should the network operators implement to allow for off-shore wind development?

**Task force 3:** How to give more flexibility to the transmission grid?

**Overall:** How scalable and replicable are the results within the entire pan-European electricity system?

6 high level demonstration objectives

2 replication objectives

1 dissemination objective
Consortium and budget

- **10 European Member States**
- **1 Associated Country**

**Total budget: 56,8 M€**
**EU contribution: 31,8 M€**
Work Plan: Workpackages Structure and Interaction

Task Force 1: Contribution from intermittent generation and load system services
- Demo IBR
- WP3 R&D
- WP9 Demo
- Demo DONG
- WP4 R&D
- WP10 Demo

Task Force 2: Allow for offshore wind development
- Demo RTE
- WP5 R&D
- WP11 Demo
- Demo ENERGINET
- WP6 R&D
- WP12 Demo

Task Force 3: Give more flexibility to the transmission grid
- Demo ELIA
- WP7 R&D
- WP13 Demo
- Demo REE
- WP8 R&D
- WP14 Demo

WP15: Economic impacts of the demonstrations, barriers towards scaling up and solutions (Comillas-IIT)
- Demonstration analysis
- Demonstration analysis
- Demonstration analysis
- Demonstration analysis
- Demonstration analysis
- Demonstration analysis

WP16: EU-wide integrated assessment of the demonstration replication potential (RISOE)
- Synergies between solutions
  - EWIS upgrade
  - UPWIND upgrade
  - TRADEWIND upgrade
- Taskforce Replication plan

WP17: Offshore barriers (TENNET)
- Offshore deployment barriers
Replication work packages: barriers and up scaling

**WP 15: Economic impacts of the demonstrations, barriers towards scaling up and solutions (Leader: IIT)**

- Assess the local **economic and/or technological impact** of each demo.
- Identify the **barriers to scale-up** the outcomes at a member-state or regional level, and propose **solutions** to overcome these barriers.

**WP 16: EU wide integrating assessment of demonstration replication potential (Leader: RISOE)**

- Assess **portability** of voltage control, frequency control and VPP model to **other countries and regions**.
- Evaluate North European 2020 **offshore wind power variability**, **hydro potential and barriers** and **grid restriction** studies.
- Pan European economic impact study.

**WP 17: EU Offshore barriers (Leader: TENNET)**

- Address the issues of **smart licensing of submarine interconnectors** with and without wind parks in the North Sea and Baltic Sea.
- Identify **common licensing barriers** and propose regulatory measures.

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DEMO1: SYSERWIND DEMOSTRATION
Enhanced System Services From Wind

Roberto Veguillas, Iberdrola Renovables
SYSERWIND Demo Description

Main objective: On-site test of new wind farms active and reactive power control services to the system, based on new operation strategies at EMS level using improved systems, devices and tools, but keeping the current hardware at wind farm level.

Main tests:

1. **Active power regulation**: with the objective to perform secondary frequency control, several wind farms will be aggregated to provide secondary frequency regulation.

2. **Reactive power regulation**: with the objective to stabilize voltage in a region or zone of the TSO network, several wind farms will be aggregated to provide a voltage regulation.

Expected impact: Preserving the stability and security of the energy transmission system, a higher controllability of the wind energy would be achieved, and the current barriers that impede a further development of wind power connected to the grid would be lowered.

Partners:

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**SYSERWIND Demo Description**

- **Active Power Control**:  
  - The active power produced by 3 clusters will be **aggregated and curtailed**.
  - An active power **regulation band** will be created.
  - An AGC control will be checked, to **maintain, increase and decrease the power** at TSO’s request, according to the Spanish Secondary Frequency Control rules.

- **Reactive Power Control**:  
  - Cluster reactive power test, to check the accuracy of the **available reactive power**.
  - Cluster voltage control test, to check the accuracy of the **cluster voltage control**.
  - Wide-area voltage control (EMS level), the cluster capabilities will be included within the voltage control tool of the TSO in order to **control the voltage profile in a wide area of the grid** considering the three cluster’s capabilities together.
SYSERWIND Demo Description
SYSERWIND Demo Description
Demo Implementation Architecture

The project global architecture will be defined considering four control levels:

1. **Wide-area level control** (REE Control Centre, CECRE).
2. **Clusters level control** (IBR Control Centre, CORE).
3. **Wind farms cluster level control** (Communications and Control Unit, UCC).
4. **Wind farm level control** (Wind farms Control Systems, GAMESA SCADA).
Active Power Control – Test Procedure
Active Power Control – Test Procedure

- **Active Power**
- **P available**
- **P max**
- **Reg. Band**
- **P min**
- **Reg. Band**
- **P offered**
- **Offered Regulation Band**
- **P max Reg. Band**
- **P min Reg. Band**
- **Considered forecast deviation**

Diagram:
- **Active Power** graph showing set points each 4 seconds.
- **P requested**
- **P offered**
- **1 Hour**
- **Time**
Reactive Power Control – Cluster Test Procedure (Q)

Test of the reactive power compensation capabilities of the whole cluster at different production scenarios:

<table>
<thead>
<tr>
<th>Production</th>
<th>Voltage in cluster</th>
<th>Set point</th>
</tr>
</thead>
<tbody>
<tr>
<td>1)</td>
<td>Low</td>
<td>Mid-range</td>
</tr>
<tr>
<td>2)</td>
<td>Low</td>
<td>Mid-range</td>
</tr>
<tr>
<td>3)</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>4)</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>5)</td>
<td>Mid-range</td>
<td>Mid-range</td>
</tr>
<tr>
<td>6)</td>
<td>Mid-range</td>
<td>Mid-range</td>
</tr>
<tr>
<td>7)</td>
<td>Mid-range</td>
<td>Low</td>
</tr>
<tr>
<td>8)</td>
<td>Mid-range</td>
<td>High</td>
</tr>
<tr>
<td>9)</td>
<td>High</td>
<td>Mid-range</td>
</tr>
<tr>
<td>10)</td>
<td>High</td>
<td>Mid-range</td>
</tr>
<tr>
<td>11)</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>12)</td>
<td>High</td>
<td>High</td>
</tr>
</tbody>
</table>
Reactive Power Control
Cluster Test Procedure (V)

Voltage set points
Cluster Voltage

< 5 min
Reactive Power Control – Wide-Area Test Procedure

Test of the voltage profile control of a wide-area of the grid:

- Capacitive voltage profile
- Inductive voltage profile
Reactive Power Control
Wide-Area Test Procedure

- Capacitive voltage profile
- Base case voltage profile
- Inductive voltage profile
CONCLUSIONS

- **Active Power Test**: Through the new active power control services tested, a **lower system power reserve** due to wind energy penetration might be needed, and a **new approach to wind energy market integration** could be addressed.

- **Reactive Power Test**: Through the new reactive power control services tested, the wind energy could participate in the **grid voltage control** in a similar way as the conventional power plants, fully integrated in the EMS system of the TSO. Therefore, it will **lower the power losses and the voltage control complexity** for the TSO.

**THE NEW WIND ENERGY SYSTEM SERVICES COULD BE MORE SIMILAR TO THE CONVENTIONAL POWER PLANTS**
DEMO 2 DERINT

Main objective

- Improve wind integration based on intelligent energy management of central CHPs, offshore wind, and local generation and load units in the distribution grid

Approach

- Mobilization of the entire value chain across central and local units
- Focus is on shorter time scale with the goal to balance wind better i.e. for a longer time and more cost efficiently
- Market shaping, regulatory recommendations and scale up rules
- 3 year iterative roll-out, growing in scale and complexity

Portfolio optimization of market positions across energy and as markets

Integrating the VPP with central power control
Demonstration in Denmark – drivers for a VPP solution

Wind share of EU electricity demand by end of 2007
Demonstration in Denmark – drivers for a VPP solution

The Danish Electricity System – Development and Policy

Long-term vision: Fossil-fuel independence

Possible doubling of wind-power from 3 GW to 6 GW ~ 50% coverage!

Up to 2012: 1.300 MW of new wind-power capacity ~ +40%!

EU 20-20-20 target – 30% renewables
In 2020, the power system may have to handle 50% wind-power
Managing Wind Power in Denmark today – and tomorrow – System safety, market integration and portfolio synergies

"Water level" is maintained at 50 Hz
CHP Plant optimization for managing the power balance
A limit has been met and the markets are showing negative prices

- In December 2009, negative electricity prices were introduced
- December alone had 9 hours with negative prices

Price duration curve for 2009
- Price peak at 200 EUR/MWh
- 56 hours with zero or negative prices
Demonstration:
DONG Energy and the existing Danish market setup
Windfarms have extreme regulating capabilities and rapid response proven at Burbo Banks.
Integration of offshore wind into the central portfolio control – optimization across energy markets and ancillary services
Demonstration: Integrating the VPP with central power control

DONG Energy
Central Power Control

Central Power Plants & Wind Farms

Integration platform

VPP Generation and Consumption Units
Actual demonstration - The VPP intelligently controls several points of supply and/or consumption

Example:
Harteværket (hydro power plant) delivers primary regulation
VPP is a "Hub" for energy services and can provide benefits for the whole energy value chain

- In the geographies where DONG Energy is a full-value-chain energy company, a VPP can enable cross-value chain synergies
- In other markets, a VPP can provide market opportunities towards partners thus enabling access to new places in the value chain

**GENERAL ENERGY SUPPLY VALUE CHAIN**

- **Fuel procurement**
- **Wind farms**
- **Power generation**
- **Power Exchange trade**
- **Transmission, ancillary services**
- **Services**
- **Distribution**
- **Sales**

- **Cheaper ancillary services**
- **Supplement grid reinforcement**
- **Balance the intermittency**
- **Cheaper production of internal balancing and ancillary services**
- **New types of flexibility products**
- **New types of energy services companies can offer various kinds of flexibility to many types of customers**
- **Energy optimisation**
  - New income opportunities
  - Green profile
Demonstration and industrialisation of the Power Hub in the Twenties EU project together with TSOs

Starting from

- B2B business models
- Large local units (LUs)
- Short-term energy control
- Existing power market terms and ancillary services
- Denmark
- DONG Energy specific solution

Towards

- B2C business models
- Small-scale LUs
- LU owner needs
- Energy control along longer time spans
- Grid optimisation services
- Development of new power market terms and ancillary services
- EU and international solution
- General solution and possibly a standard product
DEMO3: Economic and technical feasibility of HVDC off-shore grids

Samuel Nguefeu - RTE
Aim of DEMO3 - R&D demo + development

- Propose a methodological approach to design an HVDC off-shore grid
- Identify the technical barriers to be overcome
- Propose a prototype for a DC breaking function with laboratory tests
- Elaborate a realistic road-map and time-schedule for future off-shore wind power connection to the mainland grid
Off-shore wind in Europe over next 20 years

**How much?**

- 2 GW in 2009 (PTPC)
- 40 GW in 2020 – 150 GW in 2030 (EWEA)
- Ambitious 2020 objectives:
  - UK > 33 GW – DE > 20 GW – FR > 6 GW

**Where?**

- North Sea, Baltic Sea, British Isles
- Atlantic shore?
- Mediterranean shore?

**How?**
From PTPC to a HVDC grid, via MTDC
Economic and technical detailed feasibility analysis
Off-shore DC connection today

« Easy » to build – local / bilateral initiative

« Easy » fault localisation

- No need for a DC breaker, ..... 

“Only” dedicated to wind energy

- No additional interconnection capacity for the electricity market

No smoothing of wind intermittency

High N-1 impact, ..... 

- Limited flexibility and security (both for the producer and the TSO)

- How many GW can safely be interconnected to the European power system with PTPC ???
Advanced functions that might be provided by an off-shore grid

*Investigated in Demo3 – Probabilistic economic approach*

1. **Mitigate wind intermittency for “more constant” injectors to the AC grid**
   - same reserve for a wide range of wind conditions
   - better control of operational over-costs for high levels of wind penetration

2. **Offer additional interconnection capacities to the electricity market**
   - efficient use of the HVDC grid under “low wind” or “no wind” conditions
   - avoid or postpone the development of mainland interconnections

3. **Offer interconnection capacity for future marine energy (?)**

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Operational functions that might be provided by an off-shore grid

Investigated in Demo3 – “Multi-leg VPP functions”

4 - Contribute to congestion and losses management on the AC grid

- elaborate coordinated control on the injectors to the mainland grid, depending on wind conditions and AC grid operational state
- minimize operational losses

5 - Provide ancillary services to the mainland power system

- frequency regulation, voltage control
- PSS compensation for substituted conventional generation
- autonomous black start capability

6 – Partial operation of the VPP in emergency conditions

- storm, short-circuit, wind turbine tripping, ....

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Protection of an off-shore grid

1 - Detection, localisation and fault clearing process

- protect the devices
- protect the stability of the whole DC / AC power system
- isolate only the faulty section
- within appropriate delay
- breaking function for DC grids
- no DC grids if no appropriate DC breakers

2 – Design a complete protection plan
Progress of work 1 - Towards a target off-shore grid

Are we able to design scenarios for a target off-shore network [2030-2050] at the European level?

- from local or bilateral projects to a regional / European view
- taking into account:
  - wind time series characteristics on wide marine areas over Europe
  - on shore wind developments and on-shore wind characteristics
  - storage capacities (Scandinavia, Alps)
  - conventional generation development
  - potential other renewable energy sources
  - load evolution
- costs and benefits assessment – RTI estimation
- optimal zonal topology (-ies) for the off-shore grid

Probabilistic economic approach with the tool ANTARES (RTE)

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Progress of work 2 – Technical analysis of basic topologies

- DC node?
- Breaking functions?
- Robust control laws
- Inter operability for different technologies
- LCC / VSC (Light, Plus)
- Evolution capabilities

MATLAB/SIMULINK/SPS
EMPT-RV

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WP11 Technical specifications towards offshore HVDC networks – DC GRID

- Demo 3 focus: DC network key technologies – Protection and fault management
- WP11 DC:
  - Fault-event characterisation
  - Development of a DC breaker prototype
### DC-breaker functions

<table>
<thead>
<tr>
<th>Breaker state</th>
<th>Without power</th>
<th>With power</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal condition</td>
<td>DC fault condition</td>
</tr>
<tr>
<td>Open state</td>
<td>• Voltage withstand</td>
<td></td>
</tr>
<tr>
<td>Closing</td>
<td>• Let-through current</td>
<td>• Let-through current</td>
</tr>
<tr>
<td></td>
<td>• Load switching</td>
<td>• Let-through current</td>
</tr>
<tr>
<td></td>
<td>• Fault switching</td>
<td>• Close on fault</td>
</tr>
<tr>
<td>Closed state</td>
<td>• Low resistance, voltage withstand to ground</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Let-through current (short time &amp; peak current withstand)</td>
<td></td>
</tr>
<tr>
<td>Opening</td>
<td>On idle line or cable: no current, no TRV → no problem</td>
<td>• Load switching</td>
</tr>
<tr>
<td></td>
<td>• Terminal fault</td>
<td>• Short line fault</td>
</tr>
<tr>
<td></td>
<td>• Long line, cable fault</td>
<td>• Long line, cable fault</td>
</tr>
<tr>
<td></td>
<td>Highest rate of rise of current, highest prospective fault current</td>
<td></td>
</tr>
</tbody>
</table>
Performance indicators and targets of DEMO#3

1. Voltage withstand in open state
   - Target: lightning impulse withstand voltage peak > 650kV
2. Over-current conduction in closed state
   - Target: 3000A_{dc} during 1 minute
3. Prevent harm on power transformers by reducing peak current
   - Target: \( \left( \frac{\text{Peak fault current without action}}{\text{Peak fault current with DEMO#3}} \right)^2 > 1.2 \)
4. Current interruption duration
   - Target: less than 40ms (common value of AC circuit-breakers)

Targets to be surpassed