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European Wind Integration Study (EWIS) – Reference Study towards a successful integration of wind power into European Electricity Grids

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SUMMARY

The support of renewable energy sources (RES) is one of the key issues in European energy policy. The development of wind energy is crucially important to meeting Europe's' renewable energy targets. Given the variable nature and distributed location of this generation, the services provided by the interconnected European transmission networks are essential to harnessing this energy source efficiently, economically and in a secure way on a European level. So far no reference study at a pan-European level exists as a complement of several investigations performed in different sectors and/or at national level [3, 7, 9, 12, 13, 14]. In order to cope up with this challenge European Transmission System Operators launched a European wide grid study on the integration of wind power (EWIS) [2, 6]. The EWIS project, coordinated by European TSOs covers all four synchronous areas [11, 12, 9] such as UCTE, UKTSOA, ATSOI and NORDEL, fills this gap as unique project gathering both technical and market as well as legal aspects in these four synchronous electricity systems in Europe, focusing on measures needed to be taken by legislators, regulators, grid operators and grid users. A Consortium of 15 Transmission System Operators (TSO) from 14 countries, (with ELIA TSO acting as a coordinator) representing the synchronous electricity systems in Europe, will provide a specific support. External stakeholders are invited to join a Consultation Board based on the needs of the study and the respective commitments about an active participation (e.g. European Commission, EURELECTRIC, EWEA etc.). Attention will be in a later phase of the study focused on the system interaction of various wind turbine types, the effect of their variable power output on the system and their ability to provide system services to enable the stable operation of the electricity grid. The final objective is to obtain the necessary information for technical and operational measures for risk mitigation and secure operation of the European electricity grid identified by the steady state and dynamic investigations on electricity grid models which are established within the study. For this, market and regulatory aspects will be taken in to consideration as well. The study will examine potential reinforcements of transmission network pinch points, improved operating procedures linkages with markets arrangements and technical and connection requirements for wind generators [15].

KEYWORDS

Congestion Management, European Exchange Scenarios, European Reference Study, European Transmission Grid, EWIS, Grid Enforcement, System Security, TSO Study, Wind Integration, Wind Power.

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Scope of Work

The scope of EWIS work covers all relevant technical, operational and market aspects related to an integration of large scaled wind power over Europe. For each of these aspects EWIS project is subdivided into work packages such as present situation and market aspects, scenarios and exchange schedules, power system analysis, operational aspects [4], cost calculation and communication. The objective for the present situation (2008) is to bring solutions to the actual problems of load flows due to wind power, identified in the European grid [10]. For longer term (2015), the goal is to bring common pan-European recommendations and grid enforcement measures in order to avoid that the actual problems repeat in other European areas wherever wind power is introduced at a larger scale.

Present situation: First results for the time horizon 2008

A five-fold increase in European wind power capacities is expected from about 34 000 MW in 2004 to 180 000 MW in 2020. For 2006 around two thirds of the wind power capacities worldwide are located on the Europe. Detailed analysis shows, that most European countries have plans to increase the installed wind power to nearly 67 000 MW in 2008. Germany, Spain, Denmark, Portugal, France, Sweden, Ireland, the Netherlands, Italy, United Kingdom will be the countries with the most installed wind power. Most of the wind farms will be onshore, with some offshore plans in Germany (1.830 MW), Belgium (180 MW), United Kingdom (455 MW), Denmark (326 MW), the Netherlands (220 MW) and France (105 MW).

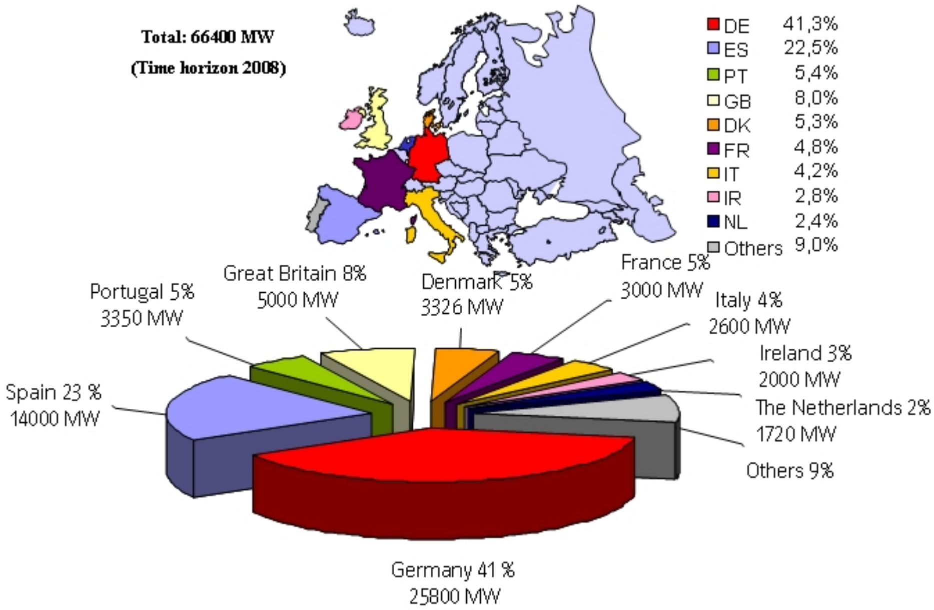

Figure 1: Concentration of Installed Wind Power in Europe: Time horizon 2008

Figure 1 shows the collected data for the installed wind power in Europe available by the European TSOs, which are the basis for the investigations for present situation 2008. The highest amount of wind power is concentrated in Germany, where ca. 40% of the total installed capacity in Europe is expected in 2008. This is followed by Spain and Great Britain, whereby these three countries will represent more than 70% of the total installed European capacity. Furthermore, Italy, France and Greece are expected to see strong increases in installed wind power capacity. With such a high growth rate, there are currently serious doubts about the ability of the manufactures to correspondingly increase their production.

<u>Scenarios</u>

The study comprises two wind situations with major impact on the operation and security of the European transmission network:

Wind Situation UCTE North: Maximum wind power production of northern UCTE countries (Austria, Belgium, Czech Republic, Denmark, North-France, Germany, Hungary, The Netherlands, and Poland)
Wind Situation UCTE South: Maximum wind power production in southern UCTE countries (South-France, Greece, Italy, Portugal and Spain).

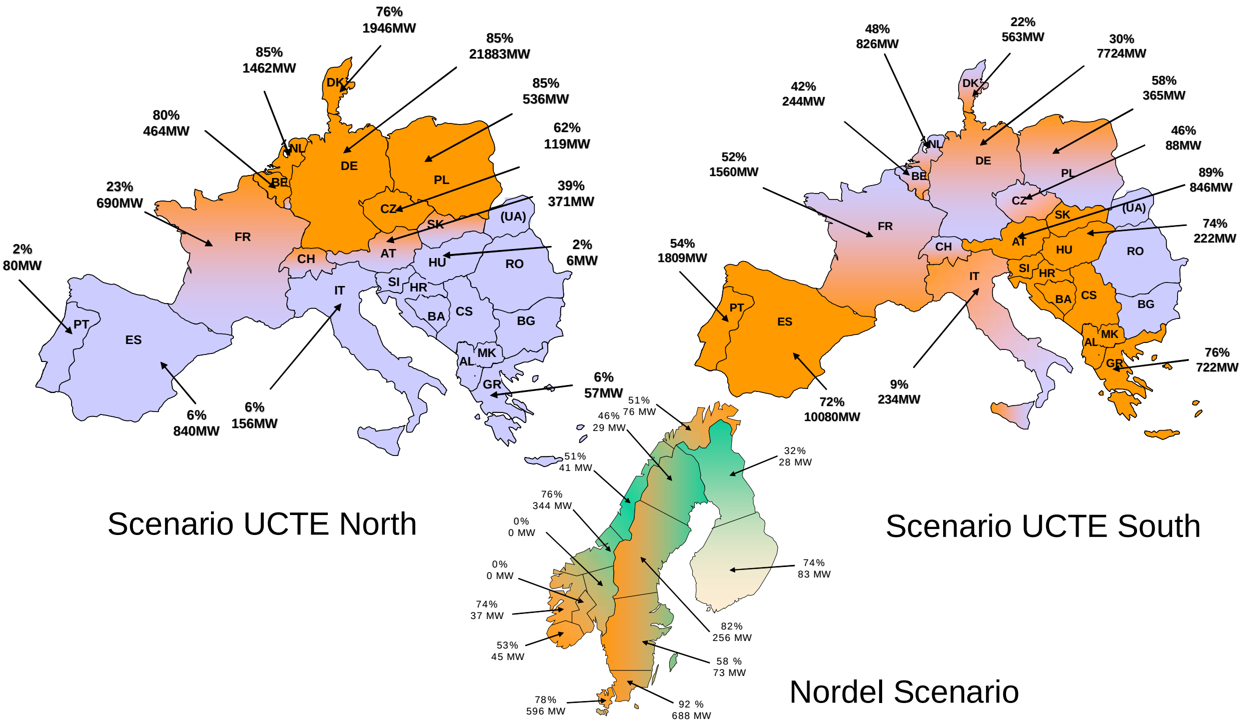

Figure 2: Scenarios

Using existing time-series of the wind power production, a point in time with the highest simultaneous wind power production in the northern UCTE countries was identified for UCTE Scenario North. For UCTE Scenario South the highest simultaneous wind power production in southern UCTE countries was identified as well. The resulting wind situations (see Figure 2) give realistic cases of strong wind power production in the north of the UCTE area as well as in the south of the UCTE area. The overall wind power production in wind situation UCTE North is 28 600 MW and in wind situation UCTE South 25 300 MW, compared to an installed capacity in 2008 of 56 500 MW in the UCTE area.

For regional investigations in each synchronous area, a comparison between a Base Case Scenario for the time horizon of 2008 (normal wind situation) to the high wind UCTE Scenarios North and South described above is necessary. For the UCTE system, the Base Case Scenario used is a snap shot of the grid, representing a low wind power production and high load situation in Europe.

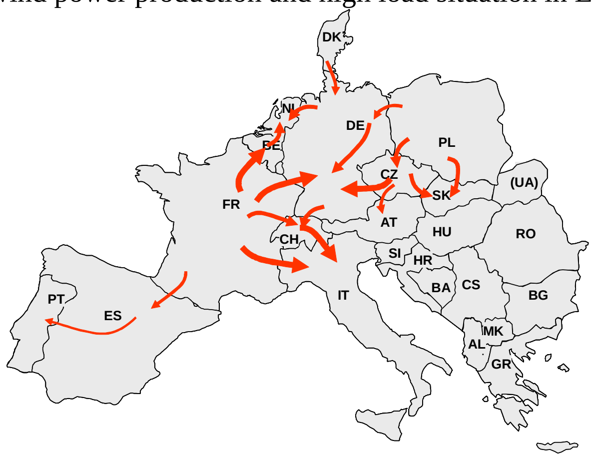

Figure 3: Main corridors of electrical power transmission in the Base Case Scenario

In case of low wind power production the main corridors of power transport are from

- France to Germany, Belgium, Italy and Spain
- France via Germany and Switzerland to Italy
- Poland to Germany, Czech Republic and Slovakia
- Czech Republic to Germany, Slovakia and Austria

Analysis of UCTE Scenario North

Wind UCTE Scenario North addresses situations where wind power generation especially in the northern part of Europe is high. High wind power generation in Northern Europe can have significant repercussions on the European electricity system as a whole. It is significant that generally the countries with the highest wind power production and their neighbours are strongest affected by the changes in conventional generation, e.g. Belgium, Czech Republic, Denmark, France, Germany, The Netherlands and Poland. The reduction in power generation compared to the Base Case generally affects oil, gas and hard coal power plants. In case of UCTE Scenario North with high wind power production in northern Europe, where the most of the wind power capacity is installed, large deviations between scheduled exchanges and physical power flow are detected (see Figure 4).

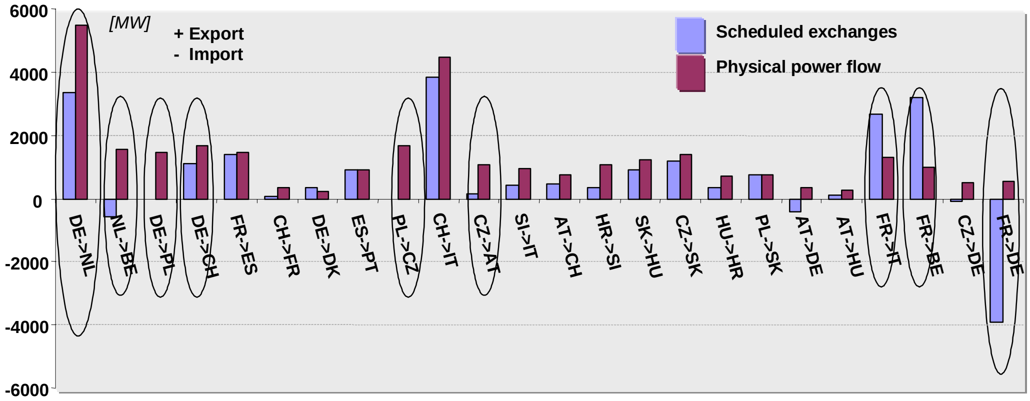

Figure 4: Physical power flows and scheduled exchanges of UCTE Scenario North

Large deviations of physical power flows from the exchange schedules occur especially on the axis Germany-The Netherlands-Belgium-France on the one hand and Germany-Poland-Czech Republic-Austria on the other hand. Although there is a large scheduled import from Germany to France in UCTE Scenario North, the physical flow is from France to Germany.

Analysis of UCTE Scenario South

In case of UCTE Scenario South with high wind power production in southern Europe, where the most of the wind power capacity is installed in Spain, Portugal, France, Italy and Greece, smaller deviations between scheduled exchanges and physical power flow compared with UCTE Scenario North are detected (see Figure 5).

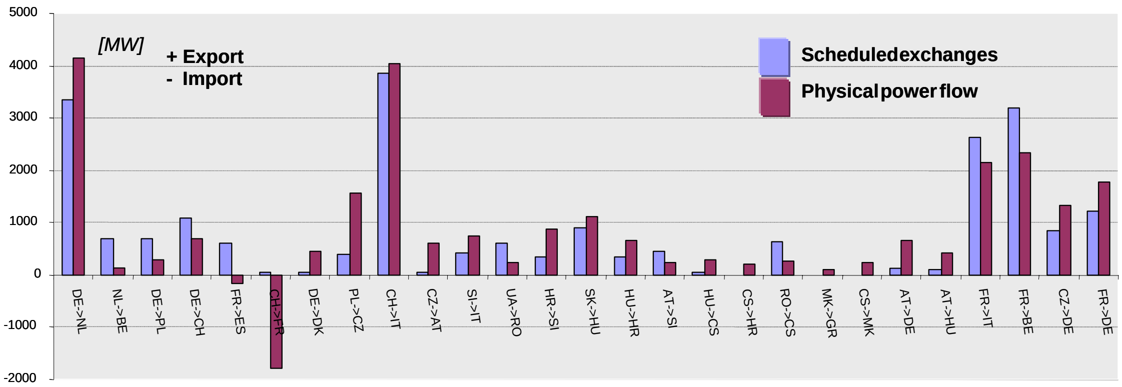

Figure 5: Physical power flows and scheduled exchanges of UCTE Scenario South

The main difference in import/export levels between the Base Case and UCTE Scenario South is the change from import to larger export of Spain to France due to high wind power production. This import could result in a decreasing damping of inter area-oscillations due to less Power System Stabilisers (PSS) activated in Spain. The stability analysis to this issue will be investigated in the next phase of the project.

Resulting Power Flow Pattern

In case of UCTE Scenario North the main corridors of electrical power transport are going from the regions with high surplus of power production to the regions with surplus of power demand (see Figure 6). The surplus of power production in northern Germany due to the high wind power production is transmitted to southern Germany, further to Switzerland and Austria and further to Italy reducing the exchange from France to Italy via Germany and Switzerland to the Netherlands and Belgium to Poland and Czech Republic back to South of Germany and to Slovakia and Austria via Denmark to NORDEL. The surplus of power production in France is transmitted to Belgium, Germany and Spain and further to Portugal and North Africa, where less power is produced at the same time.

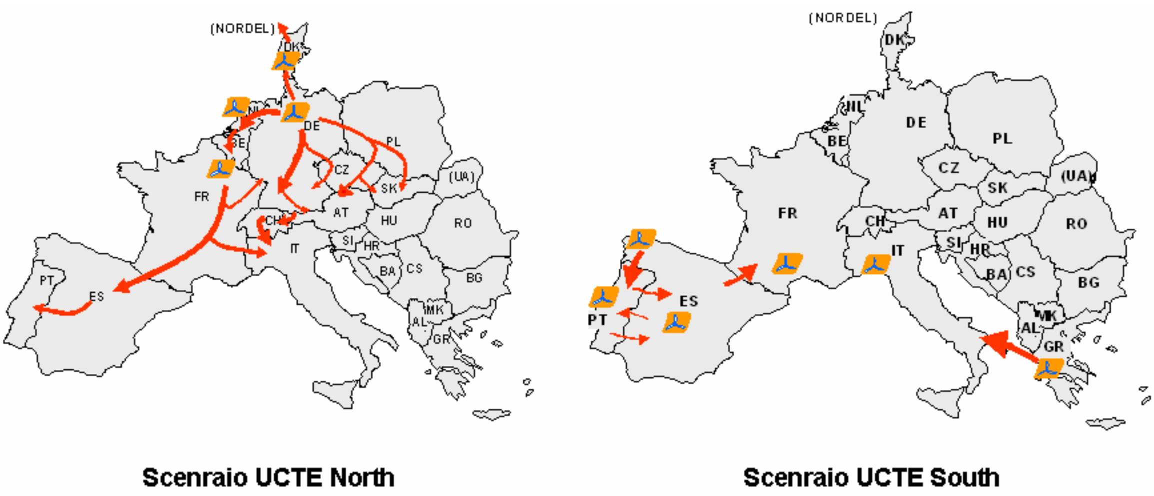

Figure 6: changes in the power flow pattern

The growth of wind power generation has significant effects on the European electricity system as a whole. As stated in the previous sections, investigation shows that a concentrated and high wind power in-feed in northern Germany producing a high surplus of power production results in temporary large load flows inside Germany and through the neighbouring transmission systems in Benelux and Central Eastern Europe [16]. These flows will affect system stability and available trading capacities increasingly. In case of UCTE Scenario South, the surplus of power production in the Iberian Peninsula is transmitted to northern Europe via France and Switzerland. Furthermore, as a result of high concentration of wind power in the Spanish Galicia region, loop flows from Spain to North-Portugal and back to Spain are increased.

N-1 grid security

According to the reliability, operational and planning standards used by TSOs, highest importance is attached to the calculation of N-1 grid security based upon the electrical and physical realities of the transmission network and the electrical power system in general. This means, any probable single event leading to a loss of a power system element should not endanger the security of interconnected operation. The remaining network elements, which are still in operation, should be able to accommodate the additional load or change of generation, voltage deviation or transient stability regime caused by the initial failure or outage.

The loss of any power system element (generating unit, compensating installation, selected bus bars or any transmission circuit or transformer) must also not jeopardise the security of operation of interconnected networks as a result of limits of current, voltage magnitude, stability, etc. being reached or exceeded and accordingly cannot cause cascade tripping of installations with interruptions of supply. For UCTE Scenario North bottlenecks on internal and cross-border lines in northern Europe are detected. The overload during N-1 conditions varies from 100% to 180% (see Figure 7).

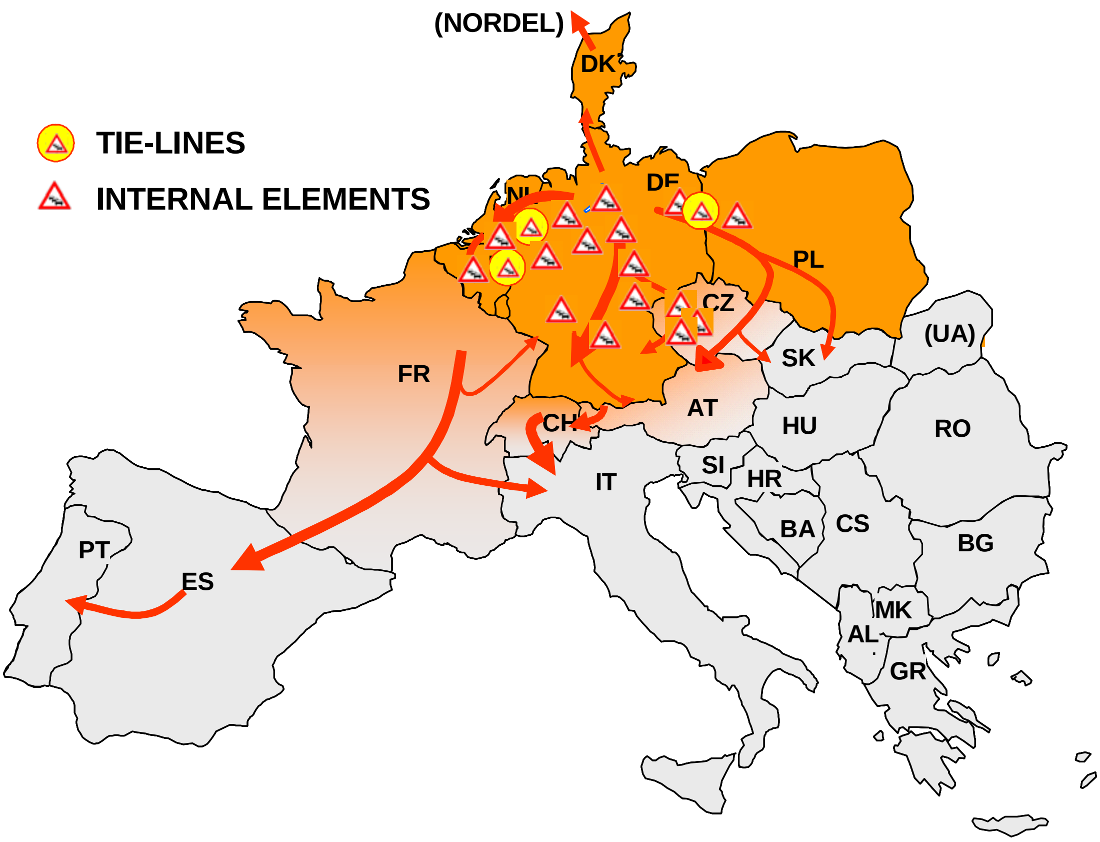

Figure 7: Detected bottlenecks during N-1 conditions of UCTE Scenario North

Cross-border bottlenecks

Without the use of phase-shifters, overloads of tie-lines are observed between Germany and The Netherlands, and between Germany and Poland. By adjusting the settings of the phase-shifters in The Netherlands, Germany and Belgium to limit cross-border flows, the overloads of the tie-lines between the Netherlands and Germany can be reduced in 2008. Overloads near the Dutch-Belgian border can also be reduced with the use of phase-shifters in Belgium. The precise impact of these phase-shifters as well as their influence on neighbouring grids will be further analysed in later part of the study. The bottleneck between Germany and Poland is subject of bilateral investigations. Nevertheless, considering the already planned network enlargement inside Germany (new 380 kV double overhead line between Neuenhagen and Bertikow) in UCTE Scenario North, overloads of the interconnection between Poland and Germany will not occur any more. Until the realisation of this line, which is planned for 2009, a set of temporary operational measures will be taken in order to ensure operational security.

Internal bottlenecks

High wind power generation combined with high power production of conventional power plants with comparatively low marginal costs in the North of Germany and additional large import from NORDEL results in large north-south power flow in Germany. This causes several internal overloads during N-1 conditions. Internal overloads are also observed in Czech Republic, Poland, Belgium and The Netherlands for N-1 conditions in UCTE Scenario North. Investigated measures to eliminate these overloads are described in the detailed analysis.

Outlook

TSOs call upon the European Commission and national authorities to undertake urgent action to accelerate transmission line authorization procedures in the third energy package and to harmonize renewable energy promotion schemes EU-wide [5, 8]. The final results are expected by October 2009 and will comprise not only the necessary requirements for the further increase of wind capacities in national/regional generation mix in terms of system reliability, but also measures to counteract identified limitations, assessment of the costs and expected TSO investments of such measures, and consequences of existing, medium and long term issues related to the integration of wind power [1]. Furthermore, the final results will cover stability assessments and impacts, and give recommendations of harmonised grid code requirements for wind turbines to ensure a successful integration of wind power into European electricity grids while maintaining system security and stability for the time horizon 2015.

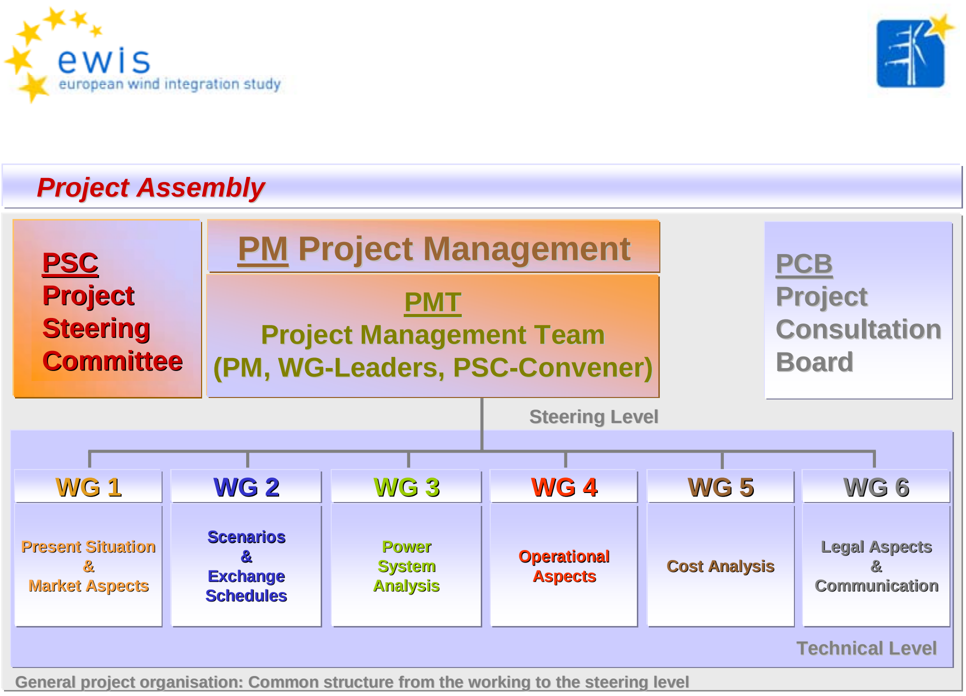

Figure 13: Project Structure

Market simulations will be performed in order to assess the wind power production, production from conventional power plants and the exchange schedules at the point in time of the scenarios for the year 2015. These scenarios will be set up depending on high wind power situation all over Europe and the most likely development (optimistic national wind power developments) over 2015. Based on the models derived from scenarios steady state analysis and transient stability analysis will be performed for all European synchronous areas. Focus of the investigations will be over determination of the transmission system development necessary for covering (N-1)-secure transmission and dynamic investigations concerning adherence to reliable limit values in the case of individual system faults. The study will identify and analyse the operational aspects related to a large scale integration of wind power over Europe for the existing, medium and long term time horizon. The analysis will contain the evaluated risk for operations. Based on the analysis results possible alternative solutions (technical/operational/market concepts) for the detected bottleneck situations will be formulated. The transparent identification and quantification of all relevant costs associated with the integration of wind energy encompassing transmission grids will be obtained by market simulation. The outcome will be an economic analysis highlighting direct and indirect costs seen from a TSO prospective. The final results will be available in 2009.

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