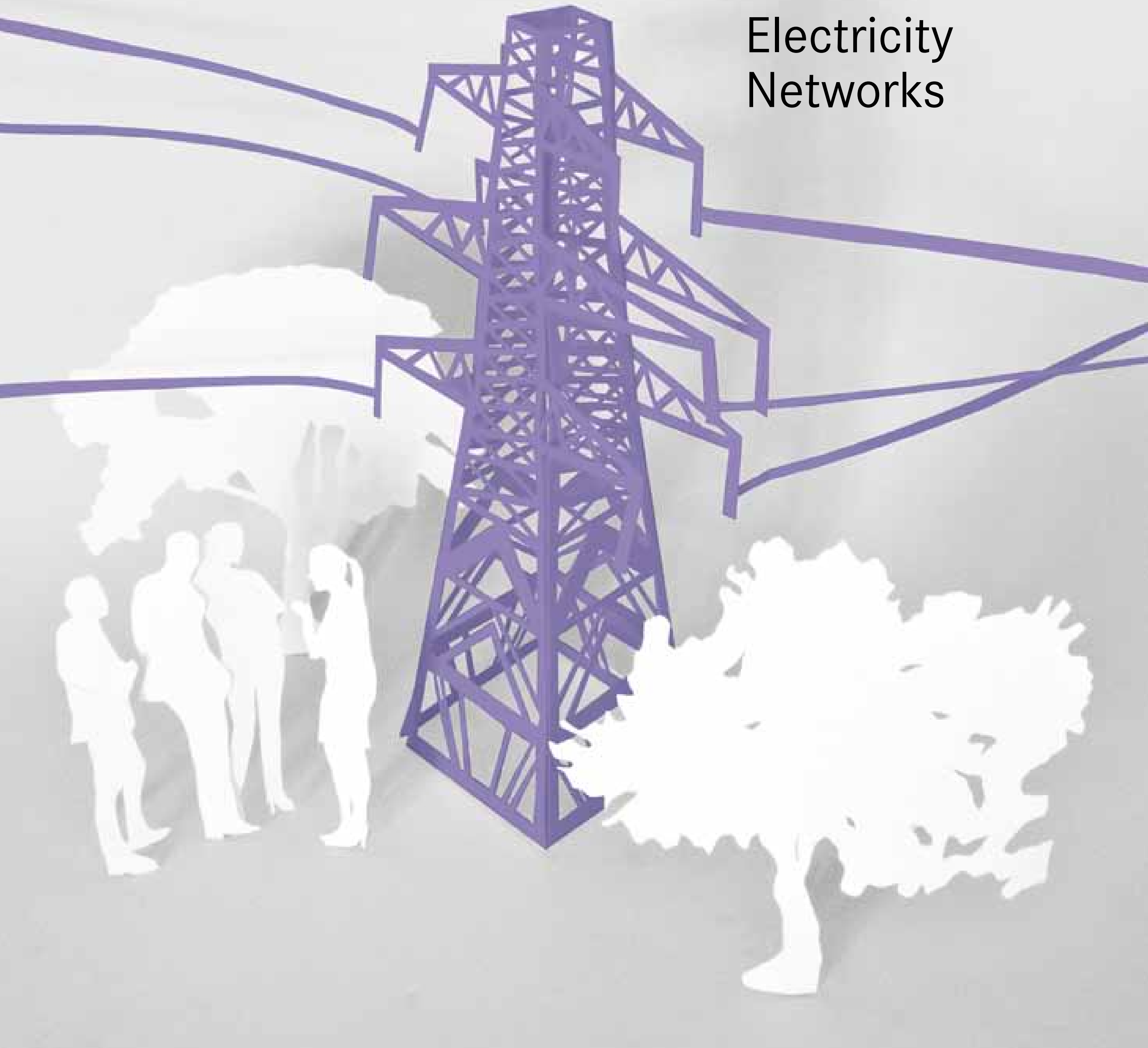
CA-RES

WORKING GROUP 6

Electricity Networks



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CA-RES CONCERTED ACTION RENEWABLE ENERGY SOURCES DIRECTIVE

In a Nutshell

Electricity Networks (WG 6) focuses on the effective and transparent integration of renewable energy sources (RES) in European electricity networks. WG 6 is a forum for participants in CA-RES to share knowledge and exchange experiences about grid integration of renewables as well as to forge opportunities for closer cooperation and coordination across national and international borders.

Cooperation and sharing of best practice between CA-RES participants in implementing the RES Directive should result in a technically and economically more efficient integration of RES into European electricity networks and ultimately deliver reliable electricity supplies with lower greenhouse gas emissions and lower network costs to consumers than would otherwise be the case.

WG 6 identified a number of barriers to the efficient integration of RES in electricity networks. These were sorted into 5 categories:
1. Technical barriers
2. Social barriers
3. Economic barriers
4. Administrative barriers
5. Regulatory barriers

Technical barriers were considered the most relevant for the participants of WG 6. Almost all participants reported that their grids are congested, which limits the capacity of electricity networks to absorb additional energy from new generation sources. The location of some RES power plants is also considered a barrier as they are often situated in sparsely populated areas with limited grid infrastructure. The participants in WG 6 indicated that in some cases grid reinforcement would be sufficient, but in many instances new transmission lines would have to be built to integrate power generation from RES plants in the future.

The variability of generation from some RES such as wind and solar also poses a technical challenge for network operation. CA-RES participants believe that interconnectors will play a crucial role in ensuring the efficient integration of variable RES in electricity networks. Greater interconnection increases the value of electricity from RES as well as reducing the costs of integrating generation from variable RES. Increasing interconnection between power systems requires collaboration and coordination between stakeholders. WG 6 is playing a role in developing common solutions and providing a forum for improved coordination between stakeholders.

Social barriers are an important issue for integrating RES as generally there is resistance to building new transmission lines from local communities. Economic issues such as sharing of costs of grid expansion between stakeholders was also identified as were administrative barriers in receiving permission for grid expansion and regulatory barriers associated with market coupling across interconnectors. These issues were also considered by WG 6.

2

Integrating RES in power systems

Power systems are dynamic, integrated systems subject to continuously changing conditions, some of which can be anticipated and some of which cannot. The primary function of power systems is to serve a continuously varying demand.

The reliability of a power system is determined by its ability to respond to and accommodate expected and unexpected changes and disturbances whilst maintaining continuity of supply to end-users.

Each generating unit influences the overall system and all generating technologies incur costs for power system integration. These costs can be divided into the following elements:

- Infrastructure costs - additional costs for expanding and developing electricity system infrastructure in order to feed electricity production into the system.
- Balancing - cost of rectifying deviations from planned production levels and additional cost of investments in reserve capacity for handling outages of power plants or transmission facilities.
- Capacity payments - the cost associated with incentivizing generation units to produce power when the electricity system most needs it.

The size of the cost or benefit of integrating a technology into the surrounding system depends to a large extent on the design of the system.

- Share of intermittent power in the electricity system - system costs increase as the share of intermittent production in the system increases. This is especially the case with regards to capacity costs and infrastructure costs.
- Characteristics of the electricity system - generally system costs depend on whether alternative flexible resources are accessible or if they have to be added, either directly or through new interconnections with other regions. The costs in small isolated systems tend to be higher than in large or highly interconnected systems.
- Operational procedures and market design - large shares of intermittent power changes the dynamic of power systems. If operating procedures and market design do not reflect this then system costs may be higher than necessary.



2.1 Intermittent generation from RES technologies

The integration of new generation into power systems is a challenge due to different production patterns and technical specifications. The intermittency of some RES technologies poses a challenge as forecasting inaccuracies and the variability of production results in a greater need for balancing reserves.

3 important issues to be addressed when integrating large amounts of intermittent RES into power systems are:

i. Generation from intermittent RES technologies is often difficult to predict accurately. This increases the need for regulating power and poses challenges for system operation.
ii. Electricity from intermittent RES displaces production from other technologies, but when there is no wind or solar generation there is a need for alternative production.
iii. Intermittent production increases the need for flexibility and a more dynamic power system.

2.2 Solutions for addressing the integration of RES

WG 6 participants discussed several important elements for integrating RES into power systems.

2.2.1 Interconnectors

Good interconnection with neighbouring power systems is an efficient tool for integrating RES. The relative intermittency of RES decreases with the size of the balancing area. It is, therefore, easier and cheaper to provide auxiliary services and balancing across larger market areas. Interconnectors increase the value of electricity produced from RES through interaction with different generation technologies, which often results in RES displacing more expensive generation, typically reducing the consumption of fossil fuels and lowering the balancing costs further than would otherwise be the case in isolated systems.

Construction of new interconnectors is costly and can take many years due to public opposition to the visual and environmental impact of overhead lines. WG 6 participants highlighted the importance of providing clear information on the benefits of interconnectors, especially for RES deployment. A high degree of transparency and streamlined permitting procedures are considered important for reducing lead times for interconnector projects.

2.2.2 Smart grids

The introduction of smart grids can provide enhanced utilisation of existing grid infrastructure and allow for greater integration[1] of RES and improved security of supply. Smart grid technologies can also activate flexible demand. This can reduce the need for regulating power capacity as demand can be increased or decreased in accordance with changes in intermittent power production. This can either be at the level of households, large industrial consumers or in district heating.

2.2.3 Balancing markets

Balancing refers to maintaining system stability in real time operation. This includes maintaining frequency and matching demand and production during system operation. In order to do this, it is necessary to maintain a certain amount of generating capacity as reserves in case of disturbances, forecasting errors and unplanned outages. The introduction of RES technologies can change the level of reserves required and thus incur new costs on the system, which should be supported by RES producers. The creation of cross-border balancing markets and increasing incentives for RES to participate in balancing markets are important steps according to WG 6 participants for addressing balancing issues.

2.2.4 Other technologies and operational tools.

The integration of RES in the system requires the development of new operational tools such as improved portfolio performance (increased dynamic performance of traditional generators), demand side management, pumped storage, along with specific control technologies and algorithms that provides a proper observability and control of RES generation. The deployment of these technological improvements should go hand in hand with a proper regulatory framework that fosters them.

[1] The European Smart Grid Task Force defines Smart Grids as electricity networks that can efficiently integrate the behaviour and actions of all users connected to it - generators, consumers and those that do both - in order to ensure an economically efficient, sustainable power system with low losses and high quality and security of supply and safety.
http://ec.europa.eu/energy/gas_electricity/smartgrids/doc/expert_group1.pdf

3 Experiences and best practice

WG 6 examined a series of issues that could address the barriers identified for the efficient integration of RES into electricity networks.

The focus of WG 6 was the technical barriers to RES integration, but some regulatory, economic and social barriers were also touched on as many issues have cross-cutting elements to them.

3.1 Member States' Experiences

3.1.1 Interconnectors

Most WG 6 participants (about 22 countries) have interconnector projects under construction or in the approval process. The major driving forces for building interconnectors amongst WG 6 participants is market integration, increased security of supply and alleviation of congestion. WG 6 participants did not identify the integration of RES as a major driving force for building interconnectors, but rather identified RES as a major beneficiary of increased market integration achieved through interconnectors which typically increase the value of electricity produced from RES.

The most common barrier to realising interconnector projects for WG 6 participants is obtaining the necessary permits from authorities owing to environmental and social objections to the building of power lines. Regulatory differences were also cited by WG 6 participants as a challenge for building interconnectors between different markets.

Cost allocation of investments across international borders is also seen as a potential problem as investments in one country may give increased utility in another. This could justify a cost sharing approach in the future. Some WG 6 participants noted that financing interconnectors could be a problem and raised concerns about the idea of private investments in interconnectors and transmission and the repercussions this might have for market allocation of capacity and the role of TSOs in the future.

The vast majority of WG 6 participants highlighted that investments in interconnectors should be based on social welfare benefits rather than congestion rents. Congestion rents arise due to price differences between two areas occurring due to limitations on the amount of electricity that can be transported between these areas. The owner of the transmission line connecting the two price areas accrues the difference in price between the low price area and the high price area. This income is called congestion rent.

A number of WG 6 participants recognised the positive role that close cooperation between regulators in the Nordic countries has played in reducing regulatory and market barriers for developing interconnectors in the Nordic market and identified this as an important element of WG 6's work.

3.1.2 Obligation of grid operators and cost allocation of RES integration

The division of costs between grid operators and RES generators was discussed at length by WG 6 participants. Connection costs generally fall into 3 categories; deep, shallow and super shallow.

Deep costs refer to all costs associated with grid connection, as well as any additional costs related to necessary reinforcements of the existing grid. While effective in that it allocates all of the costs associated with connection of the project to the project developer, thus providing the project developer with an incentive to place the project in the most cost-effective location, it also has a major drawback in that it further increases the costs of RE development for the investor. In addition, there is an equity issue that comes into play because others in the grid system may benefit from grid reinforcement paid for by the developer.

Shallow costs refer to the cost of connecting the RE plant to the grid, but not for any reinforcement of the existing grid. In practice this usually means costs associated with the substation and the power line from the substation to the existing grid.

Super-shallow costs only represent the costs of connection from the project to the connection point, usually the substation. Depending on how the system boundaries are defined, it can be difficult to determine which category a system falls into, and in practice many WG 6 participants apply a mixture of the above approaches. In some countries it can even vary depending on the voltage level, and the responsibilities of distributors and TSO are not the same. Figure 1 shows who is responsible for deep and shallow connection costs in WG 6 participant areas.

WG 6 participants discussed the authorisation and connection procedures for RES and how these can be improved to accelerate RES deployment. The discussion centred on procedures related to the connection of RES plants to the grid. Depending on the country, these procedures might be the responsibility of the TSO, the DSO, or the administration. Most WG 6 participants do not differentiate between transmission lines in general and transmission lines related to the integration of renewables as they require the creation of servitudes for access and maintenance whether they are for the benefit of RE integration or not. It could be problematic and provide perverse incentives if one were to exempt some transmission lines from certain requirements in relation to others as there is no difference in the transmission infrastructure required for transporting electricity from renewables compared to the infrastructure required for transmitting electricity from other sources. Most countries have recently improved procedures for acquiring approval for transmission expansion. These are, however, generic improvements and not for the sole benefit of renewables.

3.1.3 Smart grids and balancing markets

Smart grids have the potential to improve the integration of RES by increasing the efficiency of system operation and the management of electricity networks. This has the potential to provide increased utilisation of existing grid capacity in transmission and distribution, thereby avoiding or delaying investments in expanding network capacity to integrate RES. Public acceptance and lack of knowledge about smart grid technology such as smart meters is a barrier for some WG 6 participants. Despite the potential of smart grids it is essential to focus on the business case for smart grid investments as not all ideas may be beneficial in the long run.

Efficient markets for day-ahead, intra-day, balancing markets and distributed generation can be considered as a smart grid solution. Development of cross-border balancing markets can

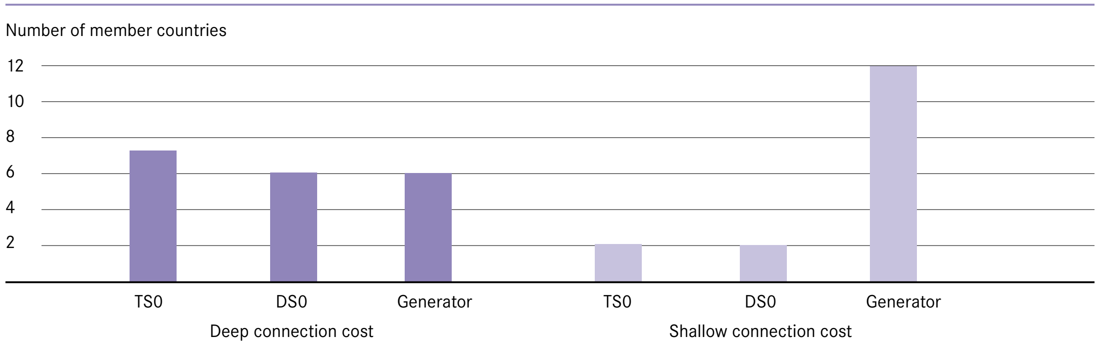

Figure 1: Division of connection costs between grid operators and RES projects in WG 6 participant areas

be beneficial as combining two power systems often results in net imbalances being reduced. Larger balancing markets will also result in higher market liquidity and better price formation.

Subsidy schemes often remove incentives for RES to participate in balancing markets. Experience has shown that including RES in balancing markets often results in improved RES forecasting. The more RES is integrated in the grid, the greater the need for balancing. It is, therefore, important to incentivise the integration of RES in balancing markets.

The forecasting of RES production is very important for TSOs to balance production and demand at any given time. The obligation to balance RES production varies amongst WG 6 participants as does the division of balancing costs.

3.1.4 Net metering

Net metering is emerging as a great opportunity to achieve the objectives of renewable energy for 2020 and to integrate renewable energy in the grid. Nevertheless this system is not directly mentioned in Directive 2009/28/EC, but it establishes that small and decentralized devices should be promoted.

The big advantage of two ways metering is that there is no lack of information. TSO and DSO need to have the information of real demand of the country (or their customers in case of DSO) for the operation of the electric system, but with net metering and billing this information is lost.

With an hourly system the DSO/TSO has more information but because the generator/consumer could adapt his consumption to prices. When all households have smart meters this option will be easier. The problem of these options is that the administrative costs are higher than in the yearly net billing system. In net metering systems the generator/consumer is using the grid in all occasions, when he is consuming or when he is injecting energy in the grid. He should pay network tariffs in any case for the disposal of the grid. The level of these should be discussed in each country.

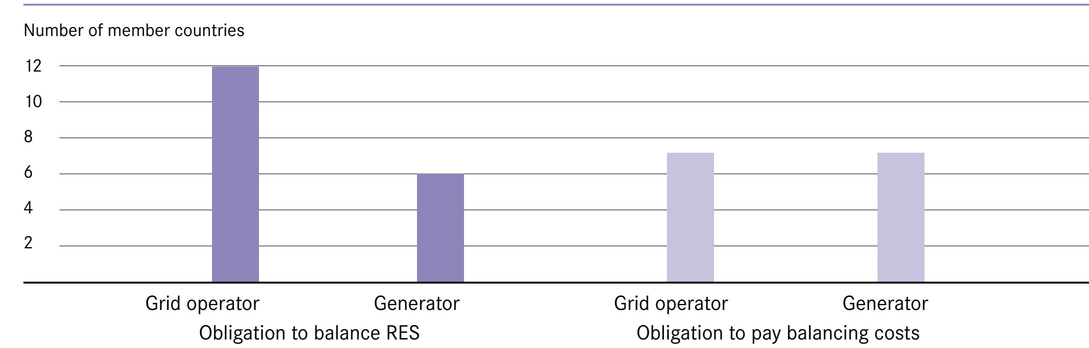

Figure 2: Division of obligation to balance RES generation and balancing costs

3.2 Good Practices

3.2.1 The South West Link: an interconnector project between Sweden and Norway

The South West Link has been chosen as an example of good practice for interconnectors based on the transparent planning process, the inclusion of a wide range of stakeholders in the process and the consideration of benefits for the entire Nordic market area rather than only in the two countries of the interconnector. It is also a good example of how public concerns about the project were addressed.

The transmission capacity to southern Sweden through the cross section called Section 4 has been an important issue in the development of the Swedish transmission grid. Section 4 serves two major purposes:

1. Supplying consumption in southern Sweden. This area has a deficit of production capacity, a situation that was worsened following the decommissioning of nuclear power plants in the area.
2. Transporting power to several of Sweden's interconnectors to neighbouring countries and facilitating increased electricity trade and export.

This part of the national grid came into focus following a major black-out in southern Sweden and Denmark in 2003. In the analysis following the disturbance the recommendation was made to increase the security of supply in this area by adding a new transmission line through Section 4. A Nordel study analysing the common need for reinforcements in the Nordic synchronous system included Section 4 amongst its 5 prioritised projects.

The project for reinforcement of southern Sweden was decided late in 2005 and was called the "South Link". The original idea was a reinforcement consisting of a new 400 kV AC overhead line.

A further Nordel study identified reinforcements that were needed once the 5 prioritised reinforcements from the initial study were completed. The interconnection between southern Norway and Sweden and the transmission corridor along the Swedish west coast were identified as priority reinforcements. Technical analyses showed that a highly controllable link between southern Norway, a strong point in the Swedish grid north of Section 4 and a point in southern Sweden would resolve the need for additional capacity through Section 4, a transmission corridor along the Swedish west coast and additional capacity between southern Norway and Sweden. This resulted in a new concept, the South West Link, which is basically the South Link with an interconnection to Norway.

It was designed as a combination of a new 400 kV AC overhead line in Sweden and a multi terminal VSC HVDC link with three terminals, one in Norway and two in Sweden. This new solution addresses the demands put on all new grid reinforcements:

- The national grid should be designed to reduce the risk for power outages
- The national grid should not be the limiting factor when it comes to meet the challenges from European and national energy and climate goals
- The national grid must be flexible enough to handle changes in how and where electrical power is produced and consumed and be able to connect and transport the large amount of wind power that is foreseen to be introduced in the power system

The process for obtaining permits has been challenging from the beginning with discussions about land intrusion and choice of transmission technology:

- AC overhead lines have land intrusions but give higher security of supply and flexibility to future grid development.
- DC cables have smaller land intrusion but because of their complex technical nature lead to more faults and down time for maintenance and therefore an extension to reduced security of supply. It is also considerably more challenging to extend or change system layout in a DC-transmission, but a DC link in an AC system provides new opportunities for controlling power flow.

The debate clearly showed the problems that exist with grid reinforcements being made for the benefit of global/European/national goals like reducing CO_2 emissions by integrating European electricity markets and on the other hand local environmental interests that will be affected by the transmission line.

The permit application for the Swedish part of the project has been approved. The project is now in the purchasing phase and will be in operation in 2015. The interconnection to Norway has now been cancelled as the Norwegians feel that there is greater socio-economic value in a connection to Germany rather than Sweden. The total cost of the projects is expected to be MEUR 800.

3.2.2 Control centre of renewable energies (CECRE of Spain)

To guarantee the security of the system, the Spanish TSO requires real-time communication with the generating stations, enabling it to know at all times their conditions and variables of operation and to issue the necessary instructions relating to production conditions in order for them to be duly fulfilled by these stations.

The telecommunication deployment carried out among generation, transmission and operation activities allows the complex integration of distributed sources by reducing the time response. In Spain that has been achieved as a result of the aggregation of all the distributed resources of more than 10 MW in Renewable Generation Control Centres and the connection between them with the Central Control Centre for Renewable Energies of Spain.

Due to the high number of generators present in the Spanish electrical system, secure and efficient communication between the Central Control Centre and generating stations requires the integration or affiliation of the latter with generation control centres, whether dedicated to special regime generators or another type. The generation control centres must not only have sufficient capacity of control, command and monitoring over the generators assigned to them but also a suitable connection with Red Eléctrica's control centres and the appropriate skills level in its human resources to guarantee secure liaison with Red Eléctrica and its operation, 24 hours a day and 365 days a year.

In June 2006, Red Eléctrica, as TSO, started up CECRE, a worldwide pioneering initiative to monitor and control these energy resources. CECRE is an operating unit integrated into the Power Control Centre (CECOEL). The generation of the renewable energy producers, which have been set up in Spain are managed and controlled by CECRE. In addition, this centre is the sole interlocutor in real time between CECOEL and each one of the authorised generation control centres, to which the wind farms are connected.

The generation control centre to which an electrical energy production facility is assigned acts as its Generation Control Centre and interlocutor with CECRE. Therefore every generation control centre must be connected with CECRE and have been previously approved by Red Eléctrica, for which it must be able to provide proof of, through the corresponding tests, the capacity to meet several requirements.

The requirements to be met by the generation control centres are related to equipment, necessary for connection to the Red Eléctrica control centres, which must be implemented by generators within the period established by law, as well as the information requirements to be submitted to CECRE, both in its content and its timing and precision.

3.2.3 Other good practices

Flexible Alternating Current Transmission Systems (FACTS) is an umbrella term that encompasses several technologies designed to enhance the security, capacity and flexibility of power transmission systems. FACTS manage to increase the existing transmission network capacity while maintaining or improving the operating margins necessary for grid stability. Dynamic line rating is where temperature measurements on overhead lines can determine the actual, possible maximum capacity. In cold and windy situations overhead lines can transfer more, than in hot calm days. Higher available capacity and better security can be the result.

Wide Area Measurement Systems (WAMS) can be used to avoid voltage collapse in the system. The major black-outs that occurred over large areas have been related to voltage collapse (e.g. Denmark/Sweden 2003, and Italy 2003, North/East USA, 2003). Voltage collapse occurs when the long distance transport of electricity is too large. This typically occurs after a series of other faults that lead the system into an unstable situation. It is not possible to measure the threat of voltage collapse locally. Other smart grid technologies include demand as a frequency controlled reserve. Demand that can be disconnected for a few minutes without disturbing the comfort levels of the users, can act as fast reserves in the system. Frequency can be measured locally and no communication is needed. ENTSO-E has in its new Demand Connection Code suggested that in the long term all thermostatically controlled units could be activated to be frequency controlled[2].

State estimators can be used to compute load and voltage for all grid elements. A state estimator is a calculation tool designed to create an overview across the entire state of the power system. It models the network and the flows, and based on numerous measurements (some of which are erroneous) the model creates a comprehensive description of all power flows. State estimator results are used in real time to analyse the impact of potential contingencies of plants and other components in the system, as well as suggestions for preventive action.

Storage devices maximize the integration of RES energy and facilitate the system operation, as they avoid the spillage of RES generation when there is a surplus production. Furthermore, storage devices ease the modulation of the demand curve, the power-frequency regulation and the voltage control. Pumped hydro is an example of a large scale storage technology.

Portfolio performance improvements that can provide increased flexibility and dynamic capabilities from the entire power system can play an important role in integrating RES into national power systems as well as improving existing conventional generations'- and consumers'- ability to respond to market signals. Portfolio performance refers to the ability of existing power plants and infrastructure to respond to changes in production from variable generation.

Facilitating the process of connection is very important in order to clarify all processes including easier procedures for small plants, which should be different from those of the big plants. A good practice is the One-stop-shop system (established in Italy for example). The permit is obtained for construction and connection to the grid at the same time. This is also a simplified process for small projects.

[2] See: www.entsoe.eu/resources/network-codes/demand-connection/

4

Main Findings and Achievements

The main findings of WG 6 are:

1. A review of on-going interconnector projects indicated that investment decisions in interconnectors typically have market integration as the key driver, whereas integration of RES and security of supply to a lesser extent are driving investments in new interconnectors. However, RES generally benefit from new interconnectors through greater market integration and interconnectors are very important for RES integration. The actual benefit depends on technology mix, market design and market behaviour.
2. Interconnectors are not the only solution and their use must be balanced with other measures such as demand side management and portfolio performance.
3. All WG 6 participants have identified barriers in the procedures for grid access and connection. The barriers are often related to a lack of coordination amongst authorities, the requirement for permits from many different authorities and the lack of a one-stop-shop for investors.
4. It is important to facilitate grid connection by clarifying all permitting processes and developing simpler procedures for small plants and a one-stop-shop system for larger investments.
5. Regulation on smart grids should be more proactive and closely related to the needs of the power system and electricity markets.
6. Cross border balancing markets may facilitate the integration of variable RES units into the electricity system more efficiently than national balancing markets.

Topic	Issue	Outcomes	Future
Interconnectors	Permitting and approvals, cost allocation of interconnectors across borders, regulatory differences across interconnectors.	Better communication of the advantages of interconnectors. Increased cooperation on regulation and market integration.	Greater market integration and uniformity of national regulations will provide basis for cheaper, more efficient integration of RES in Europe.
Obligations of grid operators and cost allocation for grid connection	Allocation of costs should provide incentives to develop RES projects in most cost effective sites whilst maintaining affordability of RES and equity of grid users.	Greater awareness of connection procedures for RES in different countries and initiatives implemented to accelerate RES deployment without compromising other users and incurring unreasonable costs.	Develop regulation to address the division of costs, grid connection and equity issue.
Smart grids and balancing markets	Public acceptance and lack of knowledge about smart grid technology is a barrier. The more RES is integrated in the grid, the greater the need for balancing, yet subsidy schemes often remove incentives for RES to participate in balancing markets.	Incentivise the integration of RES in balancing markets. Developing cross-border balancing markets could be beneficial as combining two power systems often results in net imbalances being reduced.	Utilise smart grid technologies that contribute to integration of RES, improve efficient utilization of electricity networks and reduce requirements for reserve generating capacity. Cross border market develop to reduce the cost of RES integration and increase market integration.

5 The Way Ahead

In the framework of WG 6 a large number of topics which affect the integration of RES energy in the grid have already been tackled. However, some specific problems and topics which affect the integration of RES into the framework of a future single European market should be discussed.

Furthermore, WG 6 should also tackle issues related to the challenge of reaching the stage where RES energy can be treated as any other energy source in the electricity market. Some issues to study have been identified:

- Clarify the concept of security of the system: this term is difficult to understand for people not being technicians. Therefore, it is proposed to explain what this means and what must be done to ensure it.
- Relation DSO-TSO in priority of dispatch.
- Storage as a mechanism of integration of RES energy.
- Market rules related to the integration of RES energy in the market.
- Interface between policy and technical problems. The policy makers should understand the necessities of the system.
- International integration of RES energy into the grid. After domestic integration it is important to discuss the cross border integration of RES.
- Demand response.
- Public acceptance of new infrastructure investment.
- Balancing costs and how these affect the grid costs and operating costs.
- Cost effective solutions: Is it better to look for other solutions (not a new grid) as improvements in distribution, control centres, storage, etc. ?
- Impact of transit flows in neighbouring countries.
- Interaction of the integration of RES energy in the markets and the harmonisation of rules would have to be studied.

6 Abbreviations

Abbreviation	Full name
AC	Alternating Current
CA-RES	Concerted Action on the Renewable Energy Sources Directive
CECRE	Control centre of renewable energies of Spain
CECOEL	Power Control Centre of Spain
DC	Direct Current
DSO	Distribution System Operator
EIA	Environmental Impact Assessment
ENTSO-E	European Network of Transmission System Operators for Electricity
FACTS	Flexible Alternating Current Transmission Systems
kV	Kilovolt
RES	Renewable Energy Sources
TSO	Transmission System Operator
VSC-HVDC	Voltage Source Converter – High Voltage Direct Current
WAMS	Wide Area Measurement Systems
WG 6	Working Group 6: Electricity Networks

This is a public CA-RES report
The Concerted Action to support the implementation of the RES Directive 2009/28/EC (CA-RES) was launched with the participation of the responsible authorities from 30 EU countries and supported by Intelligent Energy Europe (IEE) in July 2010 to provide a structured and confidential dialogue on how to address the cost-effective implementation of the RES Directive 2009/28/EC.

For further information please visit **www.ca-res.eu**