Impact of Grid Management on Wind Energy In Turkey A Case Study – The Marmara Region

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Abstract: - Turkey has one of the largest and fastest growing populations within the EU-27 Member States and Candidate Countries. This population growth comes with a rapid urbanization and high demand for electricity. However, Turkey's conventional energy resources are limited and this high energy demand has resulted in a high dependency on energy imports; primarily oil and natural gas. At present, around 30 per cent of the total energy demand is being met by domestic resources, while the rest originates from a diversified import-portfolio. Turkey, on the other hand, is blessed with ample renewable energy resources such as wind energy and solar energy. This paper makes a quick review of Turkish Energy outlook and emphasizes the importance of renewable energies for Turkey. Afterwards it analyzes the new era of Renewable Energy in Turkey, through the analysis of the recent advances in the legal infrastructure, latest agreements and projects for the advancement of renewable energy sector in the country. It is accepted that the most important renewable resource of the country is the wind energy and this paper concentrates on the wind energy potential in general. One of the most significant criteria for the feasibility of the wind related investments is the grid connectivity. Since Turkey acts like a network hub between the Europe and Asia, the quality and the management of the grid and the grid connectivity of the renewable projects is important not only for this country, but for EU member states as well. Because, the Marmara region has the highest wind energy potential and it is the western most region of the country, this paper concentrates on this region as a case study. The final part of the paper analyzes the grid connectivity to Europe, EU directives and their impact on Turkey's grid management.

Key-Words: - Renewable energy, grid management, electricity production, wind energy, Turkey

1 Introduction

Turkey has one of the largest and fastest growing populations within the EU-27 Member States and Candidate Countries. This population growth comes with a rapid urbanization and high demand for electricity. Electricity consumption in the EU-27 Member States and Candidate Countries has continued to grow in the last years despite numerous energy efficiency policies and projects at EU and national level. Total electricity consumption in the residential sector in the EU-25 has grown by 10.8% in the period 1999-2004, at almost the same rate as the economy (GDP). Similar trends are also observed in the tertiary sector and to a lesser extend in industry. The electricity consumption in the tertiary sector has grown by 15.6% in the period 1999-2004 and by 2.0% in the period 2003-2004[1].Whereas during the same period the electricity consumption in Turkey has increased over 30% [4].

Turkey's conventional energy resources are limited and this high energy demand has resulted in a high dependency on energy imports; primarily oil and natural gas. At present, around 30 per cent of the total energy demand is being met by domestic resources, while the rest originates from a diversified import-portfolio. Turkey attaches utmost priority to further diversification of imports in both type and origin. Exploration and production activities are also being intensified in this context. It is important to underline here that although Turkey is not a major hydrocarbon producer, its merging role as an important energy transit country makes it increasingly important to world energy markets and especially for Europe [2].

Concerning renewable energy sources, the Law on the Encouragement of the Utilization of Renewable Energy Sources for the Purposes of Generating Electricity was adopted in 2005 for promoting electricity production from the renewable energy sources in liberalized energy markets. In order to use energy efficiently, prevent waste, mitigate the burden of energy costs on the economy, and increase the efficiency in the use of energy resources and to protect the environment, the Energy Efficiency Law was enacted on 2007 [3].
On the other hand Turkey has great renewable energy sources comparative to others. (Table 1)

2 Major Milestones for the Renewable Energy and Electricity Sector after 2005

After 2005 a new era in Renewable Energy and Electricity sector has begun. The following subjects are a brief introduction to the milestones in Turkey that affects the subject including the law, regulations and also major projects.

2.1 Law on Utilization of Renewable Energy Resources for the Purpose of Generating Electricity ('Law on RES'), No: 5346 (Official Gazette: 18 May 2005, no. 25819)

The purpose of this Law is to expand the utilization of renewable energy resources for generating electrical energy, to benefit from these resources in secure, economic and qualified manner, to increase the diversification of energy resources, to reduce greenhouse gas emissions, to assess waste products, to protect the environment and to develop the related manufacturing sector for realizing these objectives. It provides an overview of the general provisions of the Law, as well as other supporting legislation regarding renewable energy sources ("RES").

2.2 RES Certificate Regulation (Official Gazette: 4 October 2005, no. 25956)

The Law 5346 provides that legal entities generating electricity from RES will be granted by the EMRA, Energy Market Regulatory Authority, however a certificate entitling the holders to benefit from the incentives under the Law. The procedures and principles regarding the issuance of this Certificate are specified in this regulation.

2.3 Communiqué for The Tariff Equalization Mechanism (Official Gazette: 21 December 2006, no.26383)

According to the Law 4628 and this regulation, starting from December 2006, the distribution companies are subject to a cross subsidy between themselves during a transition period until 31 December 2010. A price equalization mechanism is implemented in order to ensure a uniform price all over Turkey during this period. In line with this, the distribution companies are to be reimbursed according to their income requirements.

2.4 Law on Energy Efficiency, No: 5627 (Official Gazette: 2 May 2007, no 26551)

The purpose of this Law is to increase efficiency in using energy sources and energy in order to use energy effectively, avoid waste, ease the burden of energy costs on the economy and protect environment.

2.5 The Electricity Distribution Rehabilitation Project (11 February 2008)

The Republic of Turkey, TEDAŞ (Turkish Electricity Distribution Company), and the World Bank signed the agreement on a €205 Million (US$ 269.4 Million Equivalent) Electricity Distribution Rehabilitation Project Loan for Turkey. The loan will be to TEDAŞ, the government-owned electricity distribution company, and will be guaranteed by the Republic of Turkey. The Electricity Distribution Rehabilitation Project aims to improve the reliability of power supply to consumers in Turkey. The project will support the rehabilitation and expansion of electricity distribution in critical areas, help reduce interruptions in supply, and help improve the distribution system's compliance with safety regulations. The project includes: Rehabilitation and Expansion of the Distribution Network of the regional companies of TEDAŞ namely: Ayedaş, Uludağ, Meram, Gediz, Toroslar, Menderes, Osmangazi, and Akdeniz. Planned investments will target those parts of the distribution network with the most serious capacity, efficiency, and safety challenges. Technical Assistance to TEDAŞ and the regional companies in managing and supervising the implementation of the investment projects will be done. The details of the project on public available information on World Bank web site [4].

2.6 REPA Turkish Wind Energy Potential Atlas

The wind atlas developed by EIE, General Directorate of Electrical Power Resources Survey and Development Administration aims to support wind industry development in Turkey by a meteorological tool. REPA covers all areas in Turkey. This wind atlas was prepared by NWP models with 200m resolution. REPA will help wind sector, investors, universities and individuals. Information is available in English and Turkish [5].

2.7 Determination of Wind Energy Potential Regulation Guide 25 September 2007 (Draft)

For the project management and feasibility studies EIE prepared a roadmap and guide for

Determination of Wind Power according to the Turkey and reference calculations based on Turkey [6].

2.8 Wind Energy Report by TUREB

This report prepared for wind energy production sector and includes the current status of wind energy in Turkey. This report also includes the upcoming wind power station projects to year 2010 [7].

3 Wind Energy Potential of Turkey and the Marmara Region

Turkey has a land surface area of about 800,000 km2. The country is surrounded by the Black Sea in the north, the Marmara and the Aegean Sea on the west and the Mediterranean Sea in the south. Turkey has a very long coast line 8500 km. Theoretically, Turkey has 160 TW h a year of wind potential, which is about twice as much as the current electricity consumption of Turkey. The values of technical wind energy potential of European countries are given in Table 1. As shown in the table, Turkey has the highest share in technical wind energy potential in Europe [8].

Table 1 Wind Energy Potential of European Countries

	Total Area m^2	**Technical Potential**	
Country		**GW**	**TW/year**
Austria	84	2	3
Belgium	31	2	5
Denmark	43	14	29
Finland	337	4	7
France	547	42	85
Germany	357	12	24
United Kingdom	244	57	114
Greece	132	22	44
Ireland	70	22	44
Italy	301	35	69
Luxembourg	3	0	0
Norway	324	38	76
Portugal	92	7	15
Spain	505	43	86
Turkey	781	83	166

For the efficient and economical use and forecast figures of wind power in Turkey varies between different institutions and organizations due to various reasons. However, major disagreement between the official directorates and state owned companies such as TEIAS and NGOs stems from the fact of the grid connectivity. TEIAS and others make their forecasts base not on the actual wind potential but on the limitations of the grid. For example, according to EIE expected electricity production from renewable energies is 12GW, and nearly 4 GW of wind. On the other hand, TEIAS assumes a total installed generation capacity of 73 GW is expected in 2015 - which includes 2.4 GW wind. In that period, peak load will be about 70 GW. A total of 15 GW wind would correspond with a wind power penetration of roughly 20 % related to the system peak load. These numbers can be seen from Table 2 [9]. These levels are much below the actual potential of this country.

Table 2 Renewable Projections for 2008-2013 by EIE

Source/Years	2008	2009	2010	2011	2012	2013	Total MW
Hydro	121	578	2.396	2.633	1.354	1.134	8.216
Wind	483	361			1.041	1.885	3.770
Geothermal	45	8		10		62	124
Bio-energy		8					8
Solar					10	10	20
Grand TOTAL							12.110

3.1 Current Status of the Wind Power Stations

Before 2005 and the Law on Utilization of Renewable Energy Resources Turkey's the use of wind power was mostly theoretical and on a pilot plant basis. This was due to mainly lack of incentives, lack of purchasing guarantees and as a result limited feasibility of Wind Power Stations. Economic fluctuations prevailing in the same period only worsened the chance of the potential projects then. Especially after the economic crisis of 2000, most of the investors avoided long term investments such as wind power. After 2005 and the law, the wind energy production in Turkey started to increase significantly and within three years the total installed capacity grew more than ten times from 20MW to 291MW (Table 3).

As it can be seen from the Regional Distribution graph Fig. 1 Major portion of these installations are in the Marmara region. This region has the highest wind energy potential. In addition, the region is the most industrially developed region of Turkey.

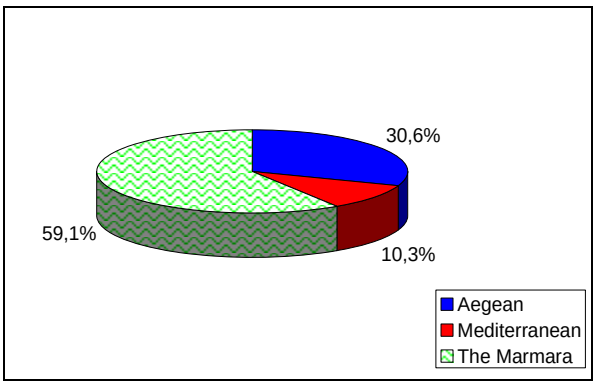

Fig. 1 Regional Distribution of Wind Power Stations in Turkey in Operation

Table 3 Current Status of Wind Power Stations in Turkey

Location	Region	Date of Operation	Installed Capacity (MW)
İzmir-Çeşme	Aegean	1998	1,5
İzmir-Çeşme	Aegean	1998	7,2
Çanakkale-Bozcaada	the Marmara	2000	10,2
İstanbul-Hadımköy	the Marmara	2003	1,2
Balıkesir-Bandırma	the Marmara	I/2006	30
İstanbul-Silivri	the Marmara	II/2006	0,85
İzmir-Çeşme	Aegean	I/2007	39,2
Çanakkale-İntepe	the Marmara	I/2007	30,4
Manisa-Akhisar	Aegean	I/2007	10,8
Çanakkale-Gelibolu	the Marmara	II/2007	15,2
Manisa-Sayalar	Aegean	II/2007	30,4
Hatay-Samandağ	Mediterranean	II/2007	30
İstanbul-G.paşa	the Marmara	I/2008	24
İstanbul-Çatalca	the Marmara	I/2008	60
		Total	291

In 2006, EMRA (Turkish Energy Market Regulatory Authority) stopped accepting applications for new wind power projects without explanation. This trend was reversed by a call for wind and solar projects in the autumn of 2007. As a result, EMRA has received applications for 751 projects, all from the private sector, for a total capacity of 78,151 MW, including 3,791 MW offshore, from over 380 companies. This number greatly exceeds all previous estimates and is the proof of the high wind energy potential in the country. It has to be pointed out, however, that many of these applications compete for the same sites. Nearly half of the applications were for projects of fewer than 50 MW. In addition to local companies including Sayres Elektrik, Akyelres Elektrik, Guneyres Elektrik and Uzay Enerji, major international players such as Iberdrola, BP and Westwind have submitted applications. EMRA is expected to offer licenses for up to 10,000 MW of wind energy, while saying that 30,000 MW would be feasible [10].

Table 4 License Applications for November 2007 by Regions

Region	Capacity of Projects MW	% of Capacity	Number of Projects	% of Projects
The Marmara	38.093	48,9%	366	48,7%
Aegean	17.227	22,1%	176	23,4%
Mediterranean	8.054	10,3%	36	4,8%
Central Anatolia	6.819	8,8%	70	9,3%
Southeastern Anatolia	5.918	7,6%	79	10,5%
Black Sea	1.705	2,2%	20	2,7%
Eastern Anatolia	56	0,1%	4	0,5%
Turkey	**77.871**		**751**	

Nearly 20 of these license applications have a capacity at 500MW-1000MW range and 10 of the projects are more than 1GW. The summary of these projects can be tracked from Table 4. This unusual interest in the wind power in Turkey has surprised most of the authorities and also some projects are really looks out of engineering like the 3GW of off-shore wind farm in Izmir.

3.1 The Marmara Region and Grid Management for Wind Energy

As was stated before, Turkey is planning to reach a renewable energy production level of 10-15 GW and this can not be possible if the existing grid infrastructure is vastly improved. This holds true not only for wind generation, but also for hydro and even for conventional lignite based electricity generation, which is currently dominating the power supply in Turkey. Similar to wind plants, both hydro and lignite power plants are constructed within the resource and mine areas and are connected to the load centers by transmission lines.

At present, there is a reasonable match between the potentially attractive wind areas on the one hand and load areas and transmission infrastructure on the other hand. Additionally, the substantial hydro capacities in the East of the country anyway require an East-West transmission backbone. Using this infrastructure also for wind power further limits additional investments exclusively related to wind. The specific benefits of matching wind and hydro have been investigated in a specific R&D Annex of the Implementing Agreement of the International Energy Agency[14].

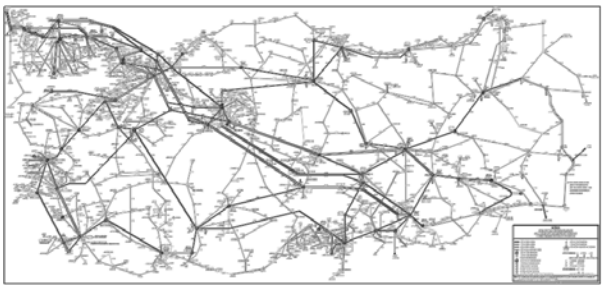

Fig. 2 Current Electricity Grid Lines in Turkey -2007

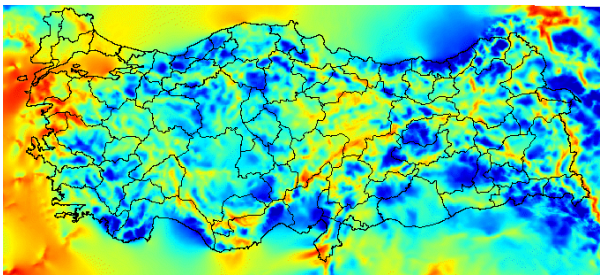

Fig. 3 Wind energy Potential at 70m –REPA

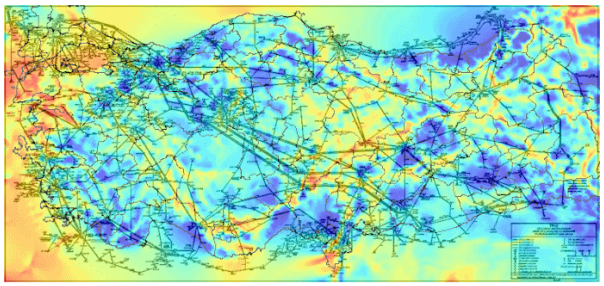

Fig. 4 Overlapped Map for Grid and Wind Potential

Wind Power Stations can be connected to either the 34.5 kV lines owned by Turkish Electricity Distribution Company or 154 kV lines owned by Turkish Electricity Transmission Company. Both utilities have set a limit to the maximum wind power, which is 5% of the short circuit power at the connection point in order not to cause grid interference. Turkish Electricity Distribution Company allows the wind power plants only to connect directly to the 34.5 kV bar at the nearest transformer substation by installing a new line and does not allow any other customer to connect to this new line.

Since the Marmara region is Turkey's only gateway to connect EU grid and highly industrialized areas of like Çorlu, Istanbul, Gebze, Izmit , Adapazari the major electricity grid composed for 380kv and 154kv grid line is the most suitable region of Turkey when compared with the other potential regions and areas.

As can be seen from Fig. 5, the current status of the grid is quite favorable for the upper Marmara Region. However, in the lower Marmara region there are only two 380kv grid and some minor 154kv grids (Fig. 6). According to the license applications more grid connections both 154kv and 34.5kv will be needed in order to accommodate additional wind station projects. However in some areas where the grid is weak and not available due to geographical conditions such as coastal parts new transmission line will be required.

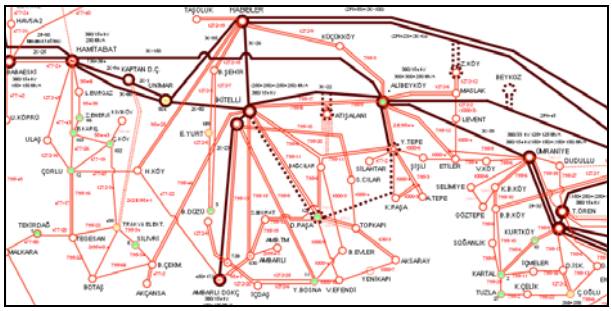

Fig. 5 Electricity Grids in Upper Marmara Region

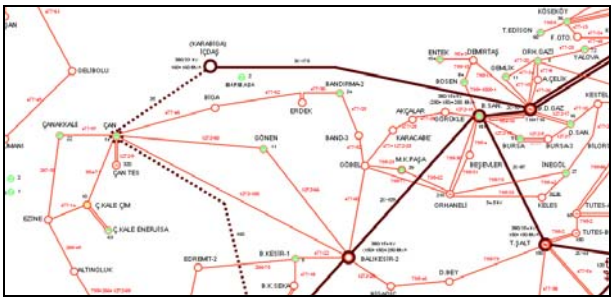

Fig. 6 Electricity Grids in Lower Part of the Marmara Region

In Fig. **7,** wind energy potential, grid status and current/future wind power stations can be seen together in one overlapped map. As can be seen from the graph most of the wind power stations concentrated near Istanbul area and close enough for the grid. For those power stations grid availability is good enough for feasible and easy connection. However, for the potential stations in the lower Marmara region, new grid lines are needed and the existing ones need to be rehabilitated.

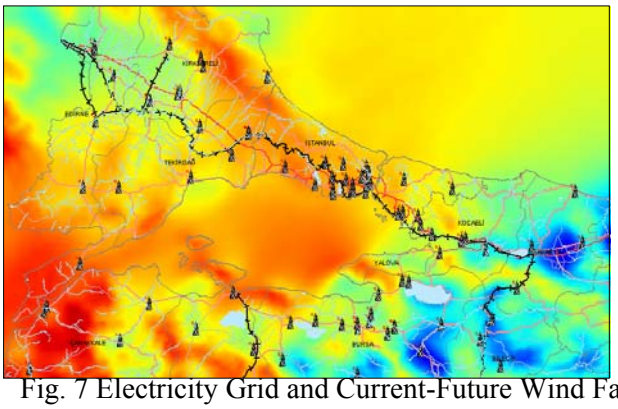

Fig. 7 Electricity Grid and Current-Future Wind Farm Locations for Marmara Region, [9]

4 System Integration and Grid Managementroblem Solution

4.1 A Brief Theory about Grid and Integration

The national grid is a network of power lines which allows distribution of electricity throughout all or part of a country. The grid can be connected to a single power source or electricity generating plant but is usually linked with other plants to provide a more flexible and reliable network. The electricity is usually transmitted at very high voltage, typically several hundred thousand volts (depending on power transmitted, national guidelines, etc.) as this reduces losses and means that smaller cables can be used, reducing the overall cost of the network. Bulk electricity is generated and transmitted in 3 phase, alternating current (AC. - 50 or 60 cycles per second) form and distributed to the consumer as three phase or single phase depending on the end use requirements. Transmission by direct current

(DC)is also used, losses associated with DC electricity being lower than AC, but other costs are incurred as heavy duty rectification equipment is then needed to supply AC electricity to the consumer [12].

In general, two methods exist to facilitate access to the grid: regulated access and negotiated access. When negotiated Third Party Access (n-TPA) is in effect, the buyer and the producer of electric energy have to negotiate on the sale, and afterwards they have to negotiate with the grid operator(s) on the access to the grid and the price for the transport. Regulated Third Party Access (r-TPA) also involves negotiations between customer and producer, but the price for transmission of the electricity is fixed. The transmission system operator (TSO) sets up objective criteria to access the grid and publishes them publicly. These criteria are valid for all market players. In the liberalized market, r-TPA is the only valid alternative. Currently, r-TPA is obligated in the EU (2nd directive) [13]. The European countries are currently adapting their regulation to comply with the new policy. Turkey is also working on this issue with EU and World Bank projects. The national grid is a network of power lines which allows distribution of electricity throughout all or part of a country. The grid can be connected to a single power source or electricity generating plant but is usually linked with other plants to provide a more flexible and reliable network. The electricity is usually transmitted at very high voltage, typically several hundred thousand volts (depending on power transmitted, national guidelines, etc.) as this reduces losses and means that smaller cables can be used, reducing the overall cost of the network. Bulk electricity is generated and transmitted in 3 phase, alternating current (AC. - 50 or 60 cycles per second) form and distributed to the consumer as three phase or single phase depending on the end use requirements. Transmission by direct current (DC)is also used, losses associated with DC electricity being lower than AC, but other costs are incurred as heavy duty rectification equipment is then needed to supply AC electricity to the consumer [12].

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4.2 Existing Situation in Turkey

Grid connectivity is an important input for the feasibility of any wind energy project. It affects not only the size of the investment because of the connectivity requirements stemming from the grid availability and grid management restrictions such as allowing only 5% short circuit power at the connection point, but the investment level as well. For example, the connection to grid by a dedicated line may be required; the cost of which must be born by the potential investor.

The specific conditions for wind Energy in Turkey are rather advantageous. There is a reasonable match between potentially attractive wind areas on the one hand and load areas as well transmission infrastructure on the other hand. System integration costs are lower than usually anticipated. Costs for additional transmission lines range in the order of magnitude of 3-4 €/MWh_{wind}. Additional operating costs that might come up at higher penetrations are below 4 €/MWh_{Wind}, This figure is likely to be substantially lower as the high share of hydro for electricity production is a good basis for compared to wind generation costs which are in the order of 50 €/MWh , the share of integration cost is rather low [14].

The aim of liberalized electricity markets in Europe is to increase production efficiency through competition and to decrease the electricity prices for the end consumers. However, the EU directive 2001/77/EC partly contradicts with this aim. The directive deals with the promotion of RES-E in the European electricity market. Each European country has to set a national indicative target of the share of RES-E on the gross electricity consumption. These national indicative targets should be consistent with the European Community indicative target of 12% of gross national energy consumption by 2010 and in particular with the 22.1% indicative share of RES-E in total Community electricity consumption by 2010 [15]. According to the projections of EIE and TEIAS Turkey will also reach that indicative target.

The Turkish power system is currently not set up for synchronous operations with other countries, but there are several interconnections such as to Azerbaijan, Armenia, Bulgaria, Georgia, Iran, Iraq and Syria. There are plans for additional 400 kV connections with Greece, Iran, Iraq, and Syria.

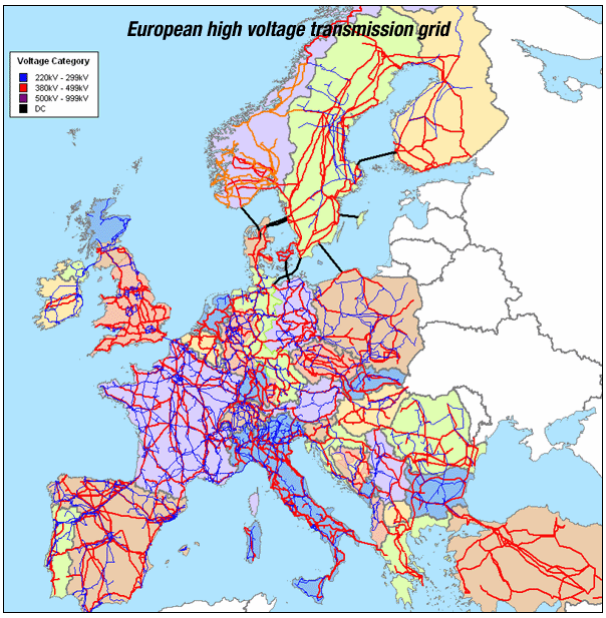

Fig. 8 European High Voltage Transmission Grids

Another view for connecting the grid to EU is UCTE (Union for the Co-ordination of Transmission of Electricity) is a TSO (Transmission System Operators) organization, whose main role is to maintain the security of supply and the quality of the energy delivered. In this context UCTE and its member TSOs support the goal to promote renewable energies and reduce CO2 emissions according to EU and national targets. As a result of the political efforts for a sustainable development, renewable power has increased its penetration in the electricity world. The integration of renewable energy sources especially of wind energy generation changes the power system conditions which must not lead to negative changes of supply quality. For the connection of Turkey to the EU electricity grid, another project provided complementary technical studies for the synchronization of the Turkish power system with the UCTE (Union for the Co-ordination of Transmission of Electricity) system (2003). The project had a total budget of € 1.45 million. In order to improve the conditions for cross border electricity trade in Turkey in compliance with the best practices in the EU, a Twinning project for € 1.38 million was programmed in 2006. Turkey has recently become an UCTE member.

More than 24000 MW in wind power stations are already connected to the UCTE networks, this enormous figure is not uniformly distributed over UCTE. Three countries, Germany, Spain and Denmark (WP) contribute with, approximately, the 98% of the total [16].

The Commission approved the establishment of the FEMIP (Facility for Euro-Mediterranean Investment and Partnership) support fund for Turkey in 2005. The Fund aims at financing technical assistance activities complementary to EIB operations. Total budget is € 3 million and 50% of the funds are allocated for infrastructure related projects. The fund can be used as a tool to support large scale EIB interventions in the energy area as well.

After 2005 a new era has begun for the renewable energy sector in Turkey. However this rapid improvements and increase in the sector comes with some problems and obstacles. Projects and regulations will be finished within next 3-5 years like Electricity Distribution Rehabilitation and success of the wind power stations and more clear observations can be done.

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