Integration of Renewable Energies to the East German Grid - Actual Problems and Possible Solutions -

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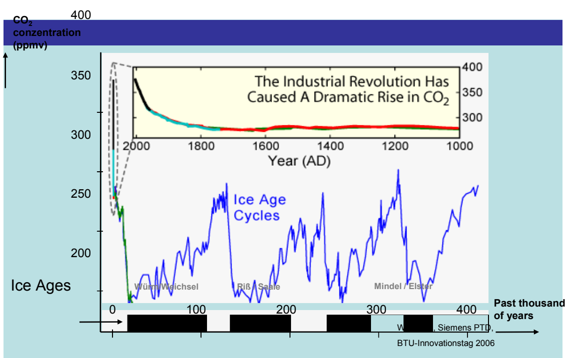
Abstract: - The rapid growth of the renewable energies causes difficult load situations in the power supply system in Germany. The legislator prescribes that the network operators have to connect all dispersed generation. Especially the distribution networks become overloaded during strong wind situations combined with low network load. Furthermore the stability of the transmission system will be endangered more and more. The paper describes the actual problems and the ongoing activities to find solutions, how to integrate renewable energies to the grid in a more system compatible manner.

Key-Words: - Renewable Energy, Grid Integration, Virtual Power Plants

1 Introduction

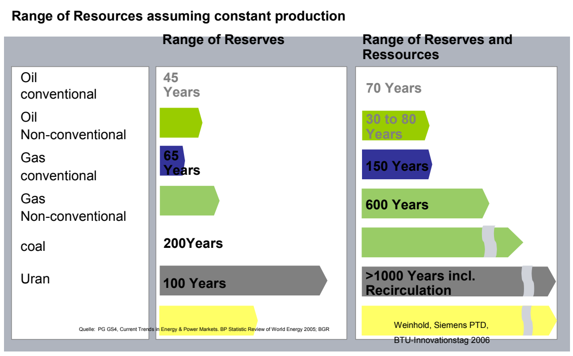
Within the past hundreds of thousand of years the CO_2 concentration in the atmos-phere varies between 200 .. 300 ppm. During the last 100 years a permanent increase (see fig. 1) up to roughly 400 ppm can be detected.

Fig 1: CO_2 Concentration in the Atmosphere / 1 /



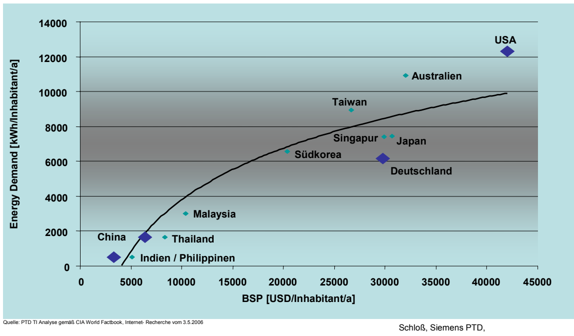
Due to the different worldwide discussion this increase should reach values up to 900 ppm assuming an unchanged consuming behaviour and the still existing energy conversion systems. Furthermore these discussions and studies figured out that a CO_2 concentration in the range of 500 ppm might be tolerable for climate.

Fig. 2: Range of Energy Ressources / 2 /



Having a look on the availability of typical resources for energy conversion (see fig. 2) it must be stated that in the field of non-renewable energies only coal and nuclear energy will offer a reliable basis for a long term energy supply strategy. Renewable energies will have an increasing chance to severely contribute a relevant part of the total generation. Taking finally into

Fig. 3: Energy consuption versus Market Strength / 3 /



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account the energy consumption versus the economical strength of the different countries (see fig. 3) it must be stated that we will have

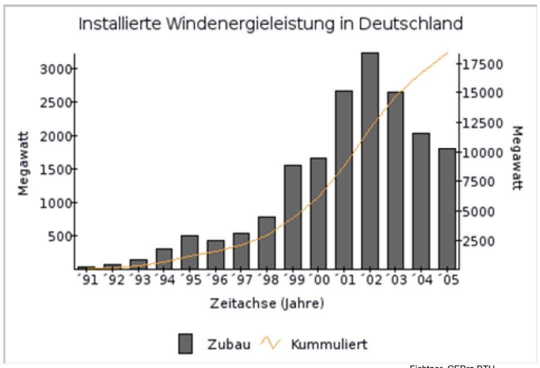
- a rapidly increasing demand of electrical energy especially in the fast developing countries also in the next decades and
- a generation of electrical energy which mainly will be based on coal and nuclear power plants on the conventional side and an increasing amount of renewable energies
- a regional diversification in the field of renewables which will reach from large water power plants (e.g. China, South America, North Europe) over an intensive wind generation (e.g. North Germany, Spain, India) to a plurality of small and medium size generation from biomass and photovoltaic

It is well known that power generation from wind and also from photovoltaic cannot yet be forecasted in a proper way. Therefore the successful use of these types of renewables for electricity supply is directly related to the compatible adoption of the fluctuating infeed to the physically based rules how to operate electrical grids.

2 Actual problems caused by wind power generation

Actually a total amount of 59.000 MW of generation from wind power is installed around the world. With a capacity of nearly 18.000 MW (end of 2005) about 31 % of the world wide wind capacity (see fig. 4) is connected to the German grid.

Fig. 4: Installed Capacity of Wind Power in Germany / 4 /



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A plateau of 25.000 MW from on-shore wind farms will be expected within the next 5 years. This should be followed by a phase of increasing off-shore platforms, which finally may reach another 20.000 MW of wind power to the German grid.

About 12 % of the actual world capacity is installed on-shore in the Eastern part of Germany and connected to the East German grid, which will be operated by Vattenfall Europe Transmission GmbH (VE-T).

On the one hand side this will lead to severe problems in the grid operation, on the other hand side it will give a severe chance to these utilities and the cooperating research institutes to contribute with relevant solutions to this world wide occurring problem.

In the following subchapters the most important of these problems will be described.

2.1 Stable Operation of the System in total

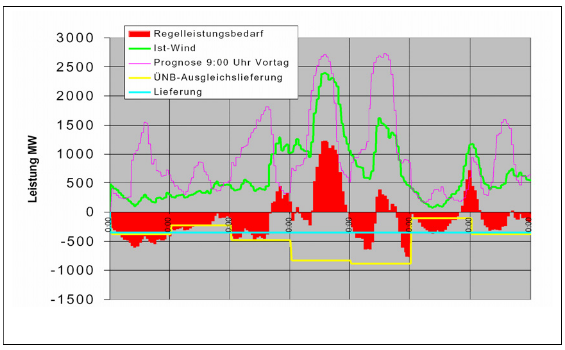
The European supply system for electrical energy is designed as a continental 400 kV system, which will be operated by several transmission system operators (TSO). These TSO`s have the responsibility for the save and reliable operation (frequency, voltage) of their part of the European grid. With respect to an intensive use of wind generation it is one of their main duties to compensate the intra day fluctuations of infeeds by wind power plants. In table 1 the tremendous amount of compensation energy will be shown very clearly for the VE-T grid.

Tab.1: Fluctuation of Wind Generation in VE-T Grid /5/

Total installed wind capacity	7.150 MW
Max. Generation Min. Generation	5.813 MW 2 MW
Max. Increase within 15 min. Max. Decrease within 15 min.	263 MW 312 MW
Max. Increase within 60 min. Max. Decrease within 60 min.	869 MW 825 MW
Max. Difference within 1 day	5.299 MW

Taking into consideration that the peak resp. low load in this grid is in the range of 11.000 / 4.500 MW a fluctuation of more than 5.000 MW within one day and nearly 900 MW within one hour will cause severe problems to keep the system stable. The capacity of the related pump storage power plants, which was designed in the past under total different circumstances is not sufficient to compensate these differ-rences between generation and demand.

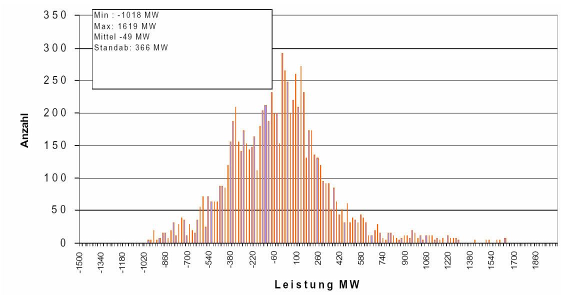
Fig. 5 Forecasted and real Wind Power Generation within 24 hours / 6 /



Quelle: e.on, 2001 -1-

Compensation energy has to be bought or sold on the spot market normally on a very high price level. Figure 5 shows an example between the day ahead forecast and the real infeed over a 24 hour period and in figure 6 an impression will be given of the distribution of the 15-min power mismatch values within a 3 month period.

Fig.6: Distribution of mismatches between forecasted and real power generation (15-min average) within a 3 month period / 7 /



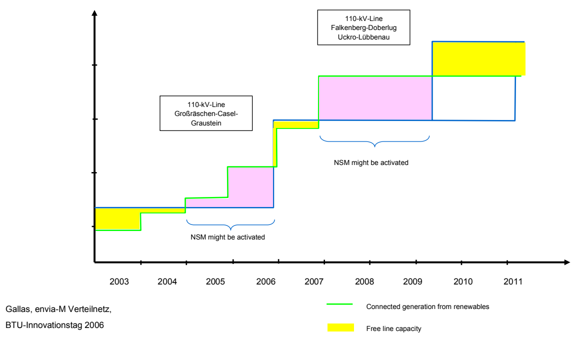
Quelle: e.on

These reflections of an intensive use of wind power generation lead to a restruc-turing of the grid structure itself. But this is a very time consuming procedure. In the actual revision of the EnWG (German Law on Energy Economics), 2005 /8/ the national government gave the opportunity to the utilities to adjust all relevant infeeds, transfers and loads in case of occurring system stability risks. To organize this on a technical basis, all generations (renewable or non-renewable), which want to be connected newly to the grid now are forced by law to install a device for remote control.

2.2 Thermal Over-Load of Lines and other Equipment

Although the system stability might be guaranteed within the grid, lines, cables or other equipment can be overloaded during a strong wind and low load situation in specific areas of the grid. To avoid disconnecting of lines due to thermal overload, dispersed generation might be disconnected within several periods of time. Network-Safety Management (NSM) Systems were commissioned in the East German Grid in the past 12 month /9/ and had to be activated for several times. Ongoing activities of the utilities to restructure their grids and to build up new lines will finally solve the problem of restricted transport capacity. Due to the erection time in Germany of up to 10 years for new transmission and distribution lines NSM-systems will become an essential part for a reliable grid operation. Figure 7 shows the up growing wind power feeding versus the increasing transport capacity.

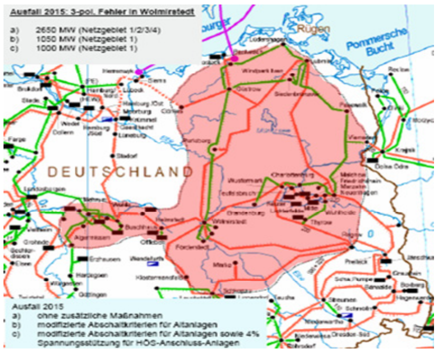
Fig. 7: Wind Power Generation versus Increasing Transport Capacity / 10 /



2.3 Voltage Drop after Short Circuit and Related Loss of Generation

In electrical grids severe voltage drops will occurs after short circuits. In case that the voltage will drop below 85 % of rated voltage, older types of wind power generators will be switched off. The investigation of the 380 kV national German grid /11/ showed that in case of a 3-phase short circuit at relevant nods in the grid a wide spread voltage drop will occur combined with an immediate loss of up to 4.000 MW of wind power. Figure 8 shows one example in East Germany where roughly 2.700 MW will be disconnected.

Fig. 8: Area with voltage drop below 85 % in case of 3- ph short circuit in substation WOLMIRSTEDT /11/



This unbalance will rapidly cause tremendous stability problems in the transmission system.

2.4 Generation of Reactive Power

The basic idea of an electrical energy supply system is to transport active power from the generator to the consumer. To energize the necessary electrical fields (voltages) and magnetic fields (currents) also reactive power must be available within the system. Actually the main source for reactive power is the generator itself. Within a conventional energy conversion system the generators are directly coupled to the grid. The adoption to the actual need of reactive power in the grid will be realized by the generator excitation system. The wind power generators usually are decoupled from the grid by frequency converters. This type of generation is not able to deliver reactive power to the grid and the frequency converter itself is a large consumer for reactive power.

In case of a strong wind situation more and more the problem occurs that directly coupled generators in classical power plants must be disconnected from the grid to keep the system stable. But this also will lead to a lag of reactive power which will be needed for the operation of the frequency converter in the wind mills. This again will cause problems with the voltage stability in the systems.

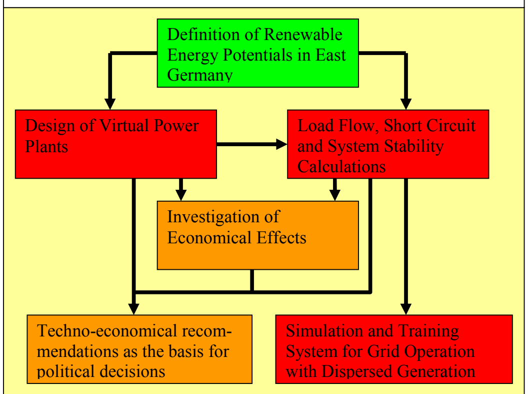
3 Possible Solutions

In spring 2006 the CEBra – Center for Energy Technology Brandenburg received the order from the Brandenburg Ministry of Economics to investigate the East German grid problems and to work out an overall strategy, how to integrate renewable energies to the East German grid within the next 15 years.

The project will be supported by Vattenfall Europe Transmission as the East German TSO and the two largest Distribution System Operators (envia-M Verteilnetz and E.ON edis) in East Germany.
Furthermore ENERTRAG as one of the largest wind farm operators (installed capacity over 500 MW) is engaged in the project.

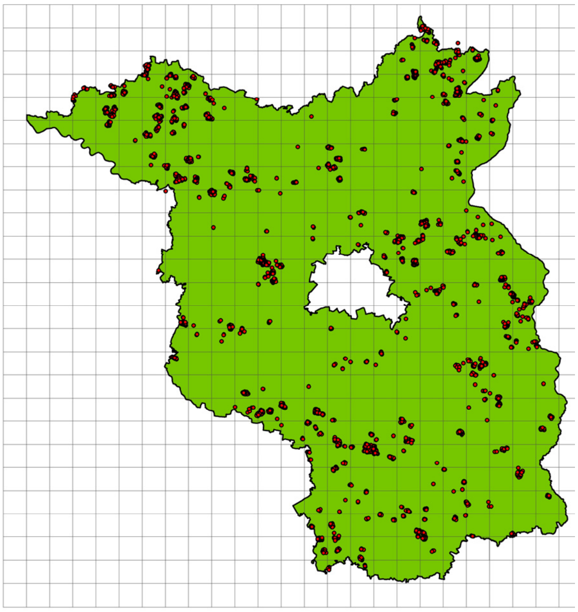
The project with a total work load of about 10 men-years in 2006 and 2007 is subdivided in the working packages shown in figure 9.

Fig. 9: Project Structure for Grid Integration Study



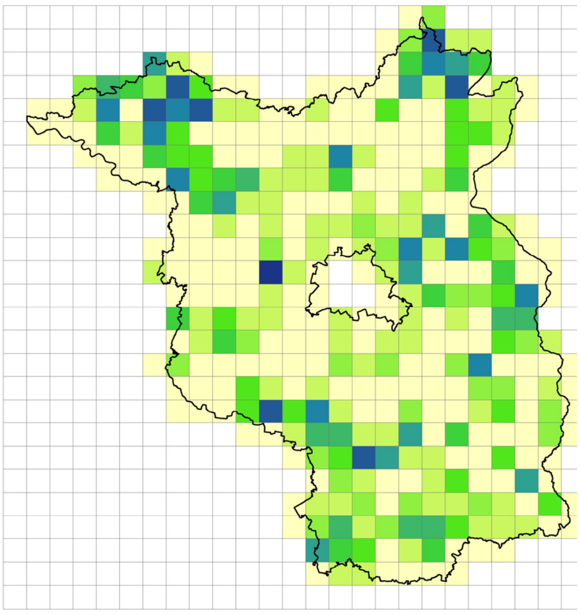
Actually CEBra works on the determination of the relevant potential of renewables (wind, water, biomass, photovoltaic) connected to the grid until 2010, 2015, 2020. Figure 10 shows an example for the distribution of the wind power plant in Brandenburg. These definitions must be made on a geographical basis, which is precise enough to use this for the following network calculations.

Fig. 10: Distribution of Wind Power Plants in Brandenburg



In a next step the geo-referenced data will be combined with the specific electric power output. The results will be clustered in a 10x10 km grid (fig. 11).

Fig. 11: Geo-referenced Electric Output of Wind Power



The following working package will investigated, how improve the network structure. Main advantage of the network calculations to be done by CEBra is the availability of the grid data from all utilities in one hand. This will offer several opportunities to optimize the overall grid structure and will hopefully lead to more cost saving solution in comparison with stand-alone solutions design by each utility itself.

Additional to these network calculations it will be investigated if virtual large scale power plants will be an adequate solution to reduce or solve the integration problems. Basic idea of these virtual power plants is to combine on a regional basis, wind or photovoltaic generation with its fluctuating characteristics with generation from biomass. Furthermore small storage systems either on the biomass or on the electric energy side will be taken into consideration. These different types of generation will be coupled with each other by private owned and operated small medium or high voltage lines and be connected to the public grid only at one connection point. This will offer the opportunity for renewable energy generation to compensate the fluctuating characteristic e.g. of wind or photovoltaic by own “regulating sources”, e.g. biomass or storages and to deliver the electric energy to the grid in a much more system compatible way.

In a following, economically based step the benefit of such virtual power plants must be compared with the optimized, but nevertheless classical network planning solutions.

Finally the project will focus on the design and installation of a grid-operation-training-system with respect to high fluctuating power flows. This training system will be either used to demonstrate the dynamic behaviour in electrical networks to non-specialist and to train utility staff in this special field of activity.

4 References

/1/ /2/ M. Weinhold
Lösungen zur Einbindung von Erneuerbaren Energien
BTU-Innovationstag Energie 2006, Cottbus

/3/ H.-J. Schloß
Aktuelle Trends im Transport elektrischer Energie
BTU-Innovationstag Energie 2006, Cottbus

/4/ W. Fichtner
EEG und CO_2 Emmissionshandel
BTU-Innovationstag Energie 2006, Cottbus

/5/ W. Neldner
Planerische und operative Beherrschung der Störfaktoren des Elektrizitätssystemes
BTU-Innovationstag Energie 2006, Cottbus

/6/ /7/ M. Luther, U.Radke
Betrieb und Planung von Netzen mit hoher Windenergieeinspeisung
ETG-Kongress 2001, Nürnberg

/8/ Gesetz über die Elektrizitäts- und Gasversorgung
Bundesgesetzblatt I-2005

/9/ H. Schwarz, S. Schulz

Increasing Dispersed Power Generation Leads to „Network Safety Management Systems (NSM) in Germany

WSEAS Transactions on Power Systems, January 2006

/10/ W. Gallas

EEG – Einspeisung – Folgen und Folgerungen für die envia NETZ GmbH

BTU-Innovationstag Energie 2006, Cottbus

/11/ Energiewirtschaftliche Planung für die Netzintegration von Windenergie in Deutschland an Land und Offshore bis zum Jahr 2020

Studie im Auftrag der Deutschen Energie-Agentur, Köln, 2005