

e-SolCar – one of the leading projects in e-mobility in Berlin and Brandenburg

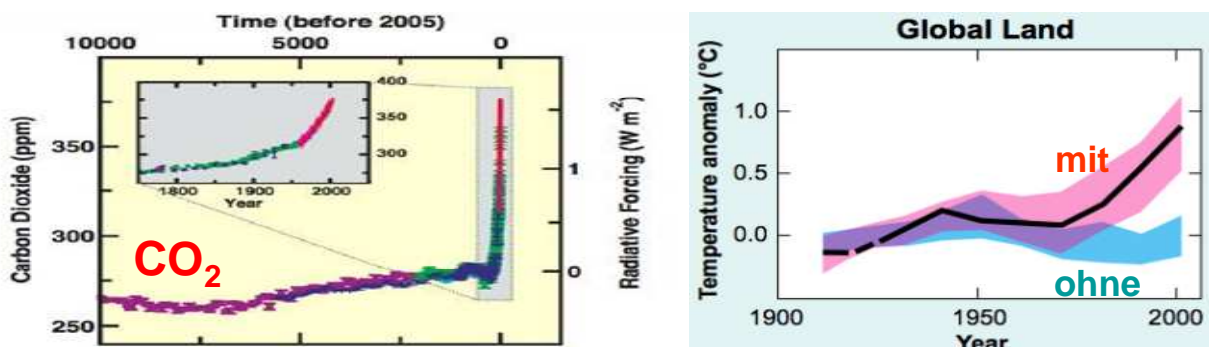
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Summary

The North-East of Germany is one of the regions of the world with the highest density of renewable energies. The consumer demand will vary between 4 GW to 11 GW. In addition to the conventional generation of about 15 GW actually another 12 GW from renewable sources and 7 GW from urban combined cycle were installed in the past decade. It will be expected that this generation capacity of 34 GW will exceed up to 50 GW within the next decade. This high overcapacity, combined with a limited transportation capacity of the transmission and distribution grids will be a real challenge for the grid operation. Together with the Ministry for Economics, the large grid and also wind farm operators Brandenburg University of Technology (BTU) in Cottbus made a large and detailed study (download www.tu-cottbus.de/cebra/) in 2006-08, how to improve the grid structure for these future needs. Based on this initial work our scope of investigation now focuses on the one hand side on different storage solutions, e.g. wide spread use of e-car batteries or use of electrolyzers, to store energy in the national gas grid. Especially the motivation for the e-mobility project e-SolCar and its interactions to other research activities on the roadmap to the total grid-integration of renewable energies will be described in the text below. Beside this, another focus will be put on the professional training of grid control staff. Together with 50 Hertz-Transmission, the East-German TSO, one of the most powerful grid research and training centers in Central Europe was built up in the past two years.

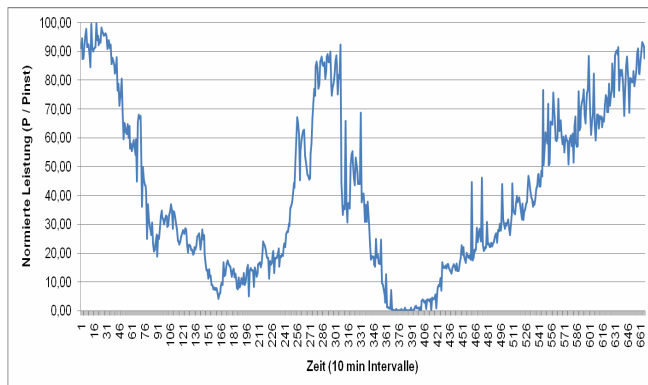
1 Motivation for the use of Renewable Energies

During the past 100 years a significant increase of CO₂ concentration in the atmosphere is detectable, which leads to a measurable increase of the global temperature.

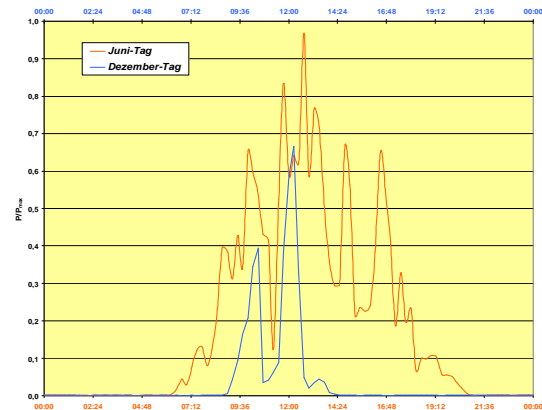


Taking also into account that about 24 % of CO₂ emissions in Germany are caused by power generation, German government decided to stimulate all kind of technolo-

gies which can contribute to reduced CO₂ emissions. This will include different solutions of carbon capture and storage in coal fired power plants, as well as a new debate to enlarge the life time of German nuclear power plants or several options to support technical equipment with higher energy efficiency. Based on the German EEG (law on renewable energies) power generation from renewable energies, e.g. hydro power, biomass or biogas, wind power and photovoltaic resp. solar or geo thermal systems will be highly supported. Especially the energy production from wind farms rose up tremendously in the past decade, followed now be an expected similar increase of photovoltaic.



Wind power Generation (5 day period)



PV Power Generation (1 day in summer (red) / winter (blue))

Due to their fluctuating power infeed, both renewable sources lead to a dramatic change in the German power supply structure.

2 Grid Restrictions for the Integration of Renewable Energies

a. Restrictions due to safety reasons

Electric current will cause ohmic losses in the lines. These losses will lead to an increasing temperature of the conductor material. On transmission lines this temperature rise will lead to a lengthening of the line conductors which will increase the slack span and will reduce the HV clearing distance to ground. In HV cables higher temperatures due to higher ohmic losses can cause damages in the cable insulation. Over-currents e.g. caused by high conventional or renewable infeed will be detected and switched off automatically to avoid any risk to personal or equipment. Depending on the actual situation, the automatic disconnection of some lines can cause a wide area black out in the electric system, Italy in 2003, N/E of USA in 2005 or parts of Western Europe in 2006.

b. Restrictions due to the balancing of generation and load

In difference to other sources is it impossible (except pump storage units) to build large storage units (hundreds of GWh) for electric energy. Therefore the generation in the power plant has to follow the consumer demand exactly minute by minute. Normal grid operation will be handled in a 15 min scale. The Transmission System Operator (TSO) is responsible to balance load and generation in Europe in an range of 50 Hz +/- 0,1 Hz. To make this tolerance band a bit easier to understand it is worth

to mention that this balancing is comparable to drive a car in a mountain area with a constant motor speed range of 3000 r.p.m. +/- 6 r.p.m.

c. Restrictions due to political decisions

Two politically driven Changes in German Power Market had a large impact to grid operation. First one is the liberalisation of Power market in Europe. Power Producer now can produce and sell electric power European wide without taking any care on the actual load situation of the grid area they are connected with. The grid operators are totally unbundled from the power producers and have to buy energy for balancing the system on stock market. The second severe change is the law on Renewable Energies (EEG) in Germany. Due to this law electric power from renewable source can be fed to grid at any point and any time and in principle without any restriction. Only in prevention of a system collapse renewable generation can be “adopted”. In this case the „not produced energy“ still have to be refunded.

3 Actual Status of Renewable Energies in Germany (N/E)

The following part is based on data from the grid operators in the North-East of Germany. This grid zone is operated by 50 Hertz-Transmission Ltd. (former Vattenfall Europe Transmission). The load in this area varies between 4 GW and 11 GW which normally should correspond with a conventional generation of about 12-13 GW and a pump storage capacity of about 2 GW.

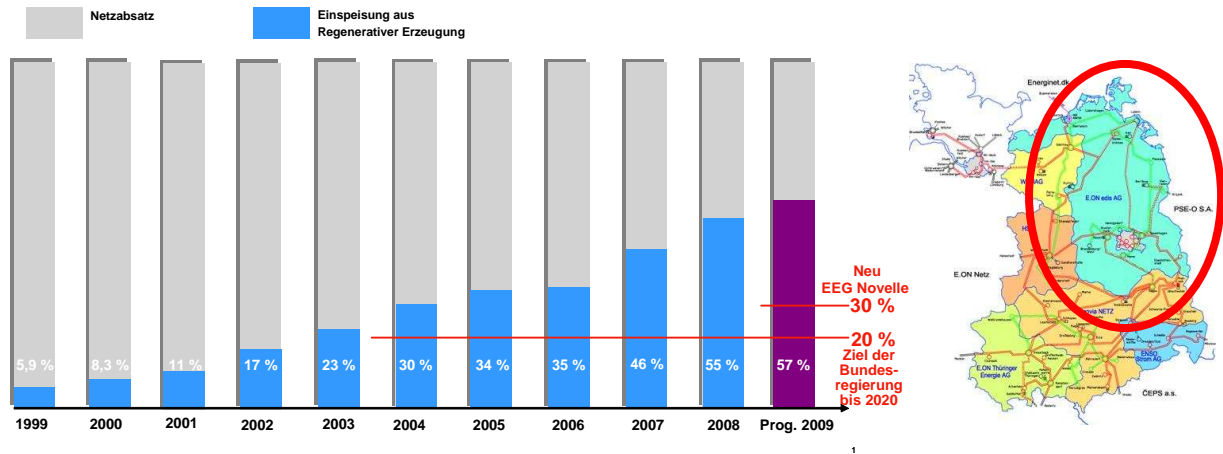


Meanwhile a total generation capacity of about 35 GW is connected to the grid and it will be forecasted to have 50 GW in 10-15 years. In strong wind situations a tremendous power flow out of this region towards south and south west (sometimes via Poland and Czech Republic) will occur, which often will bring the transmission lines to their capacity.

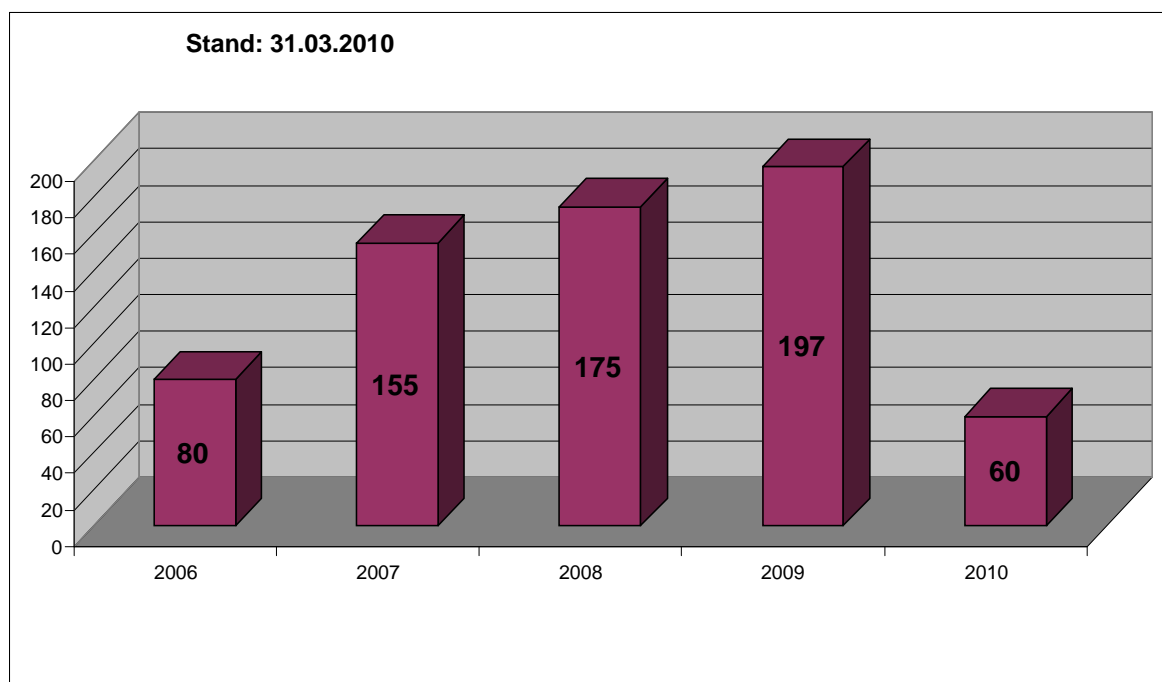


Power Plants in VE-T zone (P _{inst} in MW)	Voltage Level (kV)	
	380/220	≤ 110
Thermal	~ 12.860	~ 7.100
Pump storage	~ 2.400	~ 500
Wind enegy	~ 780	~ 9.700
Photovoltaic	0	~ 300
Biomass, others	~ 20	~ 1.200
Total	~ 16.100	~ 19.000
Total	~ 35.000	

The increase of renewable, especially wind energy in N/E Germany can be seen much better in a more detailed look on share of electric power in the distribution grid of e-on edis, the 110 kV and MV grid operator supplying the area surrounding and north of Berlin.

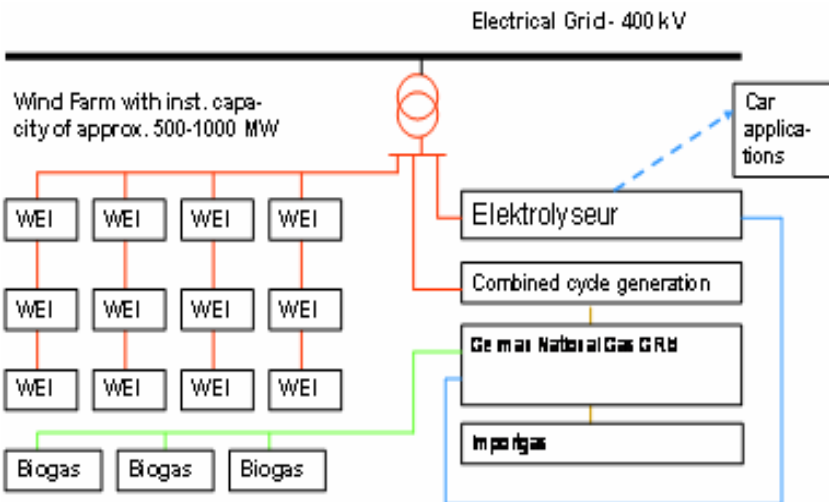
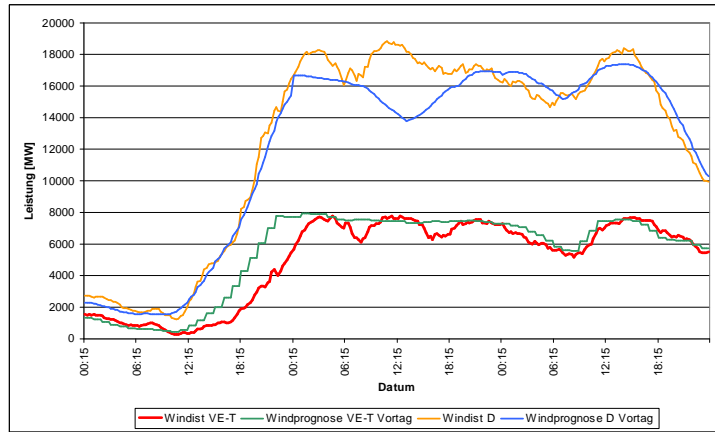


The unexpected power fluctuations in N/E Germany meanwhile reach values up to 4.000 MW per hour resp. 1.000 MW per 15 minutes. To protect the German grid against system instabilities caused by “regional over production” of renewable energies, government revised German law on Power Economics (EnWG) and put in a new paragraph, which now enables the grid operators to force e.g. the conventional power plants (independent power producers !!) to reduce their output accordingly to the needs of the grid. In the final end also renewable generation units can be forced to switch off their infeed, although German law on renewable energies (EEG) will guaranty them to feed to grid at any point without any restrictions. Especially in N/E Germany the number of days with such counter measurement permanently increased.



a. Storage as the long range strategy

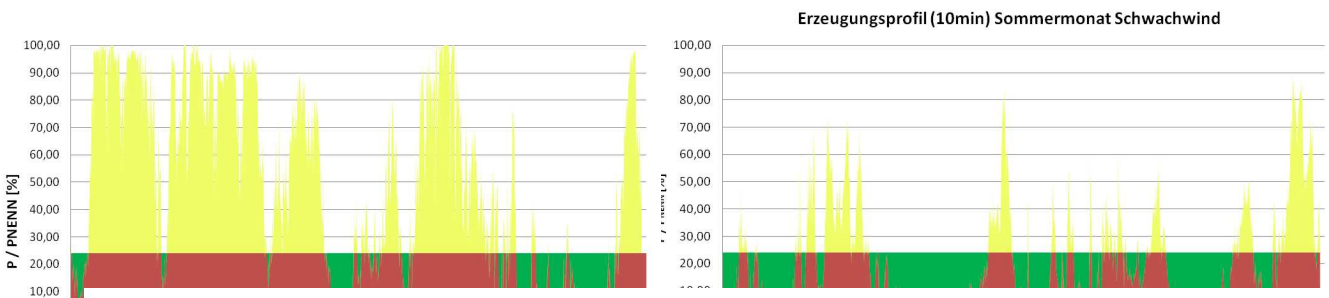
In the figure below the forecast as well as the real infeed of wind power during a strong wind situation in total Germany (upper curves) and N/E Germany (lower curves) can be seen for a time slot of about 60 hours. About 420 GWh was fed to the grid of 50 Hertz Transmission during this storm. Approx. half of this energy can be absorbed by the load. The rest must be either stored or transmitted to other regions in Germany or Europe. The largest German pump storage unit is located in N/E Germany with a capacity of 8 GWh. The whole storage capacity in the 50 Hertz-T Zone is 20 GWh, which is not sufficient to absorb the huge amount of “unneeded” renewable energy. One option to solve this problem is to build up “Renewable Hybrid Power Plants”, which will combine several renewable sources with a conventional combined cycle unit and an electrolyser to transfer electric energy to the national gas grid.



Principle Design of a Renewable Energy Hybrid Plant

BTU Cottbus investigated different options for such hybrid plants to optimize the amount of energy to be fed directly to the electric grid resp. to the gas grid in winter or summer. A direct infeed of 25 % of

the wind energy seems to be to best value to realize a fully renewable generation from the hybrid plant, based on annual energy output.



Power output of an Hybrid Plant in a winter (left) and summer (right) month
 Yellow – Power to electrolyser, brown – wind power to grid, green – combined cycle power to grid

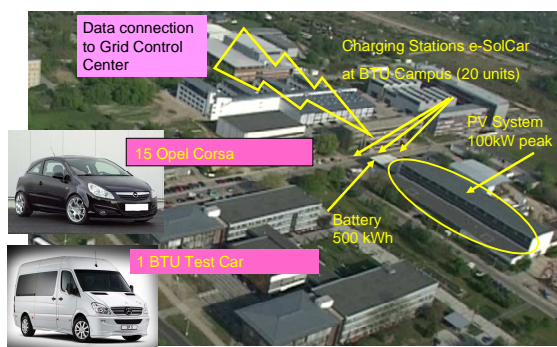
Another option for large energy storage might be the emerging grid connected electric cars (fully electric or plug-in hybrid or range extender). If e.g. all of the 8 million cars in Eastern Germany would be electric ones and equipped with the nowadays typical 20 kWh battery, a total storage capacity of 160 GWh could be established. Unfortunately several technical solutions for the data exchange between grid and cars or the needed bi-directional charging units are not available yet. Furthermore we have no experience how much of these cars will be connected to grid and will have what charging status of their battery in case of emergency in the grid. Together with

- Vattenfall Europe Generation,
- Vattenfall Europe NetCom
- 50 Hertz-Transmission,
- German-e-Cars and its newly founded sister company in Cottbus,
- Opel,
- Mercedes
- DEKRA Test Center Lausitzring and
- several federal state ministries,

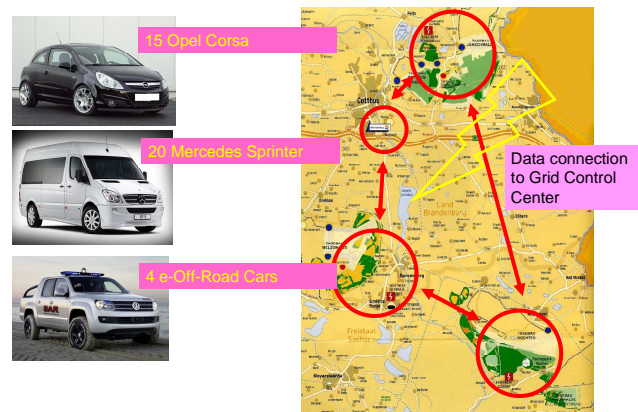
BTU will start a 3 year project called e-SolCar in autumn 2010 to investigate the impact of an e-cars based distributed storage to the grid. This project will include

- the development and manufacturing of 30 newly designed electric cars based on Opel Corsa
- the development and manufacturing of 17 newly designed light commercial vehicles based on Mercedes Sprinter either as pure electric cars or equipped with range extender
- the development and manufacturing of 4 SUV`s based on Toyota Highlander
- the development and manufacturing of bi-directional car charging units incl. communication interface between the battery management and the grid control center.
- the development and manufacturing of range extenders
- the aspect of urban PV-generation and the possible option to use this type of renewable energy directly in urban e-car-charging stations.

Part of the project at BTU-Campus



Part of the project in the Cottbus region



b. Grid extension as the medium range strategy

Together with several grid operators as well as operators of large wind farms and biomass power plants BTU carried out a large investigation for the ministry for economics in the State of Brandenburg in the years 2006-08 to define the needed grid extension to absorb the additional renewable power, which is forecasted until 2020. Actually about 4.000 MW of wind power is installed in this federal state surrounding the city of Berlin with an extension of approx. 300 km north / south and 200 km east / west. The political goal is to install another 3.000 MW in this region until 2020.



To enable the grid operator to absorb such a huge amount of renewable energy, to distribute it to the load or to transmit it to load centers far away in the south of Germany or somewhere in Europe a total redesigned electric grid on 110 and 380 kV will be needed.

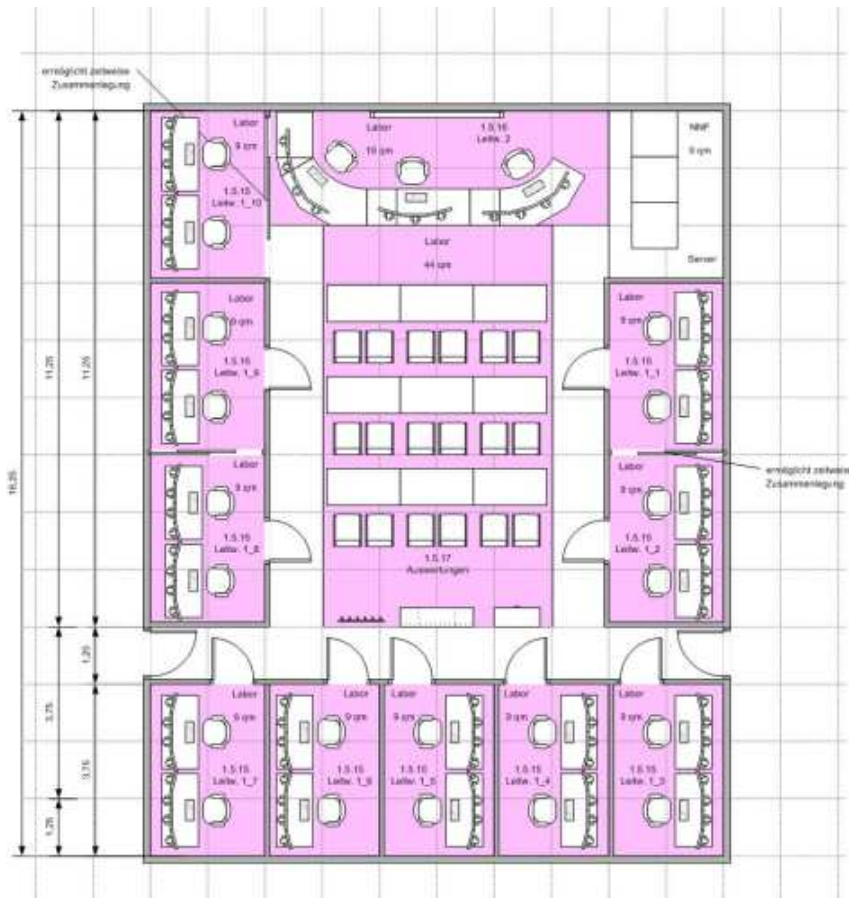
Due to BTU investigation approx. 1.200 km of new distribution lines on 110 kV level will be needed. Additionally up to 600 km of new 380 kV transmission lines will be needed in Brandenburg. Total estimated costs for these investments will be approx. 1 billion €. Unfortunately a nationwide discussion on the future power supply structure rose up in the past decade. In some regions people are demonstrating against open cast mining together with coal fired units, in other regions they protested against large wind farms or underground storages for carbon dioxide and also the erection of high voltage transmission lines can take up to 10 years to build them. Combined with the permanent increase of renewable power, a critical combination of undefined risks for a save and reliable grid operation.

c. High professional training as the short term strategy

To ensure a save operation of electric grids in Central Europe, a continuous training on high professional level for the staff of the grid control centers will become necessary more and more. In 2008 it was decided from 50 Hertz Transmission to build up such a training center at BTU Campus in Cottbus.



To build up such a training center for a complex training for up to 10 interconnected grid operators, a powerful software for grid calculation will be needed as well as a control system, which is able to simulate the same functionality the trainees know from their own grid control center. Both software packages are available on the market. Unfortunately the calculation for grid with 50.000 nodes is about 3-5 minutes, which is not suitable to realize a “real-time feeling” for the trainees. Together with several companies BTU improved the commercial system, so that the calculation time now is in the range of some seconds and can create stress situations to the trainees, similar to the ones during strong wind situations.



Training center in the new BTU building (2012)

d. High qualified research and teaching as an permanent goal

In 2005 BTU started its activities to build up a master programme in power engineering fully taught in English language, which contains 3 branches of studies with 2 specializations each in

- Electric Power Engineering with specialisations in
 - Power Transmission and Distribution
 - Electric Grids and Drive Systems in Power Plants
- Power Plant Technology with specialisations in
 - Fossil Power Plants
 - Nuclear Power Plants
- Sustainable Energy Supply with specialisations in
 - Renewable Generation
 - Energy Supply of Large Buildings

Approx. 35- 40 % of all lectures will be offered by experts from industry. The 4th semester (Internship and master thesis) can be fully organized abroad and/or in cooperation with industry.

A global network of cooperation universities in China (5), Taiwan (1), Russia (3), South Africa (2), Brazil (3), Eastern Europe (3) and Pakistan (1) was built up. Actually 3 dual degrees with cooperating universities will be offered. Medium term goal is 5-8 dual degrees.

German and international companies will offer different kind of support to students in this programme (internship, industrial supervised master theses, part or full scholarships). Actually 25 scholarships can be offered, the medium term goal is 50.

For more details please check www.tu-cottbus.de/cebra/.