

# Application of the East German Grid Experience in Renewable Energies Integration into the Brazilian Energy System

Milthon S. Silva<sup>1</sup>, Harald Schwarz<sup>2</sup>, Klaus Pfeiffer<sup>2</sup>

<sup>1</sup> CCET/NEL UFS BRAZIL

<sup>2</sup> Chair of Power Distribution and High Voltage Technology

## Kurzfassung

Brasilien, ein Land mit über 8,5 Millionen km<sup>2</sup> Fläche, erfährt gegenwärtig einen Zubau an installierter elektrischer Leistung von ca. 4,5 % jährlich und wird die 100 GW Marke 2008 erreicht haben. Die Energieversorgung stützt sich hauptsächlich auf große Wasserkraftwerke, die aber in den letzten Jahren aufgrund von zunehmendem Wassermangel nicht ihre volle Leistung einspeisen konnten. Dies hat zur Folge, dass ca. 70 % der Bevölkerung von Beschränkungen im Energieverbrauch betroffen sind. Aufgrund der Energieknappheit ist die brasilianische Regierung bestrebt, die erneuerbaren Energien zu forcieren. Die brasilianische Regierung startete im Jahr 2002 ein Alternatives Energie Programm (PROINFA), welches Anreize für den Ausbau von erneuerbaren Energien liefert. Dieses Programm ist so angelegt, dass im Laufe der nächsten 20 Jahre die erneuerbaren Energien einen Anteil von 10 % an der brasilianischen Energieerzeugung erreichen sollen. Gegenwärtig beträgt die weltweit installierte Leistung von Windkraftanlagen 59 GW, wobei davon ca. 31 % an die Netze der deutschen Netzbetreiber angeschlossen sind. Der Beitrag zeigt einen allgemeinen Überblick über Probleme der Netzintegration von Energieerzeugern auf Basis erneuerbarer Energien. Weiterhin werden Lösungsvorschläge und deren mögliche Übernahme für den wachsenden Markt in Brasilien gezeigt.

## Abstract

The Brazil a country with over 8.5 million km<sup>2</sup> of continental territory and whose electric power market is experiencing growth on the order of 4.5 % per year, and should top the 100 GW mark by 2008. The Renewable Energies especially wind energy is moving the Brazilian government politically and economically, largely due to the electricity shortages that happened in the last years for water lack in the power-generation parks that is predominantly fed by hydraulic sources, forcing 70 percent of the population to cut back on energy consumption and sent the authorities scrambling to come up with solutions. The Brazilian government launched in 2002 the Alternative Energy Program (PROINFA), which provides incentives to renewable sources. The program is designed aiming the renewable sources to achieve 10 % of the Brazilian power production and this goal is supposed to

be reached within the next 20 years. Actually there are 59 GW of wind power generation capacity installed around the world and about 31 % is connected to the German grid that is the country with bigger experience into this area. This paper presents a general overview of the renewable energies integration problems and solutions in Germany and possible implementation in the new growing market in Brazil.

## 1 Introduction

The Brazilian Government launched in 2002, the Incentive Program for Alternative Electric Generation Sources (PROINFA). The main objective of this program is to provide incentives to renewable energy in Brazil, contributing to the development of clean technologies and the improvement of the quality of the environment, taking in consideration that according the preliminary estimates the potential of wind energy generation in Brazil is 143,000 MW/h.

The main goal of PROINFA is to establish incentives to make renewable energy economically competitive in the Brazilian electric sector. This aim is backed by the guarantee of wind energy purchase by the state-run ELETROBRAS (Holding of Brazilian Power System). The costs of wind energy production in Brazil are still nearly 40 percent higher than those related to hydroelectric production. But there is a tendency for wind energy to become cheaper, agree experts. In contrast, the costs of hydroelectric energy are on the rise, especially in environmental terms, because it requires the flooding of extensive forested or farming areas in order to create the reservoirs and transmission is costly as the rivers that can be used to generate electricity are usually far from the urban centers that consume the electricity produced.

Almost 70 % of the possible future hydroelectric projects will demand higher investment than those for the wind farm projects. Another advantage of the wind farm, relating to hydroelectric plants, is that all the area occupied by the wind farm could also be used for other purposes (cattle breeding, agriculture, etc.), or even preserved as a natural habitat.

According with the CBEE (Brazilian Wind Energy Center), the implementation of wind energy in Brazil could also be used to solve the

problem of water usage (electricity generation against irrigation), as an example in the Sao Francisco River. Huge projects for irrigation purposes could cause an unexpected and undesirable impact on the water volume in the hydroelectric plants reservoir. Consequently, this would affect the electricity production and supply for the whole region. Although, looking in the wind speed shape for this region, it can be seen that the highest wind speeds occur during the river water flow minimum along the year. Thus, wind farms could generate a great amount of energy, avoiding the usage of the river water for electricity production. [2]

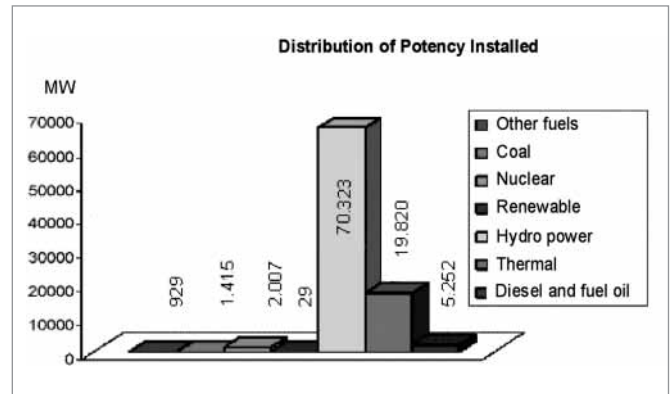
In addition to that, many isolated communities in Brazil use diesel for electricity generation. Only in the Amazon region, more than 500 communities employ diesel generator, affording operational costs between 0.20 €/kWh and 0.68 €/kWh. Wind turbines coupled to the existing diesel systems (wind/diesel hybrid systems) could promote substantial savings if we take into consideration costs involved with fuel purchase, transportation, storage, operation and maintenance of the system, never mentioning the environmental pollution reduction.

## 2 Brazil's electric power market

The Brazilian electricity system is characterized by an overwhelming reliance on hydropower as shown in Tab. 1. In years of normal precipitation, over 80 % of the country's electricity comes from a network of hydroelectric dams (Fig. 1), most of which were built by state companies over decades and are largely amortized. A few coal plants exist near coal reserves in the South, but thermal power mainly supply isolated markets.

**Table 1:**  
Power generation plants operational in Brazil (2005) [1]

Type	Number of Plants	Installed Capacity (MW)	Percent of Total Generation (%)
Hydropower	578	70.323	<b>76,2</b>
Plants	147	68.938	
Smalls units	431	1.384	
Thermal	838	19.820	<b>21,5</b>
Natural Gas	69	9.157	
Diesel and fuel oil	480	5.252	
Biomass	256	3.068	
Coal	7	1.415	
Other fuels	26	929	
Nuclear	2	2.007	<b>2,2</b>
Renewable	12	29	<b>0,1</b>
Wind	11	29	
Solar	1	0	
<b>Total</b>	<b>1.430</b>	<b>92.179</b>	<b>100</b>

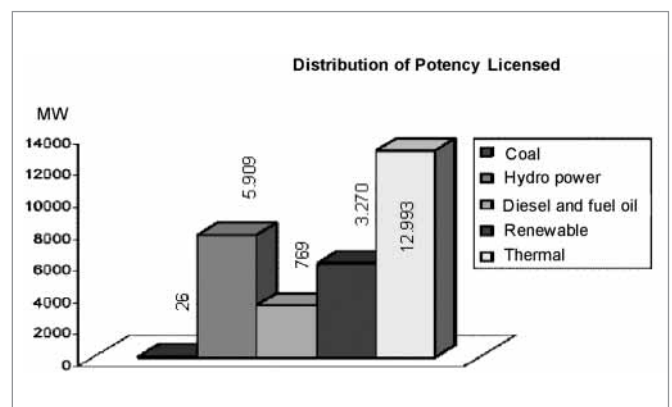


**Figure 1:**  
Brazilian energy matrix [1]

The Brazilian electricity system is large, accounting for almost 40 % of electricity consumption in Latin America. In 2000, the transmission line that links North and South started operation, creating a large single integrated system that supplies most of the country's population. Transmission remains a constraint to the flow of power between regions, particularly between the North-Northeast and the South-Southeast. Several isolated grids operate in the Amazon region, but these isolated grids are progressively interconnecting to the integrated system.

Although a substantial untapped hydropower potential remains (95 GW), the cost of developing new hydro sites is rising. The most attractive new sites are located far from the existing grid, demanding substantial investment in transmission lines to deliver their power to consumers. Moreover, new hydro sites face severe environmental regulations and their development especially by private investors faces a lengthy, expensive and uncertain permitting process.

To induce the use of renewable energy sources the Alternative Power Sources National Program (PROINFA) in the Portuguese acronym was recently created. This program offers subsidies to encourage investment in three technologies: wind power, biomass and small hydro. Projects up to about 3 GW are eligible to receive subsidies and until 2004 different projects were licensed as shown in the Fig. 2.



**Figure 2:**  
Energy potency licensed in Brazil until 2005 [1]

### 3 The Brazilian wind potential

Brazil has continental spatial dimension equivalent to 8/9 of Europe, therefore it is not inconceivable that good wind resources can be found in many parts of the country. Almost the total Brazilian territory is embedded between the Equator Line and the Southern Sub-tropical Belt. Large scale atmospheric circulation is controlled by the Tropical energy constraints, which means small potential energy reservoir and the largest latent and sensible heat stock of the planet. The geotropic adjustment does not work as a realistic assumption for numerical models and synoptical activity is lower than in Mid-latitudes. Large scale low level circulation is illustrated by the equator ward branch of the popular Hadley Cell.

Trade Winds, originated on this surface flux, are the main atmospheric characteristics of the northern part of Brazil. The Trade Winds are known as the most stable system on the earth surface, with a strong seasonal cycle controlled by the position of the Inter tropical Convergence Zone a cloudiness fine line defining the Earth Thermal Equator separating North and South Tropical Circulation. Eastern waves, originated on the African Highlands, also can be detected on the Northeast region of Brazil during last months of the year.

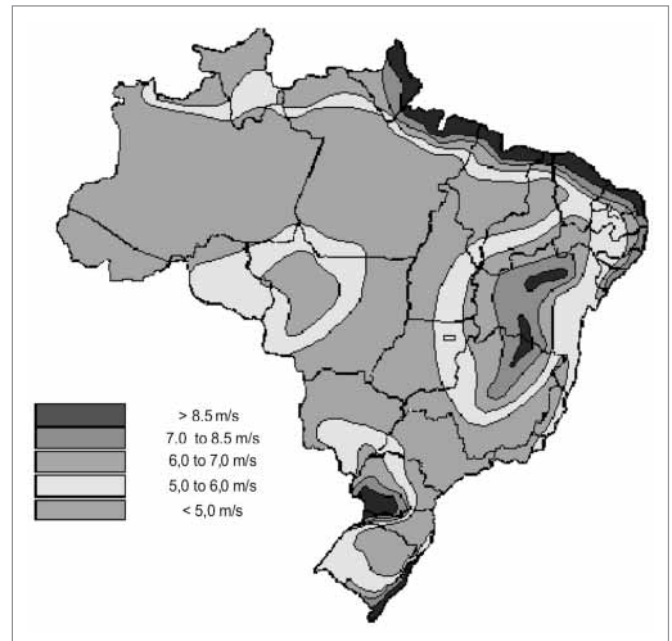
Southern Brazilian States show a hybrid tropical to Mid-latitude behavior implying greater front activities while Northern States have a basic tropical nature with short life atmospheric system and pronounced annual cycle.

Most of Brazil's orography is rather simple with neither relevant mountain chains nor highlands, emphasizing the predominate role played by the large scale circulation. Land cover, also, plays a dramatic role, especially, referring to the atmospheric boundary layer of the Amazon basin and the Northeast Region dry inner-lands. [5]

The first anemometers installed in the Island of Fernando de Noronha – Pernambuco and in the coast of Ceará (states located in northeast and north of Brazil respectively) revealed a yearly average wind speed of about 8m/s. The analysis of wind data in the last years from several sites in the Northeast coast confirmed the characteristics of the southeast trade-winds: uniformity of wind speed and direction during the whole year, exceptionally high Weibull shape factor ( $k^3=3$ ) when compared to sites in US or Europe, low turbulence intensity and low variability of wind directions (almost unidirectional wind).

The Fig. 3 shown the Brazilian wind atlas published by CBEE with support of the ANEEL (Brazilian Electricity Regulatory Agency).

The wind power generation costs in Brazil, according of different studies is already comparable to thermoelectric, nuclear and even new hydroelectric plants. The Tab. 2 below shows the generation costs of several energy sources for new projects in Brazil according, this information appear in the electric sector plan ELETROBRAS document for 2015. The cost of energy generated by new hydroelectric plants in the Amazon region (another option investigated by the electric sector) would be fairly higher than those already built.

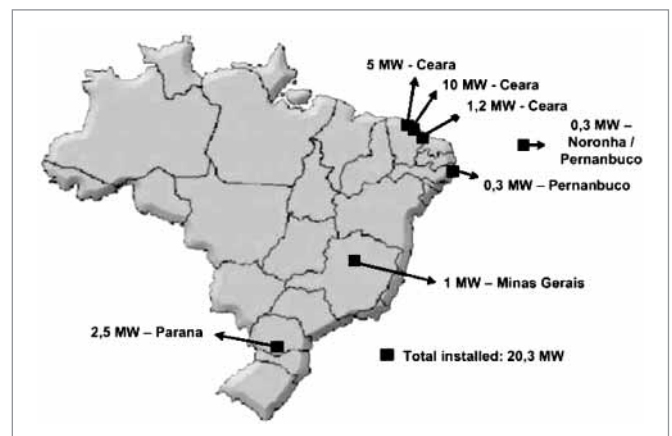


**Figure 3:**  
Brazilian wind atlas [5]

**Table 2:**  
Cost comparison of several energy sources [4]

Energy Source	Potential (GW)	Generation Cost(€/MWh)
Biomass	27,7	32 to 65
Wind	28,9	32,5 to 70
Coal	17,5	41,7 to 54,2
Natural Gas	4,8	32
Imported Coal	-	40,8
Imported Natural Gas	-	39,2

The principal wind energy projects installed until 2004 in Brazil are shown in the Fig. 4, the most of the wind parks are located in the northeast region, which is worst off as far as water sources, but much favored by the winds. [4]



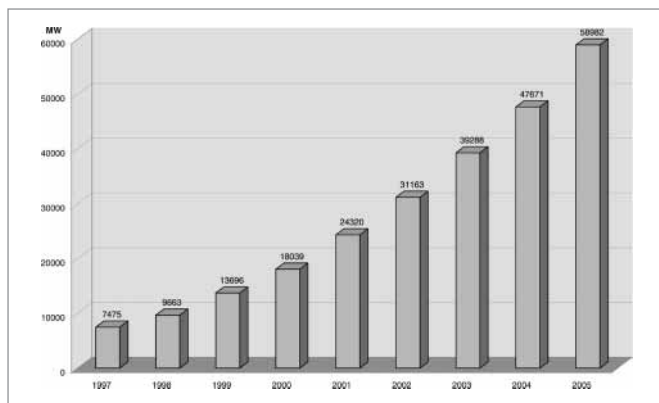
**Figure 4:**  
Wind parks installed in Brazil [2]

## 4 Worldwide Wind Energy Development and the German Market

The last year was another record period for the worldwide wind energy utilization. The wind energy international market includes more and more countries, with 59 GW installed worldwide until 2005. Worldwide, 11,3 GW were added in 2005, after 8,3 GW of additional capacity in the year 2004, and 8,1 GW in 2003. The global rate of growth increased to 24 % in the past year 2005, after 21 % in the year 2004, as shown in the Fig. 5. With this dynamic increase continuing, WWEA (World Wind Energy Association) expects 120 GW to be installed worldwide in the year 2010. Today, wind energy delivers worldwide around 1 % of the global electricity generation, with some countries and regions reaching 20 % and more. [10]

Europe remains in the position as the number one continent in terms of overall capacity (40,9 GW) as well as additional capacity of 6,2 GW representing 55 % of the globally added capacity. The European market showed a growth rate of 18 % especially Germany and Spain kept their positions as the leading markets with a robust growth.

Future substantial growth can be expected in the coming years in most of the EU countries because of the increasing awareness of the contributions of wind power to energy security. The European Commission announced recently that it will take care of an effective implementation of the directive for renewable energy electricity.



**Figure 5:**  
Worldwide wind energy evolution [10]

Generation from renewable energies was recognized in Germany since mid of 1970. In the time period from 1975 to 1995 approximately 3000 MW was installed in total, especially in wind power. At that time the German government decided to establish a national law to promote renewable energies (EEG). While the normal generation costs from thermal power plants are in the range of 0,03 €/kWh a rate of 0,09 €/kWh from wind energy is guaranteed.

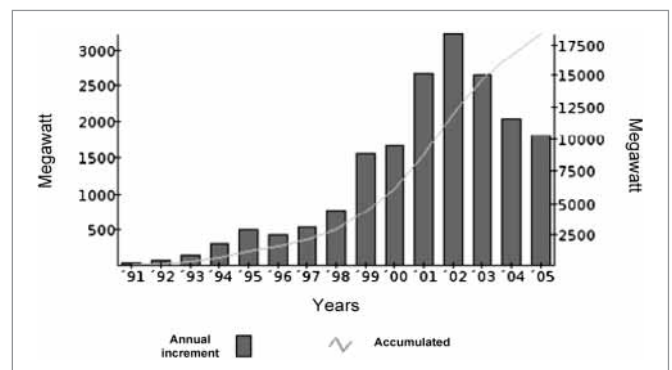
The DENA (Germany Energy Agency) presented in May of 2005 an energy electric grid study, which shows a scenario of the development of wind energy making the analyses in the long-time consequences of an increased share of renewable energy in Germany, for the electrical system, with a time horizon of up to 2020. The extension of wind power

will lead to strong geographic concentration in Northern Germany, a region with relatively low electricity demand. The integration of large amount of wind energy into the grid creates challenges for the entire power system.

A gradual increase in effective wind turbine capacity factors has been accounted for, corresponding with expected wind energy technology improvements and the use of more windy locations, especially offshore. The installed wind power increases from 14,5 GW in 2003 to 36 GW in 2015, of which 27 % offshore. The total annual wind energy output raises from 23,5 TWh in 2003 to 77,2 TWh in 2015, effectively increasing the share of wind power in covering the national electricity demand from 4,3 % to 14 %. Offshore wind energy can provide 42 % of the wind energy output in 2015. [3]

## 5 Wind energy german system experiences

Actually a total amount of 59 GW of generation from wind power is installed around the world. With a capacity of nearly 18 GW (end of 2005) about 31 % of the world wide wind capacity (see Fig. 6) is connected to the German grid. This situation in the last years is generating the lines transmission overloaded, that happen in period of time with full wind power feeding combined with low load in the grid. That leads to a national discussion to expand the high voltage overhead line, that with past experiences it can take 5 to 10 years to get all necessary permissions to build a new line in Germany. German utilities started to improve the boundary conditions to speed up network work expansion, but meanwhile network safety management systems will be established to keep the grids stable.

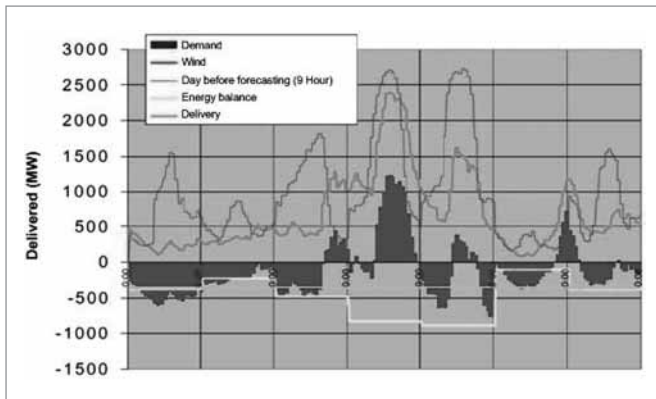


**Figure 6:**  
Wind power capacity installed in Germany [6]

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

The European supply system for electrical energy is designed as a continental 400 kV system, which will be operated by several TSO's (Transmission System Operator). These have the responsibility for the

save and reliable operation (frequency, voltage) of their part of the European grid. In consequence to an intensive use of wind generation it is one of their main duties to compensate the intra day fluctuations of infeeds, this compensation energy has to be bought or sold on the spot market normally on a very high price level. The Fig. 7 shown an example between the day ahead forecast and the real infeed over a 24 hour period.



**Figure 7:**  
*One day real wind power generation forecasting [8]*

These reflections of an intensive use of wind power generation lead to a restructuring 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), 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.

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. NSM's (Network-Safety Management Systems) were commissioned in the East German Grid in the last twelve months and had to be activated for several times. [7]

In parallel 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's will become an essential part for a reliable grid operation.

On the other hand in electrical grids severe voltage drops will occur 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 showed that in case of a 3-phase short circuit at relevant nodes in the grid a wide spread voltage drop will occur combined with an immediate loss of up to 4.000 MW of wind power. [9]

Other problem with relation to use the wind energy is the generation of reactive power, because this type of generation isn't able to deliver reactive power to the grid and the frequency itself is a large consumer of him. 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.

For the solution of the problems previously mentioned, the CEBRA (Center for Energy Technology Brandenburg) is developing a geo-referenced database will be combined with the specific electric power output. 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. 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“, example 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. [8]

## 6 Conclusions

With the implementation of the Renewable Energy Incentive Program (PROINFA), Brazil has become the leading market for renewable energies in Latin America. It is expected to be generating 150 thousand jobs in this program and leverage private investments of around 3,25 billions €. The national industry expected to produce more than 1,5 billions € in equipments and materials. Other advantage of PROINFA is the growth in renewable energy, with provides more flexibility in Brazilian power production that is mainly hydroelectric. The efficient use of renewable energy can contribute significantly to sustainable development as well as to local and global environment conservation.

Actually due to intensive funding on the part of the German government, the amount of dispersed generation (especially wind generation) increased rapidly in the last years and the legislation prescribes that the network operators have to connect all dispersed generation. However, this growth causes difficult load situations in the power supply

system especially in the distribution networks become overloaded during strong wind situations combined with low network load.

All the entities (Universities, utilities, operators, etc.) involved in the power system area mainly in the East German grid are researching and work out an overall strategy, how to integrate renewable energies to the grid in a more system compatible manner and whose experiences can be applied in the new growing wind energy Brazilian market.

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**Dr.-Ing. Milthon Serna Silva**, born in August 30 1972, graduated in electrical engineering at UN-SAAC University in 1993. MSc in 2001 and PhD in 2004 at the Polytechnic School of Sao Paulo University. Worked in construction of line and substation high voltage systems projects and Power System Planning by GyM, Siemens and GAGTD (Energy Distribution and Transmission Generation Automation Group). At the moment he is doing his post-doctoral course in Brandenburg University of Technology Cottbus and working in the Integration of Renewable Energies project in Germany. Member of Brazilian work Group SC13.23 to CIGRE and Member of IEEE.



**Prof. Harald Schwarz** (49) studied Electrical Engineering at the Technical University Berlin with concentration in Electrical Power Engineering. In the following he joined the University of Dortmund to do a doctorate. From 1987 until 1994 he was with ABB company in Mannheim. There he worked in the field of large power transformers and high-voltage substations. In 1995 he joined Brandenburg University of Technology Cottbus (BTU) where he became the Head of the Department Power Distribution and High-Voltage Technology. From 2000 until 2004 Prof. Schwarz was the Vice Dean of the Faculty for Mechanical, Electrical and Industrial Engineering. Since 2004 he is the Managing Director of the Center for Energy Technology Brandenburg (CE-Bra), which is the Energy Research Coordination Center at BTU Cottbus. Furthermore he is currently the provisional Head of the Department Decentralised Power Systems and Energy Storage.



**Dr.-Ing. Klaus Pfeiffer** (37) studied Electrical Engineering with concentration in Electric Power Supply at the Technical University Dresden. His diploma thesis was in the field of electric power systems and appliances. From 1996 until 2002 he worked as an engineering consultant for planning of electric power supplies with main focus on fundamental calculations and concepts for selective protection for new built power stations with high unit capacity. In 2002 he joined Brandenburg University of Technology Cottbus, Department of Power Distribution and High-Voltage Technology. In 2005 he received his doctor's degree with a thesis in the field of application of high-temperature superconducting fault current limiters.