# Storm signs in the grid -
## Are we able to recognize the precursory warnings signs of blackouts in time?

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*"Bulletin SEV/VSE – Bulletin SEV/AES" No. 15/2006 from electrosuisse SEV Verband für Elektro-, Energie- und Informationstechnik und VSE/AES Verband Schweizerischer Elektrizitätsunternehmen (electrosuisse SEV Association for Electrical Engineering, Energy and Information Technology and VSE/AES Association of Swiss Electricity Suppliers). It has been adapted to the "A.Eberle – print design" and also contains full length interviews with Dr. Fette and Mr. Mayer.*

*In the Annex an interview with Dr. Fette is appended relating to the Blackout on 4 November 2006, which has been published in the 5/2007 issue of „Bulletin SEV/VSE" from electrosuisse SEV.*

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# Storm signs in the grid -

## Are we able to recognize the precursory warning signs of blackouts in time?

*Being able to recognize the precursory warning signs of a grid breakdown in time can avoid a blackout. Characteristic changes recognizable in the frequency domain indicate that such an extreme event is on its way. Modern measurement devices can detect such changes. Coupled with the use of nonlinear mathematical models, we can calculate how close to the breakdown the grid lies. Given such information, a grid operator is able to take the necessary preventive steps in good time.*

The city of New Orleans has not yet recovered from the „deep impact“ of hurricane Katrina. „Katrina“ also raged in the Gulf of Mexico and 58 out of the 645 oil drilling platforms were torn apart and up to 30 have simply disappeared. A quarter of US exports into the rest of the world pass through Gulfport, Louisiana. The oil from the gulf, which makes up a quarter of the oil used up in the USA, is processed to gasoline directly by on-site refineries. Subsequently, one of the results of the hurricane, which had a rapid effect worldwide was the shortage of the mineral oil supply that has further intensified during 2005. In England, the price of gasoline temporarily reached the magical limit of £1.00 per liter and in Germany 1,50 € per liter.

It is quite obvious that the worldwide hunger for energy leads to crises which may end in disaster. Today‘s primary energy consumption greatly surpasses the forecasts that were made between 1970 and 1980 for the year 2000.

Industrial growth is directly coupled with the increasing need for electrical energy. At an economic growth rate of 10% per annum, both in China and India, the result is a permanent lack of electrical energy. Since 2004, in India many outages of the electrical current frequently left several federal states without any electrical energy supply. Recently in Israel, New Zealand and Cambodia the electricity supply grid completely and abruptly broke down, but the most severe blackout occurred in Europe on 4 November 2006. In the western area of the EU 10 Mio. people were affected when the power supply broke down for about an hour due to a cascading power collapse originating in Germany, see Annex.

So the question arises whether such disasters can be „forecasted“ or at least their precursory warning signs can be recognised and interpreted correctly. There were such forecasts for hurricane Katrina and realistic estimates of the destructive consequences for New Orleans - the last one was presented just a few months before the disaster occurred.

But is this also true for blackouts?

An apt example of the limits of scientific predictability is the weather. We are all familiar that weather forecasts are reliable only for five to six days in advance at best. The reason behind this is that even the slightest changes in the initial conditions of mathematical computer-model calculations can cause completely different results. This stems from the fundamentally chaotic character of the 'weather' system. To provide reasonably reliable long-term forecasts, supercomputers must be able to calculate all the variations for a given climate model.

## Collapse of the Tacoma Narrows Bridge

A classic example of the limits of the belief in the absolute superiority of technology is the collapse of the Tacoma Narrows bridge (Fig. 1). The bridge was completed and authorized for traffic in the U.S. state Washington on 1 July 1940. From the first day of its use the bridge boosted to swing up and down. Oddly enough, the bridge traffic enormously increa-sed. People travelled hundreds of miles to expose themselves to the thrill of traversing a „galloping“ bridge. Meanwhile the confidence of the authorities in the reliability of this bridge grew all the more so that it was seriously planned to terminate the insurance policy taken out for the bridge. On 7 November 1940 in the morning, the bridge started to move wavily and persistently and continued swinging for about three hours. In the following hour the bridge performed incredibly striking movements and finally collapsed completely at 11.10 hours.

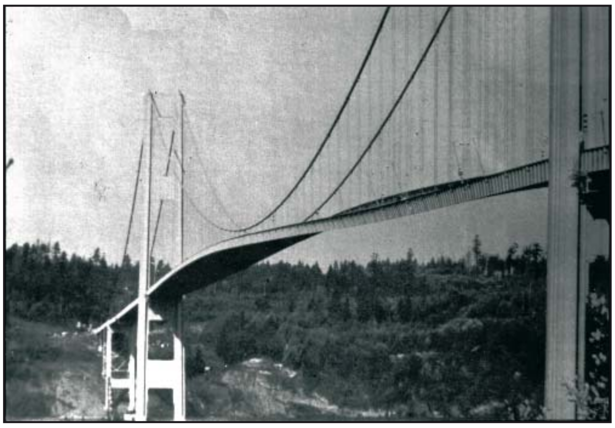

***Fig. 1:*** *The swinging Tacoma bridge.*

At the end of the day, the cause of the Tacoma Narrows bridge collapse was the lack of "thinking out"  the bridge's aerodynamic qualities. The bridge was designed too „softly“ in terms of construction technology. Once affected by the continuously streaming wind, it was caught in self-excitation mode with negative damping. This revealed itself in the known twists and torques of the bridge which finally led to its breakdown.

The collapse of the bridge did not pass without comic comments. After the collapse of the bridge, the governor of the state of Washington publicly proclaimed: "We will build exactly the same bridge again, just like before." The well-known engineer von Karman immediately made a telephone call saying: "If you want to build exactly the same bridge, exactly like the one before, then it also will fall, with the same precision, into exactly the same river".

## The blackout

Up to now, the biggest power blackout in the history took place in the Midwest and Northeast United States and Ontario, Canada on 14 August 2003. The complete electrical power supply system for 50 million people collapsed very rapidly, including metropolises like New York and Toronto. Almost 65 GW of electrical power was suddenly missing for the supply of one of the most crucial economic areas of the United States.

Blackouts were well-known during the „energy crisis“ of California in 2001. They came to an agreement that, in case of an immediately forthcoming drastic lack of electrical power supply, a controlled "rotating blackout" had to be carried out. In the course of this procedure load blocks corresponding to the consumption load of certain city districts were shed (taken off) from the grid in turns. This procedure can be compared with passing on a „hot potato“.

To obtain a clear understanding of blackouts it is essential to be aware of the entire system of electricity production, electricity distribution, electricity consumption and the mutual dependences between these domains. The balance between produced and consumed power must be kept at all times. Measures to balance production must be planned well in advance for any change in the load for the foreseeable duration.

The German electricity supply industry repeatedly assured the public that blackouts like those in the USA could not happen in Europe. Such assurance relies upon the safety reserves in the UCTE (Union for the Coordination of Transmission of Energy) area on the presumption that such a large system will never work at its full capacity. Nevertheless three blackouts occurred at the end of summer 2003 shortly and in succession; on 28 August 2003 in London, on 23 September 2003 in south Sweden and Denmark and the most serious on 28 September 2003 in Italy. For the latter, the complete electricity supply could only be re-established 20 hours later than the incident took place, affecting a total of 50 million inhabitants.

The UCTE announced several official causes for the blackout, for example the insufficient safety reserves of the Italian electrical power grid, whose infrastructure had seen little capital expenditure during recent years. The UCTE identified as a further important cause the outage of a highly loaded 380 kV tie-line from Switzerland due to tree contact, followed by the outage of a further tie-line from Switzerland due to an overload. After this official discussion of the causes, the uneasy feeling of a „coincidental“ disturbance remains. And up to now we are kept in the dark about its history and its true causes (the presentation of the chronological history of the collapse in Italy has been ‘corrected’ in contrast to the original publication – the author).

But the first really “deep impact” for the electrical power grid in Europe happened on 4 November 2006 splitting the UCTE power grid into three zones. To keep the truth of the original printed version of this article we append a short description of this blackout and its causes according to the UCTE final report released on 30 January 2007 to the Annex.

## How are blackouts explained by science?

In the report „Voltage Stability Assessment“ of the IEEE (Institute of Electrical and Electronics Engineers) in 2002 approximately 30 scientists summarized their knowledge about the possible causes of blackouts. According to this report, strong oscillations in system power, system frequency and voltage in the range of seconds (Fig. 2) can be observed immediately after the power system disturbance which has been considered to be the triggering event initiating the collapse. However, after a long enduring „drift phase“ that follows a slow decrease of all three system parameters the system frequency suddenly rises in an extreme way and thus causes the abrupt collapse of the voltage and the system power (Fig. 3).

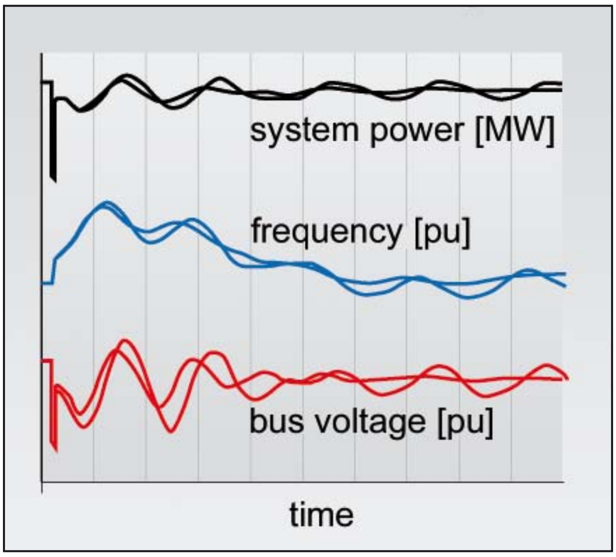

**Fig. 2:** *Oscillations in the power supply grid immediately after the event initiating the collapse.*

However, this represented only a simulation which is based on restricted model assumptions. Although several theoretical models exist to explain blackouts and their dynamics, there

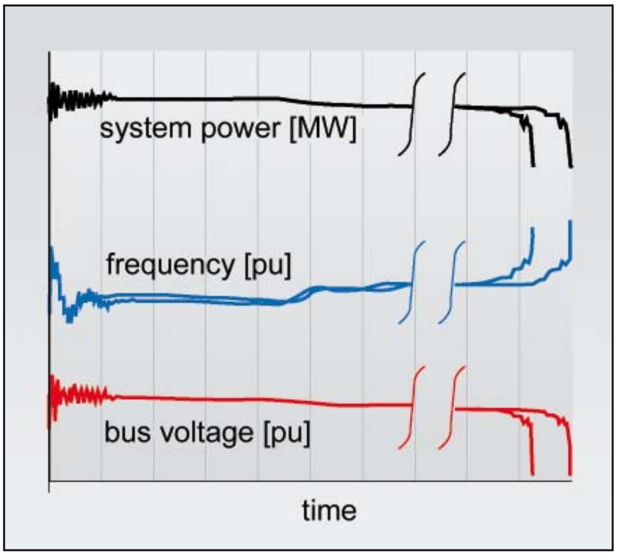

*Fig. 3:* *Long-term drift until the collapse occurs.*

was no comprehensive theory of a collapse apparent on the horizon until now. Though being not clearly aware of the nonlinear characteristics of the system - often referred to as “chaos in the net” - the findings of chaos theory and the theory of nonlinear dynamics are also quoted. These theories were proved valuable in explaining natural phenomenon such as weather and turbulence.

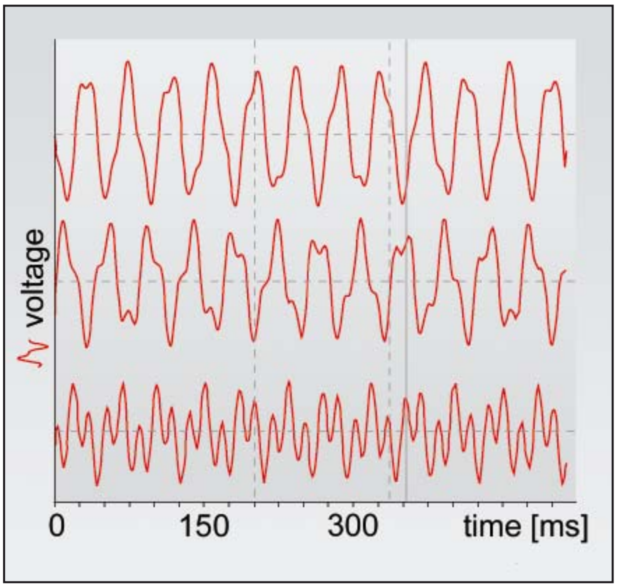

*Fig. 4:* *Signal patterns during the blackout in the USA 2003.*

For instance, with regard to changes in the dynamics of e.g. the voltage signal form during a blackout, IEEE theoretical analyses are considerably different from the signal traces recorded during the US blackout in 2003 which, in contrast, clearly and visibly differ from a normal alternating current curve (sine) (Fig. 4).

For practical purposes, i.e. for planning and operation of a power supply system, clear statements about the cause and course of a blackout would be rather helpful. The available planning tools were conceived based on theoretical model assumptions and on the classic methods of mathematics. However, the linearization applied in several model assumptions used by such tools is inappropriate to the nonlinear dynamics of a collapse of the electrical power grid.

The first important requirement on a comprehensive theory is the early recognition of (e.g. frequency) „patterns“ which are specific to the collapse. In contrast to the „triggering event“, the collapse itself is no event of pure by chance but one that develops over time. Its course can be described with mathematical methods and revealed by defining feature “fingerprints”, which can be recognized and interpreted as the precursory warning signs of a collapse (Fig.5).

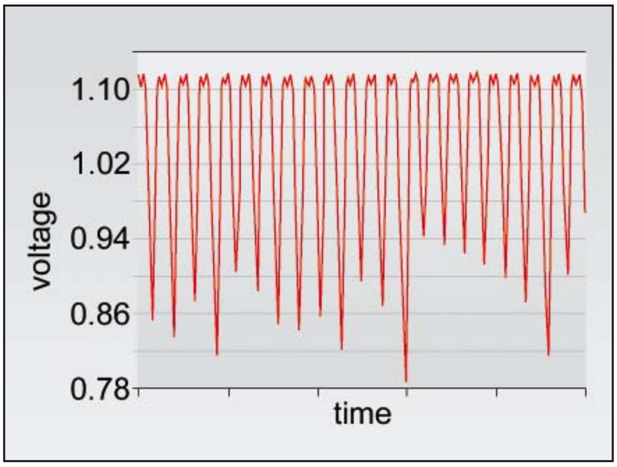

*Fig. 5:* *Frequency patterns preceding the blackout.*

The second important requirement relates to the actual technological infrastructure, i.e. the network of power generators, regulators, transformers, transmission lines. This network and especially the variety of actual load types must be mapped into a theoretical model very close to their real characteristics and behaviour. For this purpose, easy to manage substitutional models are needed, which should closely reflect the nonlinear core of the dynamic events in the grid.

## Technically, it is possible

Today's technology allows the development and manufacture of devices capable of predicting blackouts. The practical benefit is obvious - one can ascertain the stability limit of the electrical grid or at least an approximation of it. In other words: by continuously analyzing the preceding events of a collapse in the frequency domain from the current state dynamics of the power grid, an assessment can be made of how distant the collapse is.

From the results of these analyses, necessary preventive action alternatives can be derived. The measures at disposal are strongly dependent upon the grid topology and other grid related constraints.

For example, usual measures such as load shedding can now, through the use of the collapse prediction device, commence much earlier in time. As a result, smaller more controllable action is taken that may end in the "islanding" of currently stable particular power grid areas. The measures and strategy differ from case to case.

Contrary to the earlier schemes, collapse prediction devices detect instabilities in good time and this allows for more time to take the preventive action appropriate to avoid an extreme event like a blackout.

The interviews with Dr. Michael Fette and Lothar Mayer are set out below in full length. In the original article (published in "Electrosuisse Bulletin SEV 15/06") the interview with Dr. Fette was reduced in length and the interview with Lothar Mayer was omitted due to editorial restraints for publication.

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## Are predictions possible?

For the last 15 years, Dr. Michael Fette from the University of Paderborn has modelled electrical energy power systems with methods derived from catastrophe theory and the theory of nonlinear dynamics and chaos.

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## Interview with Dr. Michael Fette

***TF:*** *Dr. Fette, based on your theory, you claim that blackouts can be predicted. What makes you so sure?*

If we ask ourselves how much we know about the characteristic parameters of the power grid elements, we should admit that it is rather dull.

Detailed knowledge about elements of the grid at high voltage levels exists. In contrast, knowledge about grid elements at the medium voltage level is rather limited.

On the consumer side, i.e. low voltage range, where a lot of different electrical devices are used in the electrical power grid, we really cannot say much about their characteristics beyond the statistical methods that are used.

Sophisticated computational models used for planning purposes of a power grid normally take nonlinearities into account only in a very „selective" form. This doesn't allow analyzing their interaction within the system in its entirety. The nonlinearities that we are concerned with originate from the area of the system load behaviour. Until now, we only knew a few facts about their dynamics.

To compensate for this, we developed mathematical models based on the theory of nonlinear systems which strictly orientate themselves on the description of the physical effects appearing in the power grid.

It is therefore possible to observe the unfolding of the nonlinearities just in the load area and to determine the characteristic features based on conventional models and their extension in the sense mentioned above.

We have done this so far and the results of our studies have given us the confidence you've asked me for.

***TF:*** *What mistakes were made for blackouts to happen?*

Planning and operation software packages of the day provide you with the answers to the questions you ask them. More importantly the question asked must be within the context of the model assumptions.

It is a fact that during the US blackout in 2003, computers in the control centres reported „everything OK". Those programs did not have any pre-programmed scenario for the blackout to appear at all! However, they recognised that the collapse was there once it happened.

Where can we get the knowledge that a collapse is imminent? Neither operators of the power grid nor conventional computation models can provide this knowledge. Among the two, operators of the power grid are the least responsible and they cannot be blamed for the blackouts.

***TF:*** *Please describe your theory about blackouts in as few words as possible.*

Looking at existing technical infrastructure as a primary parameter, the result of our theory presented graphically shows (Fig.6) that with variation of the load (actual consumption, real power) the system exhibits the usual behaviour, i.e. decreasing voltage with increasing load.

I would like to emphasize the two distinctively different areas on the "nose curve"; one in front and the other behind the „forking" point. This point is known as the Hopf bifurcation point (H) - a „forking point" H somewhere on the "nose curve".

The actual position of the bifurcation point H depends upon the above-mentioned nonlinear characteristics of the system and changes with its dynamics.

Approaching this point from the „stable" side is accompanied by more and more increasing frequency oscillations which are, however, still „good-natured".

If, due to the changes of the load behaviour, the bifurcation point H is passed, these frequency oscillations will get more and more „malicious" and will amplify themselves. During the long enduring "drift phase" that follows, the system's nonlinear dynamics also change. The system is hereby undergoing a "structural" transformation. Consequently, to overcome the lack of its capability to sustain the transformation of its own dynamics, the system battles with itself. If, in this situation further (no matter how small) changes in the load behaviour take place, this inevitably leads to the system collapse which we call a blackout.

***TF:*** *Where does your theory differ from the procedures which are currently used?*

The decisive difference lies in our ability to analyse the changes of the behaviour in the load area. This in turn provided us with the knowledge about the ways and means in which the nonlinearities interact.

For a given power grid, computer planning tools were developed for each voltage level. Hence, the analysis of their interaction was not possible. So far, to make a bad situation worse, only linear models were used!

Our goal was to take the entire system into consideration, with its structure appropriately reflected within its nonlinear behaviour. Thus, we want to obtain all solutions of the appropriate mathematical approximation models which are "normally" hard to get.

***TF:*** *That sounds rather complex. Is the implementation of the theory simpler?*

One thing that counts is to detect the correct signals as early as possible. This allows the time to take the preventive measures. With our device we can observe a frequency domain with high resolution, in which significant

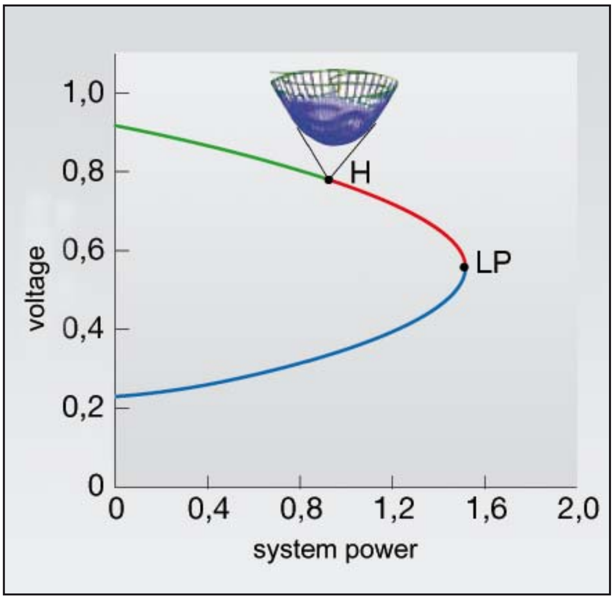

***Fig. 6:*** *Nose curve*
*The nose curve portrays the voltage V depending on the power Q. Two distinctive areas are coloured, green (stable) and red (unstable). The Hopf-bifurcation point is marked with H.*

„fingerprints“ of the frequencies appear that indicate an upcoming blackout.

To get the right idea about our solution, look to the simulation (Fig. 5). The „dents“ in the traces shown, reflect the actual signal behaviour at the US blackout 2003 (Fig. 4) quite well.

However, this frequency analysis must always be carried out together with permanent analysis of the changes in the nonlinear dynamics of the whole system. The detailed picture we yield through this procedure makes it possible to keep the efficiency and interaction of all control facilities in the power grid under surveillance.

The damping behaviour of all grid elements can therefore be determined with a high-resolution frequency analysis.

The ability to know the grid damping behaviour represents true and genuine progress compared to the earlier models applied in planning and operation of the power grid. For the grid operator, the knowledge about grid damping behaviour would in practice represent a very useful „red alert light“ for planning purposes.

This light would always be lit if, for example, in a liberalized electrical power market a trade option, which is not (or should not be) possible in the power supply system at the time, is exercised. In this case a „de-attenuation“ with fatal consequences for the complete system is likely to take the place.

Provided that the damping behaviour of the system at its boundaries and at its neuralgic points is well known, a specific intervention in the power grid is possible to avoid an upcoming blackout. An example of such intervention is the correction of false control and regulation behaviour. Looking at it from this perspective the measures that were undertaken until now were in some cases counterproductive.

***TF:*** *Dr. Fette, how do you see the future?*

Power supply companies will obviously get into the defensive. In the future, liberalized power trade and multiple increases in distributed generation from renewable energy sources will increase the demands on power system infrastructure. Investments into infrastructure are just one side of the coin. Beyond the sheer amount of the energy needed, the other side of the coin is the changing nonlinear characteristics of the power grid, coupled with an ever increasing generation of real power. Since a superior power supply performance will be provided for the customers, it is exactly this coupling that will severely complicate management. If we do not take this into account, we will have serious problems.

## Interview with Lothar Mayer, managing director of A.Eberle GmbH & Co. KG

***TF:*** *Mr. Mayer, in cooperation with Dr. Fette, you have developed a device which is capable of predicting a blackout. What is the practical benefit of your Collapse Prediction Relay (CPR-D)?*

The CPR-D identifies the approach towards the stability limit in the power grid. In other words, it makes a robust assertion of how far a system is from collapse by analyzing its precursory warning signs in the frequency domain.

***TF:*** *What happens if a blackout foreshadows itself in this way?*

From measurement results, we are able to derive a variety of different action alternatives. The action to be taken up depends completely upon the grid topology and many other limiting conditions. Normally, general „load shedding“ is a good start, which can now take place much earlier. It can also end at the „islanding“ of a single network into areas which are generally easier to manage and simpler to control. A different strategy is adopted from case to case. In simple terms: contrary to what we had before, since we can see the danger earlier, we simply have now more time to react adequately.

***TF:*** *Do you already have interested economical parties? What is the customer response?*

The interest is just as big as the problems our economies are confronted with in this area at the moment. If you consider how large the economical damages associated with power net collapses are, you can easily imagine the interest in relatively inexpensive devices which help to prevent the collapse.

***TF:*** *Are you able to estimate the economic advantage for your customers created by the CPR-D?*

At the moment I only can help with numbers from Austria which certainly looks quite similar for Germany. For the 110-kV network, this is about two Million € per hour. At the 380-kV group one can count up to 40 Million € per hour. If you imagine that a 110-kV level is lost and it lasts for some hours until the power grid is ready again, one has to rapidly deal with a two-digit million € amount.

***TF:*** *What importance does such an invention hold for a medium-sized enterprise like yours?*

As I see it, to invent is the challenge for us. Innovations have justified our advancement within the last 10 years and we will keep at it. The risk of this development is great, but calculable. We have a great responsibility for our employees and must not jeopardize the existence of our enterprise, even though the idea might be, on the face of it, brilliant. However, if we can put the product successfully on the market and meet the expectations of our customers, this certainly has a significant positive influence on our export business. Initially the effect is less in terms of the turnover, but rather on our image. An invention in this category firstly creates opinion quotas. If you have gathered these, there is no need to worry about market shares.

***TF:*** *The hunger for energy worldwide increases without restraint. Are you therefore looking forward to a bright economic future?*

I don‘t see our business future as simply rosy, but I am, however, very optimistic. I am of the opinion that, from a social point of view, the current energy hunger of the world cannot lead to a good long term result. However, I wouldn‘t like to repeat arguments which anyone with some common sense has at hand anyway. I must admit that my personal stance on this subject corresponds more and more to the opinion of the recently deceased philosopher and writer Carl Amery. In the catastrophes of our time he saw signs evolution is out to get rid of a warm-blooded animal, which arguably turned out to be an evolutionary blind alley. Whatsoever, our ravenous appetite for energy is satisfied by violating human dignity and is nothing else but a half blind march into a future, where life and survival will obviously get very hard. On condition that this march will not be led into a direction where “a sustainable world” is not merely a pointless phrase, we must ask whether life would then be still worthwhile at all. That´s, to my opinion, the meaning of “The mankind at a crossroads”.

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This article is a shortened version of an essay in German language, whose full version including the references can be downloaded from the following Internet address:

**http://www.a-eberle.de/sonderdr/pdf/sturmzeichen_d.pdf**

# ANNEX

A 2$^{nd}$ Interview with Dr. Fette is appended, which has been published in the 5/2007 issue of “electrosuisse Bulletin SEV”, entitled with

## “The Blackout on 4 November 2006 in Europe”

The short introductory comprehension of the blackout was written in German language by Guido Santner from “electrosuisse Bulletin SEV”. Dr. Fette was interviewed by Dr. Thomas Fritsch (TF). We present an extension of the version in the printed issue of “electrosuisse Bulletin SEV” which was shortened due to editorial restrictions in print space. For a detailed description of the events on 4 11 2006 and their analysis we refer to the final report of UCTE:
**http://www.ucte.org/pdf/Publications/2007/Final-Report-20070130.pdf**

## Interview with Dr. Fette:

***TF:*** *Dr. Fette, you claim, that the Europe-wide disturbance could have been avoided? What are your reasons for this claim?*

We thoroughly analyzed the data, which have been made available to us from different TSOs (transmission system operators, i.e. power supply companies, TF). The quality of this data with respect to the time resolution and to other criteria which are relevant for an effective grid-monitoring can only be described as mediocre. Nevertheless, our analytical software displayed “RED” in all frequency ranges we consider to be relevant. The grid definitely was unstable already one hour before the “real” disturbance occurred at 22 hours on 4 11 2006.

***TF:*** *Could you work out the details of your analysis more precisely?*

The preliminary conclusion, we can draw from our analysis (e.g. spectral analysis with special signal transforms) is, that the precursory processes of a collapse could be detected before the Conneforde-Diele line was disconnected from the grid. In the aftermath these processes took shape more intensively. They cropped up in frequencies in the range from 0.1 Hz to 0.5 Hz. We assume, that this reveals certain lowfrequency modes, which shaped up after the disconnection of the Conneforde-Diele line, but which of course already existed much earlier. You can get a good picture of this from the threshold violations in the spectrograph, indicated by the color “Red” (see Fig. 1).

***TF:*** *Can you give some practical advices based on your results?*

When a line disconnection takes places like the one from 4 November 2006 and after the detection of certain low-frequency modes it is strongly recommended to monitor the grid very closely. Direct interventions should be renounced in order to avoid the stimulation of further critical modes. All trading transactions should be proved and – if necessary – stopped. In this case all automatic tap changes should be suspended. The evolution of the low-frequency modes must individually be observed in detail. Only if the frequency modes unfold more and more, further possibly “striking” interventions should be attempted.

***TF:*** *Then your opinion is quite different from that of UCTE, which considered the “system damping of inter-area oscillations”* *as “satisfactory” and recommended that the TSO´s should be given the possibility to take substantial influence on the production of electricity?*

Well, that´s a double-edged sword. The claim in the UCTE final report, that a “satisfying system damping” could be observed, cannot seriously be maintained, if we perform an analysis of the system disturbance with a much more adequate time resolution of the data.
Whether it makes sense to give the TSOs the allowance to turn the set-screws in case of a big disturbance, depends upon which analysis methods of the grid are generally used and how the decisions of the TSOs in this situation are made under these preconditions!
Massive interventions in a critical situation of the grid may even aggravate the problem. They should only be taken into consideration, if the TSOs are obliged to coordinate their actions based on a good communication. Furthermore, the grid situation should thoroughly be proved in advance on the basis of analytical models, which take the nonlinearities in the grid into account.

***TF:*** *What is your perspective concerning the planned intensification of electrical power trade in the light of the events on 4 11 2006?*

In future we will have to face a lot of problems. I want to paraphrase the problem arising with the trade of electrical power with the following allegory.
Imagine the grid of electrical power supply as a big bath tub with some defined drain holes, varying in width and with some defined inflows, which are also varying in time. We would have to pay attention very carefully, that the water level in the bath tub would not change not in the least at every time instant. In this analogy the trade with electrical power could be represented by the fictitious idea, that it would be possible to bore up the tub walls in order to take out water at any position on the tub walls you want.
The president of UCTE pointed out, that it is definitely clear, that the bath tub, i.e. the grid, was not designed and constructed for that purpose!
If you consider the intended increase of trading transactions by a factor of 100 in the near future and if you are aware of the fact that in the same time it should be made possible, that the planning schedules for intra-day trade could also change within the same day, then there is a tremendous contradiction between economical wants and technical reality. If these plans become reality without substantially changing the grid infrastructure than the probability of blackouts can increase very rapidly.

***TF:*** *Just shortly after the Europe-wide disturbance on 4 11 2006 took place, the German minister of economic affairs verbatim told the public: “You just cannot produce more wind power, than it can be transported through the grid.” Could you support this position? Or in other words: Are wind power and other renewable energies like photovoltaics really as dangerous for the grid as it is claimed? On condition that it would be like this, how could the EU-goal be attained, that in the average 20% of the total energy production in the EU should be gained by renewable energies?*

For reasons of climate protection and as a precaution for the imminent depletion of fossil fuels we are forced to integrate renewable energies like wind power and photovoltaics into the grid infrastructure. But this introduces a coincidental component, that means stochastics, into the centralized power supply system in Europe and this could - in certain critical situations - destabilize the system.
Technical solutions exist for the problems arising with this new technology. The Danes for instance provided frequency control within their offshore wind parks. But the problem to find a conception which covers the full process of the necessary conversion of the electricity supply system to an adequate consideration of renewable energies still remains to be solved. More decentralization and regional autonomy would surely help to ease the situation. As a positive example I would like to mention that on 4 November 2006 wind power had a stabilizing effect in the high-voltage

range, when the grid was split into 3 areas. On the other side, the opposite effect could be observed in the low-voltage range during the resynchronization phase.
Therefore the influences of renewable energy sources have to be considered carefully in the different voltage ranges. Concerning the question, whether the EU-goals for 2020 could be achieved, I am sorry to say: Not with these grids!

***TF:*** *Dr. Fette, could you give us some information from your perspective and insight, which practical measures the TSOs have taken in consequence of the "almost-blackout" on 4 November 2006?*

I believe that the TSOs have got the "message" if they are willing to take the dynamic processes in the grids into account when they want to plan the further development of the grid infrastructure in accordance with the demands of the present time. We have several requests for the collapse prediction devices. And there is an explicit need for nonlinear descriptions and analysis of the grid. So far a number of testing installations at TSOs are currently on the way to meet this need. The results will provide us with much better data than we have currently at our disposal and will significantly improve the analysis of the grids.

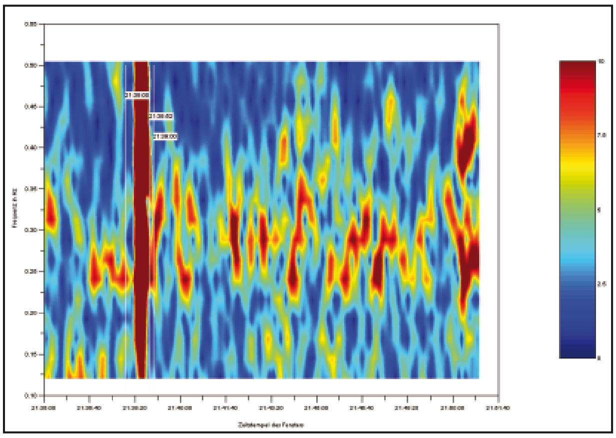

*Fig. 7: Short-time spectrograph (threshold violations in color red)*

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