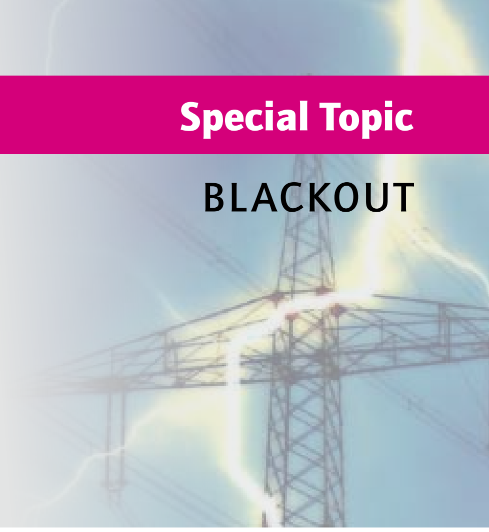
KoCoS A FRIEND OF ENERGY



Special Topic

BLACKOUT

EPPE CX
Reducing the risk of blackouts with systematic data acquisition

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Power failures / blackouts in recent years (table 1) have shown how vulnerable society has become to disruptions in the power supply. This paper discusses new approaches for identifying and reducing the risk of blackouts and describes the consequences. The authors aim to demonstrate how today's technology can be used to improve the assessment of the potential risk.

Background

When estimating the risk of a blackout, it is important to remember that today's power supply systems were planned and built on the premise that central power stations provide electrical power which is distributed to end users through networks. The transformation of these networks ultimately made necessary by the shift to renewable energy sources, or „energy revolution" as it is often known, is „analogous to open-heart surgery"[1]. The transformation of the networks into smart grids requires the creation of an information infrastructure for data transmission in addition to the power engineering infrastructure. The use of standardised communication devices within this information infrastructure calls for a brand new approach to safety assessment. The interdependencies which exist between individual sectors and industries increase the risk of major power failures. Failures in one sector can lead to failures in other sectors, triggering off a domino effect.

The effects of a blackout

A blackout lasting several days has serious and complex effects on modern, technology-based societies. Blackouts impact on every sub-section of society as well as on each and every individual member. Even services which do not immediately appear to be dependent on electricity can be affected, the consequences ranging from limited availability through to complete unavailability.

The impact on sectors with critical infrastructures is inevitably enormous because of their high dependency on electricity. The following sectors are particularly severely affected by blackouts:

- information and communication technology (ICT),
- power generation and distribution,
- the media,
- transportation and traffic systems, including all carriers,
- industrial and manufacturing companies,
- the public health sector, including the emergency and rescue services,
- the water supply (drinking water and water for industrial use),
- the food supply including transportation logistics,
- the disposal of sewage, harmful substances and waste,
- public authorities and administration,
- the banking and financial sector including the supply of cash.

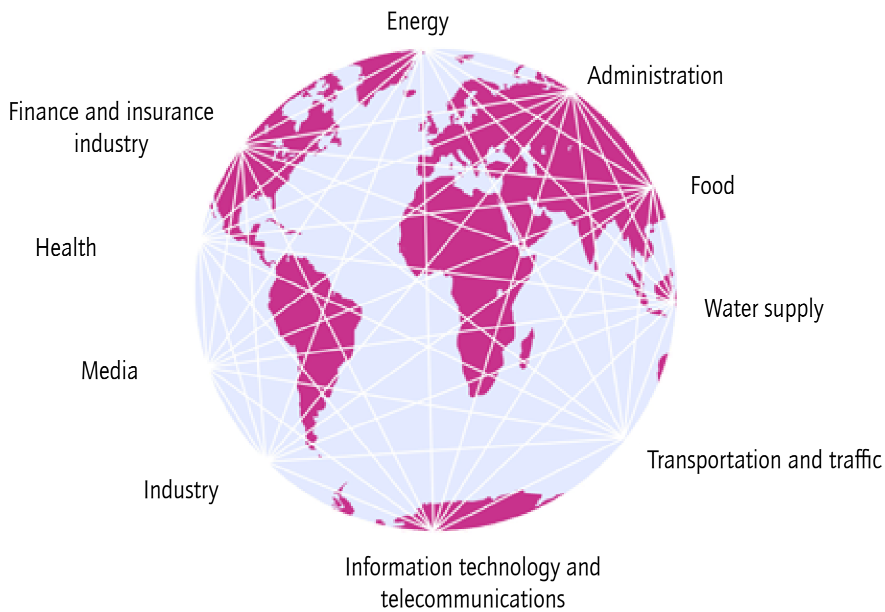

Fig. 1: Interdependencies

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Within a relatively short period of time, even sectors which do not immediately appear to be dependent on electricity will be subject to limited availability or complete unavailability. The water supply and sewage disposal services are good examples: both depend on electrical pumping and heating systems as well as on electronic management, control and monitoring systems for their operational reliability. The same applies to the banking and financial sector. The supply of cash through automated teller machines and electronic cash register systems and the electronic transfer of funds and international securities trading all require electricity. The multifarious intra-dependencies and interdependencies which exist in connection with power failures in different sectors and industries are currently under analysis (see [6]), so it is to be expected that new, as yet undiscovered consequences will come to light in the near future.

Immediate effects on the population

The population will feel the effects of a blackout in every area of life. In the private domain, basic services, family life and leisure activities will all be affected. Blackouts will also immediately and significantly interfere with work and service facilities. The most serious direct consequences will be the impossibility of heating buildings in winter or keeping them cool in summer, the absence of electric light, telephone services, the

Date	Country	Parties concerned	Cause and amount of damage
November 2012	Germany, Munich	450,000	Short-circuit of 100 kV overhead line, over 1 million Euros
November 2012	Germany, Ruhr region	500,000	Problem at a substation
July 2012	India (North + East India)	600,000,000	Overload of the electrical grid in 20 of 28 federal states, estimated 75 million Euros
September 2011	California/Arizona/Mexico	5,700,000	Breakdown of a 500 kV overhead line
February 2008	U.S.A. (Florida)	6,000,000	Malfunction at a substation in Florida
July 2007	Germany (Düsseldorf)	150,000	
July 2007	Spain (Barcelona)	350,000	Switchgear failure
July 2007	Georgia (Tbilisi)	1,100,000	
November 2006	Germany / North-West Europe	10,000,000	Circuit faults
November 2005	Germany (Münsterland)	250,000	Icing/electricity pylon break/bend
June 2005	Switzerland	200,000	Problem with the railway network
May 2005	Russia (Moscow)	2,000,000	
November 2004	Spain	2,000,000	Transformer fire
September 2004	Germany (Rhineland)	1,000,000	Short-circuit
July 2004	Athens		Collapse of the power system, possibly caused by air conditioning systems
December 2003	Germany (Gütersloh)	300,000	Sabotage
September 2003	Sweden / Denmark	4,000,000	Circuit faults
September 2003	Italy	56,000,000	Breakdown of a high-voltage line
August 2003	U.S.A. /Canada	50,000,000	Computer error / outdated grid / 7 - 10 billion USD
August 2003	Great Britain (London)	1,000,000	Incorrect safety equipment
June 2003	Italy	6,000,000	Insufficient power station capacity, 151 million USD
January 2001	India (New Delhi)	200,000,000	
January to March 2000	California	several 100,000	Power failure caused by insufficient electricity generation capacities »Rolling Blackouts«, 1.7 billion USD per week
December 1999	France	3,400,000	Windstorm »Lothar«
December 1995	U.S.A. (Oregon)	2,000,000	Windstorm
July 1977	U.S.A. (New York)		Lightning strike, 350 million USD
November 1965	U.S.A. /Canada	30,000,000	Defective relay, 452 million USD

Table 1: Historical blackouts

Internet, radio / TV reception and the inability to preserve food through refrigeration or freezing as well as the possible collapse of the drinking water supply. This would mean that it would no longer be possible to flush faeces down the toilet and as a result multi-storey buildings would soon have to be evacuated because of the risk of epidemics. The failure of traffic lights and street lighting would cause traffic systems to breakdown, at least in cities. Shops will have to close because cash register systems will not work anymore and because there will be no lighting, heating or air conditioning. Because of the breakdown of just-in-time logistics, basic necessities, especially food, will soon be in short supply.

Blackout:

A sudden, large-scale and long-lasting power failure with no clear quantitative containment. The term „blackout" is used to describe a power failure which affects a large area when external help cannot easily be provided or when the power failure lasts for over an hour.

Security of supply is non-negotiable

It is to be expected that critical infrastructures will become even more important for the German population in future. This type of critical situation arose in the transmission system as recently as in March 2013 [3]. According to information from various sources, network operators were forced to intervene on an almost daily basis in order to prevent negative effects on the network [3 + 4]. The Federal Network Agency makes the following point in this connection: „It is no good constantly formulating new requirements for energy policy with gay abandon without giving a thought to the security of supply. The energy revolution can only succeed if the security of supply remains non-negotiable" [2].

As early as in 2011, the Office of Technology Assessment at the German Bundestag (TAB) published a report which discusses in depth the effects of a blackout [5]. The scenarios and dependencies described in this report were systematically analysed by the GRASB research project [6]. One of the insights to emerge was that blackouts are caused by a concatenation of various triggers and a combination of different events. This new insight becomes even more significant in times when the structure both of the networks and of the decentralized energy sources which feed into them are changing and when external intervention in control mechanisms is to be expected as the smart grid develops. To mention but one example of such an intervention, even today, during network frequency measurements, the beginning and the end of an accounting interval on the electricity market can be seen by measuring the frequency jumps caused by the start-up and shut-down of block heat and power plants induced by stock exchange trading.

In addition, the project found that the risk of blackouts in electricity supply networks can be identified and reduced by means of systematic data acquisition. Systematic data acquisition involves carrying out permanent power quality measurements and recording important operating statuses (e.g. circuit breaker tripping).

Permanent power quality measurement

When systematically measuring power quality and determining the quality of supply, it should be noted that reliable information as to trends and developments can only be provided after a recording period of three to five years. When the recorded values are integrated in models for determining blackout risk they can help point to possible causes of changes in the quality of supply.

Power quality data collected over a wide area can be used to assess and improve fluctuations in power quality and in the reliability of supply in the long-term and therefore to assess and improve the security of supply. The measuring systems required for this purpose must be capable of being integrated in any kind of communication network as well as in wireless network structures. Even if no networked communication connection is possible, the option of regular data downloads from the device must be available, e.g. via USB flash drive.

Some of the technical prerequisites for measuring systems used for long-term power systems analysis are listed below:

- Integration in various communication networks
- Easy installation of the measuring device
- Absolute synchronization of data acquisition
- High-accuracy measuring device
- Secure data acquisition
- Large measurement data memory
- Central evaluation and monitoring

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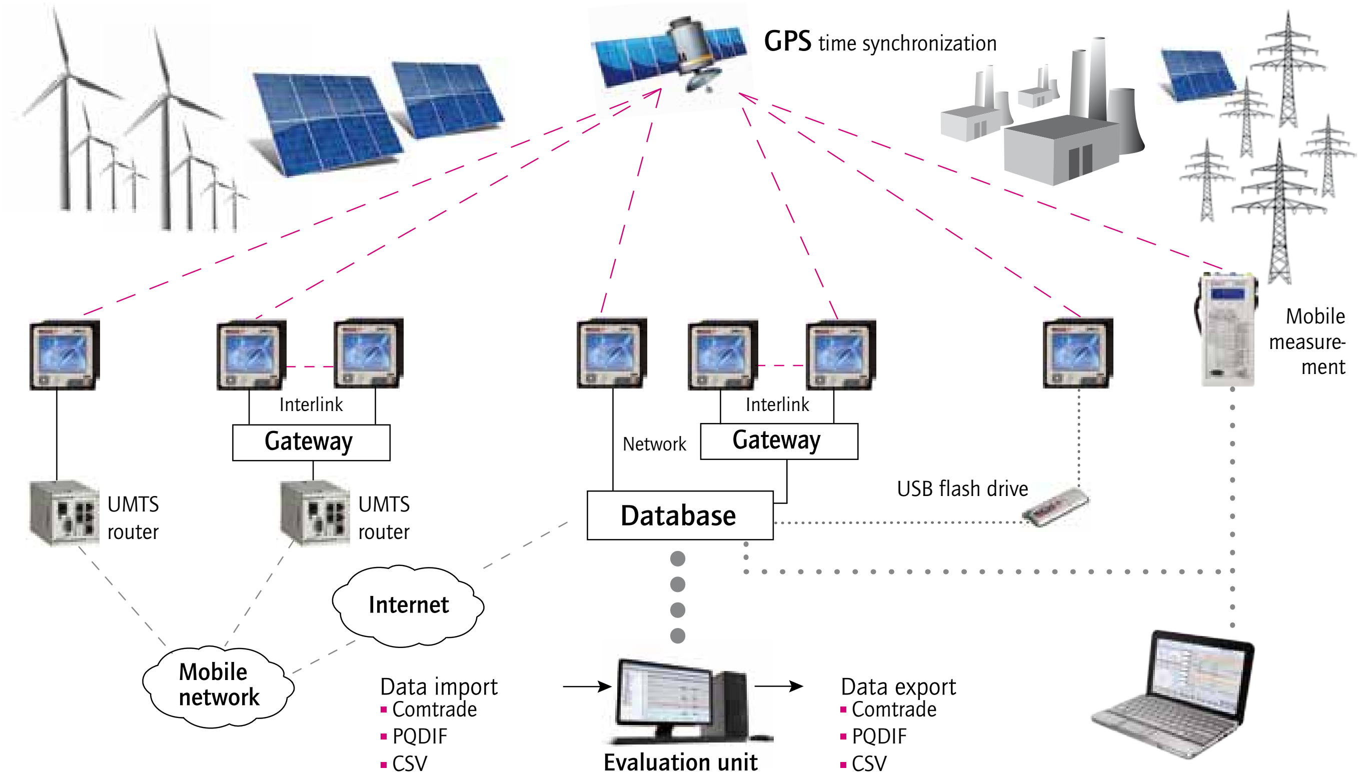

Fig. 2: Communication and time synchronisation model

Power quality measurements with wide area coverage call for the values measured by all devices to be recorded absolutely simultaneously. The measurement results of a number of measuring systems can only be monitored and analysed simultaneously if a suitable method of time synchronization is employed. For measurements in accordance with 61000-4-30 class A, sufficiently accurate methods of time synchronization must be used, such as GPS or DCF 77, for example.

The measurement data should be copied regularly from the measuring system to a database at pre-defined intervals in order to ensure fast access at all times. As well as being saved in the database, the data can also be saved in each individual device for a certain period of time before being overwritten if the measuring systems feature a circular buffer. The memory capacity of the measuring system should be capable of recording data for a period of at least one year.

In order to be able to provide adequate power systems monitoring and analysis, the measuring systems should feature the following measurement functions which should be seen as minimum requirements:

- Uninterrupted recording of all network parameters with an adjustable averaging period (trend analysis, EN 50160)
- Event recording with configurable trigger criteria for exact observation of network disturbances and their frequency
- High-resolution fault records for detailed fault analysis

Additional sensor measurement inputs for monitoring the environmental conditions of the measuring system, renewable power systems or industrial plants are also useful. Examples of typical measurement quantities are temperature, light irradiation, rotational vibration, wind speed or wind direction. In the case of a malfunction, this additional measurement data is helpful for the purposes of analysis and for the development of remedial measures, especially when the fault has been caused by several factors.

The EPPE CX, a measuring system developed and manufactured by KoCoS Messtechnik AG, meets these requirements. This user-friendly power quality analyser provides guaranteed flexibility for a wide range of measurement tasks.

Typical examples of applications:

- Power quality analysis
- Power quality monitoring
- Differential current measurement
- Fault analysis
- Measurement of harmonics
- Monitoring and analysis of renewable power systems
- Network optimization
- Load management
- Monitoring to EN 50160
- Fault location
- Trend recording
- Critical load monitoring
- Consumption measurements, e.g. for load optimization

In addition to the abovementioned properties required of a measuring device for power systems monitoring and analysis, the measuring system also offers a wide range of additional features, including a built-in energy meter, a web server and graphical measurement value displays with touch screen functionality.

Operating software

The EPPE operating software is used to manage the measuring systems connected in a network and offers a wide range of options for configuring individual devices and for the comprehensive analysis of measured data. The software is easy to operate and exceptionally user-friendly thanks to the ergonomic user interface which is designed in accordance with the Windows® Fluent concept and geared to meet real-world requirements.

Device management

A device list provides the most important information on the current status of the devices in a clear form. The systems included in the device list can also be copied to graphical elements such as maps depicting local conditions. This gives the user a perfect graphical overview of the measuring systems installed, including their location and the most important status signals.

- Remote configuration
- Long-distance data transmission
- Alarm signals in case of a fault
- Determination of fault types
- Printout or dispatch of fault reports and quality reports
- Archiving of records in a database
- Online monitoring
- Self-monitoring

Online monitors

All measured or calculated quantities can be called up online and displayed on a PC without affecting the data recording which is currently in progress. The measurement values can be combined within display windows, rather as in a control centre system. In addition to numerical display, the system also provides a range of graphical options, including analog pointer instruments, vector diagrams, bar graphs and oscilloscope displays.

Configuration

The practical configuration module takes the actualities and requirements of modern power supply systems into account. Templates which correspond to specific standards (e.g. EN 50160) can be selected for long-term recording and event analysis, so even users without specialist knowledge can conduct a full analysis of a power system.
When using the fault recorder function, a wide range of parameters can be selected freely, including for example the sampling rate, recording duration, pre-fault and post-fault period and the variables for which triggers are to be defined.

Fig. 3: KoCoS Power Quality Analyser EPPE CX

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Evaluation

The software contains comprehensive analysis tools for the evaluation of the recorded measurement data. Power systems and power quality analysis can be carried out manually or automatically to the selected standard (e.g. EN 50160). A number of analysis tools are provided for this purpose:

- Slow changes with trend analysis
- Event recording with signature display
- Flicker analysis
- Harmonic analysis
- Analysis of interharmonics
- Event classification and assessment (UNIPEDE, ITIC, etc.)
- Graphical display of extreme value duration distribution
- Table overview of limit value violations
- User-defined limit value and analysis settings
- Automatic generation of weekly, monthly, quarterly and annual reports
- Calculation and signal display of differential current mesurements
- Useful zoom functions and variable scaling
- Superimposition of different signal characteristics
- Formulary and editor for the calculation of further power system quantities

The software also contains a comprehensive range of powerful analysis tools for the assessment of recorded data:

- Vector displays
- Harmonic analysis on the basis of full waves or to IEC 61000-4-7 with interharmonics
- Freely configurable absolute and delta measurement cursors
- Useful zoom functions and variable scaling
- Simultaneous display, superimposition and synchronization of more than one fault record
- Formulary and editor for the calculation of further power system quantities
- Individual report creation using the clipboard
- Automatic report creation

Fig. 4: Trend analysis

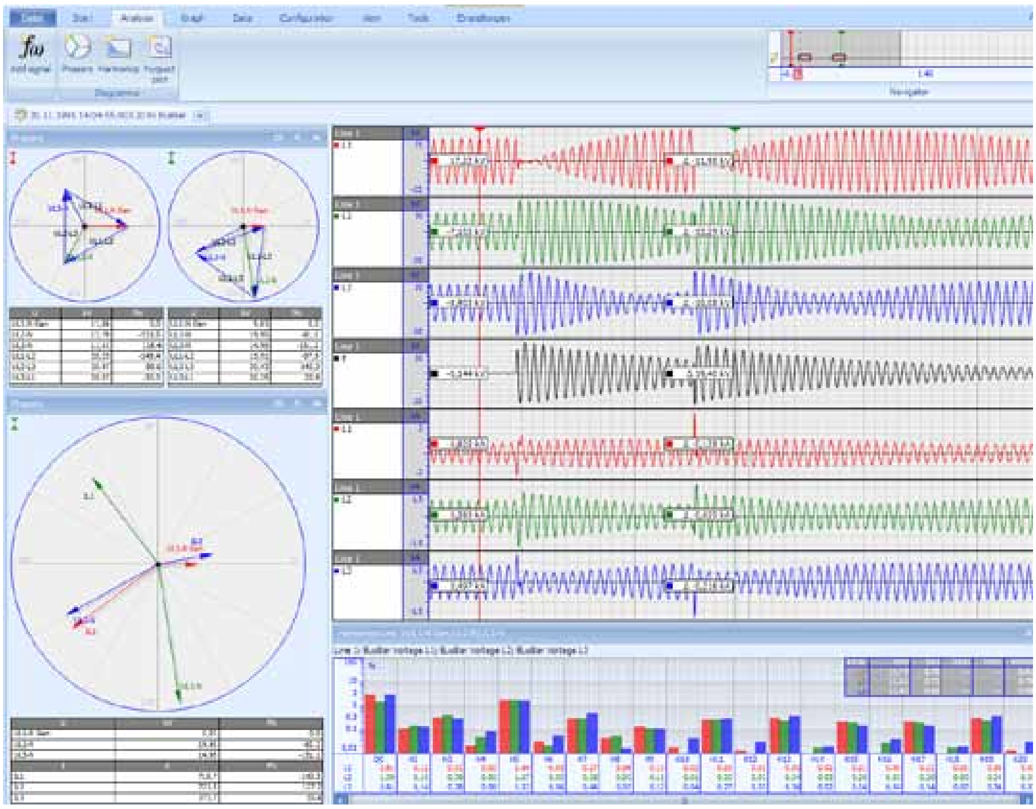

Fig. 5: Analysis of a fault record

Conclusions

The quality of supply has been hugely influenced by the consequences of the energy revolution and affects all players, from power generators to end users. Domino and cascade effects should not be underestimated. For example, the collapse of the water supply and sewage water disposal would have a strong impact on the public health sector. The risk of large-scale regional power failures or shut-downs, some of which could be long-lasting, is currently on the increase. The systematic measurement and analysis of power quality are of paramount importance for determining the risk of blackouts. The measuring technology needed for automated power quality monitoring is already on the market today.

Sources

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