TORSIONAL MONITORING SYSTEM TO DETECT TORSIONAL CURRENTS FOR CORRECTIVE ACTION

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INTRODUCTION

A growing, studied phenomenon is the failure of generator shafts and their auxiliary parts caused by high currents at frequencies below system frequency. Auxiliary parts can include the retaining rings, the shaft itself, and the connection of the blades to the shaft.

These failures are often catastrophic to date, can occur with little or no warning. They are often transient and short in duration and are mostly caused by fast changes in the load, causing a sub or interharmonic high current.

In layman's terms, the subharmonic current causes a “twist” in the generator shaft which affects the integrity of the shaft and its rigid components.

To date, most solutions have taken a physical approach to the problem, e.g. the installation of vibration dampers, feedback circuits, etc. Little has been done in the area of monitoring the electrical components.

The purpose of this paper is to introduce a system that measures the subharmonic current and provides the data in an organized manner enabling the user to make educated decisions about the maintenance of the generator with the aim of preventing catastrophic damage.

TORSIONAL EFFECTS

Every component that’s part of the generator shaft (see Figure 1) is affected by subharmonic current in a different way. Due to the fact that each generator component has a different resonant frequency, the affects of subharmonic currents on a generator shaft and its components are dependent upon the frequencies of the subharmonic currents. It is known, however, that a subharmonic current does cause fatigue, or premature aging and that after some time a failure somewhere inside the generator; the more torsional current there is, the faster the fatigue and failure will occur.

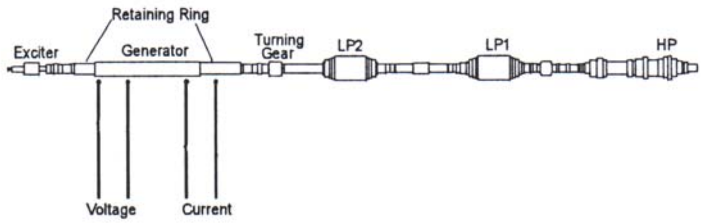

Figure 1

Even minor twists of just a few hundredths or tenths of a degree place considerable strain on the generator shaft. If the frequency of a load change is similar to the resonant frequency of the generator shaft, even relatively small load changes can cause damage to couplings or even destroy the generator shaft within a short space of time.

The resonant frequencies of a generator system are different for each individual system. Typical frequencies usually lie within a frequency range of 10 to 50 Hz.

The sources of torsional current can be any number of mechanisms to be found in a typical load profile of an electricity customer:

- motor starts
- high current switching
- interaction with HVDC
- interaction with series capacitor compensated transmission
- interaction with arc furnaces

These are just a few examples of the sources of the torsional current. These mechanisms can cause phase imbalance, negative sequence currents and power swings.

In addition, some individual transients also lead to mechanical stresses which are short in duration but very great in strength. Examples of this include

- incorrect synchronization when the generator is brought onto load
- short-circuits close to power stations

The number of occurrences, the length of time, and the produced transients are all functions that can cause the deterioration of the generator faster than anticipated.

COMMON GENERATOR PROTECTON METHOD

Measuring of mechanical vibrations

Monitoring torsional vibration directly within the generator system provides accurate and useful information as to the operating status and the amount of torsional vibration. Test and maintenance intervals can then be planned on the basis of this data. If vibrations of undue strength are detected over a significant length of time, the system can be switched off in time to avoid major damage.

The major disadvantage of this method is that high costs ensue when a generator system is switched off. In addition, measuring torsional vibration directly within the generator system only provides very limited information as to the causes of the load changes or pulses which produce the vibrations. When dealing with complex supply systems in particular, it is not possible to localize the sources of disturbance on the load using this method.

Measuring System to detect the source of mechanical vibrations

Since most of the damage is caused by frequent, fast, high subharmonic current, the idea was born to develop a system that can measure a high number of electrical characteristics of the Generator load at a very high sampling rate; a system that can identify these sources. If a high subharmonic current is measured at a certain frequency consistently, then the power plant can make a plan for inspection and service of the generator shaft at its next planned outage. If it is deemed to be more severe, fast action can prevent a major consequential failure.

A Torsional Monitor system has been developed and introduced to the industry in 2005 to fulfill these requirements. The premise is not only to measure and calculate the average of torsional components in a definable time frame, as well as the highest peak of the torsional distortion at each subharmonic frequency, but also to capture the transient and identify its cause by correlating it to the action on the network (i.e. cap bank switching, motor, etc.).

Two major requirements impacted the development of this software package: 1) the software package had to be capable of being integrated into the existing Torsional Monitoring fault recorder systems, and 2) the configurability of the monitoring criteria had to be as open and as flexible as possible to adapt the system to any kind of generator systems.

As torsional vibrations are mainly produced by subharmonic load changes below the generator frequency, the first step was to calculate the subharmonic content of the load in real time as well as the positive and negative sequence components of each individual frequency in the range of 1Hz to 60Hz. These values are calculated continuously and comprehensively.

The data volume resulting from these calculations alone amounts to approximately 52MB per day and feeder. In addition, the transient records are required for analysis when limit value violations occur for the purpose of maximum value analyses. A data volume of this order is not acceptable considering that no time limit applies, i.e. these measurements must continue without interruption for weeks, months and years at a time. For this reason it was necessary to find ways to significantly reduce the volume of data without losing any of the measurement data needed for the purposes of comprehensive analysis.

The following requirements resulted from these considerations:

- Comprehensive measurement and data recording is an absolute must.
- Measurement data which lies significantly below the critical threshold can be compressed within the measuring system before the data is saved (mean value formation)
- It must be possible to freely select the critical frequencies for the generator system which is to be monitored
- It must be possible to assign an individual limit value to each frequency to be monitored and to each positive or negative sequence component.
- It must be possible to group several frequencies together to form an event.
- It should be possible to save the measurement data with a higher time resolution when limit violations occur on one frequency or on several frequencies.

- Transient records should be triggered by limit value violations on one frequency or on a number of frequencies or by the maximum values reached within a monitoring window, even if the maximum value does not exceed the predefined limit value.

Two independent methods of data recording have been implemented to meet these requirements. These two methods can be activated simultaneously and complement each other perfectly. In practice, this has made it possible to reduce the volume of data to an average of 150kB per day depending on the specific requirements and including the transient records, without losing any of the measurement data necessary for comprehensive analysis.

The two different methods of data recording are described below:

Long-term recording:
The continuous and comprehensive recording of subharmonics provides information as to the frequencies and amplitudes the generator system is exposed to on average. Saving the mean values for the amplitude of individual subharmonic frequencies and the corresponding positive and negative sequence components is all that is necessary for an adequate assessment. Depending on individual requirements, the calculation period for mean values can be set to last anywhere between one second and a number of hours. In practice, time windows lasting between at least ten minutes and 12 hours are chosen because for each mean value it is also possible to save the highest and lowest individual value within the calculation window complete with an exact time stamp. Figure 2 shows the configuration of the calculation period and the principle of cyclic storage of minimum, mean, and maximum values.

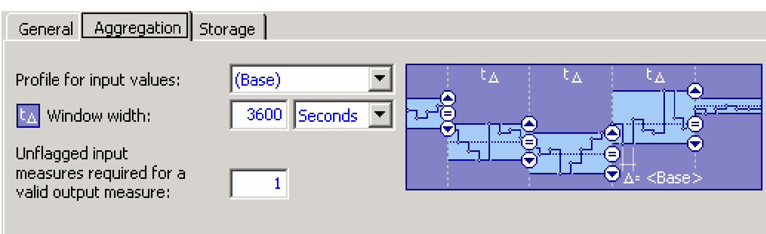

Figure 2

In addition to saving the mean values, it is also possible to generate an optional transient fault record for each time window, documenting the current characteristic of the maximum of one or more subharmonics with a pre-fault and post-fault history. A sampling rate of up to 30 kHz can be used for these records as shown in figure 3.

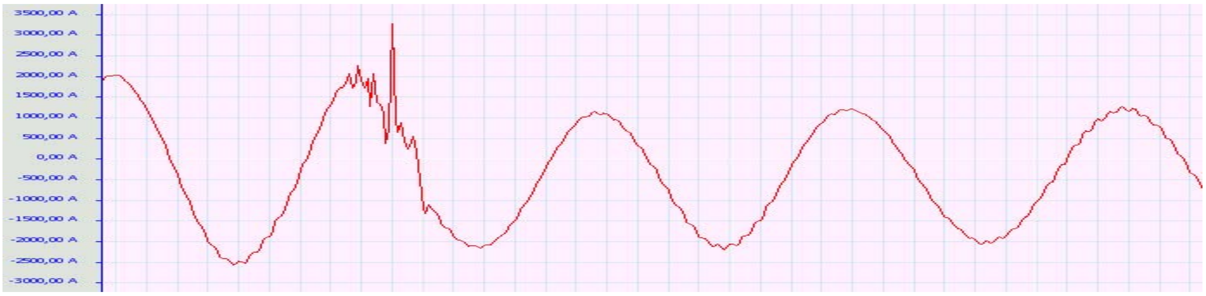

Figure 3

By chronologically correlating the data saved using the long-term recording method to action on the network, it is possible to identify at which stage in the production process the greatest strain is placed on the generator, or, to ascertain which load results in the greatest strain on the generator. Using the maximum values, it is also possible to find out if and when permissible limit values have been exceeded.

Event-controlled recording:
The event-controlled mode differs from the continuous long-term recording mode in that data is only saved if it is not within the permissible limit values. These limit values can be configured freely for individual subharmonic frequencies or for frequency groups.

When a limit value violation occurs, detailed recording of the corresponding frequency can be made with a fixed or variable time basis as required. The duration of the record corresponds to the duration of the limit value violation plus a definable pre- and post-fault history. A graphical representation of this adaptive storage principle is shown in figure 4.

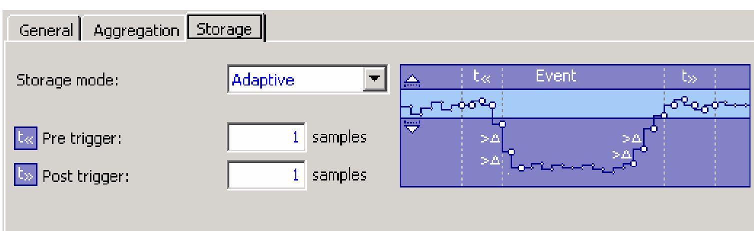

Figure 4

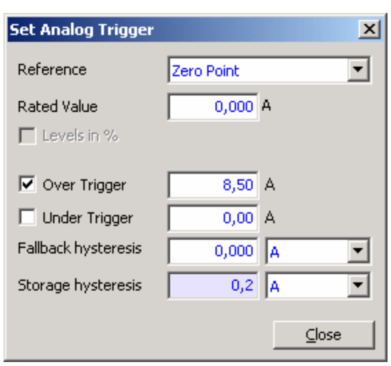

Figure 5

Figure 5 shows the threshold and storage hysteresis configuration for the adaptive storage principle shown in figure 4

The variable time basis can be set using a storage hysteresis. Measurement values are only saved when the difference between the current measurement value and the last saved value exceeds the storage hysteresis.
In other words, the storage density is higher, the faster a measurement value which is already outside the limit value

The use of this method results in records with a variable time basis usually needing much less memory space than records with a fixed time basis without any loss of fidelity.

In addition to recording the values calculated for subharmonics, it is also possible to generate transient fault records for limit value violations. These transient fault records reproduce the signal shape of the current characteristic with a sampling frequency of up to 30 kHz.

Analysis of the measurement data:
The analysis of the measurement data can be performed in two different ways.

Statistical evaluation is performed with the aid of the data gathered using the continuous long-term recording method and gives an indication of the average mechanical stress placed on the generator system. It provides detailed information on the general network and serves as the basis for planning maintenance intervals and network improvements.

Figure 6 shows the duration distribution graph of the positive sequence component for 20Hz. The x-axis shows the time (100% means total generator on time) and the y –axis shows the fraction of the pos. sequence component.

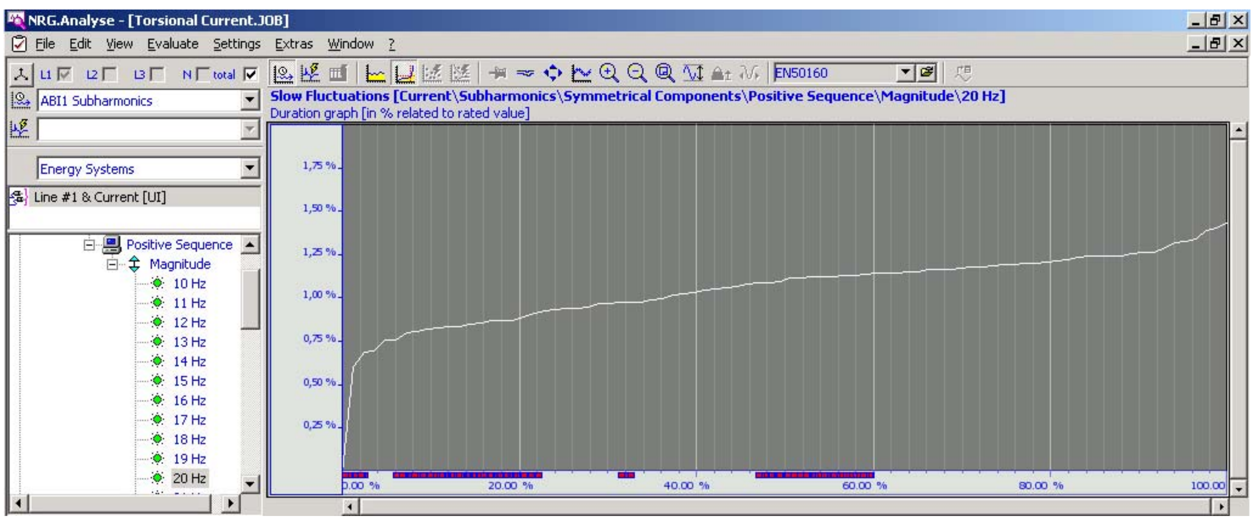

Figure 6

Figure 7 shows the slow fluctuation of the 6Hz component and its average and peak values within one hour.

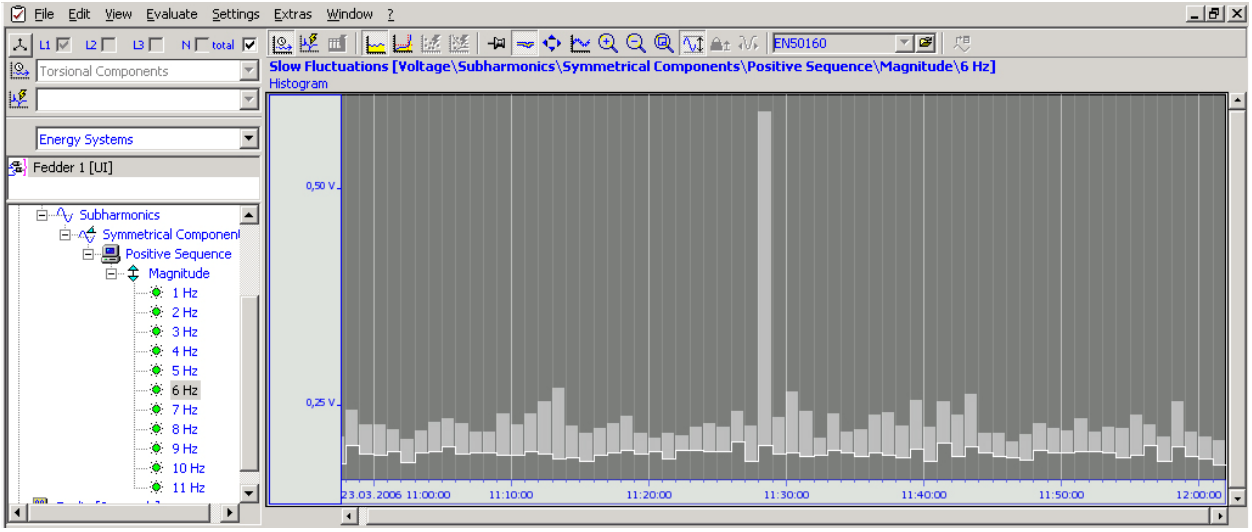

Figure 7

Analysis of the transient faults and the maximum values which occur is performed with the aid of the data gathered using the event-controlled recording method and the data contained in the transient fault records. This data provides a high-resolution record of network activity, making it possible to carry out accurate fault analysis.

Figures 8 and 9 show the current flow during a normal Steel Mill activity as a transient wave shape and the corresponding rms-envelope (only the red phase is shown).

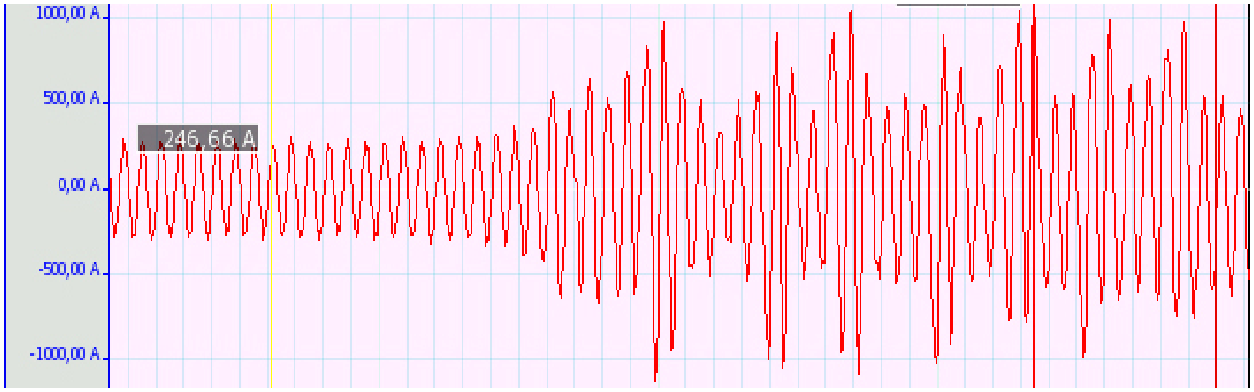

Figure 8

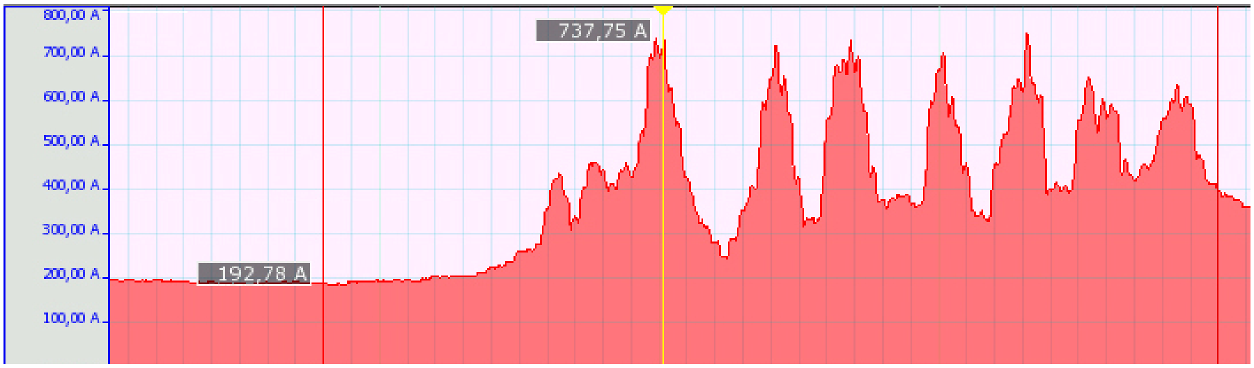

Figure 9

CONCLUSION

As energy providers are stressing their systems with more and more customers that are industrials, and are required to handle wide variations of load, torsional vibrations are becoming more and more prevalent. In addition, as generating systems age, they are more susceptible than ever to torsional vibrations, and degradation of the system.

Without having a person constantly evaluate continuous waveforms continuously, 24 hours a day, every day, the methodology put forward in this system allows a user to evaluate only the critical data that is necessary to identify potential generator torsional problems. The critical data being the long term trend, and the captured waveforms over a user identified interval is all that is necessary.

All the identified requirements and targets for a torsional measurement system have been met in full and have been successfully integrated within a Torsional Monitoring System. This means that existing fault recorder systems can be upgraded to include these features of torsional monitoring, fairly quickly and easily, without making any changes to the existing fault recorder's hardware system.

The flexible configurability of the monitoring and recording criteria makes it possible to adapt the measurement system to suit any generator system or measurement requirements.

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BIOGRAPHIES

Dipl. Ing. Michael Jesingausen is the product manager responsible for fault monitoring and disturbance recording systems at KoCoS Messtechnik AG, Germany. He has been the product manager since 2002. He studied Electrical Engineering, and digital Data processing at the University of Paderborn, graduating in 1995. Then, took a job as a Electrical Design Engineer for a Danish company, where in 1998, took a similar job with KoCoS. Based on his performance and background, he ascended to Product Manager for the Fault Recorder/Power Quality products for KoCoS.

Guy Wasfy is the Director of N. American Operations for KoCoS, responsible for all facets of the business for that region. He graduated from University of Rhode Island, with a BSEE in 1990, and directly went to work for Doble Engineering. He served many roles with that company, starting as an application engineer, then a product manager, and a regional international sales manager. In 2001, he went to work for KoCoS, starting in the role that he currently has.