SBB CFF FFS

When availability counts

Unwanted operation of protection equipment due to remanence in current transformers

Switzerland has the densest rail network in Europe. Besides tracks covering more than 3,000 km (1,900 miles) and more than 800 railway stations, Swiss Federal Railways (SBB) also operate 6 dedicated hydroelectric power plants and 7 frequency converter stations. Just like any power supply grid, the 16.7 Hz railway network is equipped with comprehensive protective equipment. In the event of a malfunction, this equipment shuts down the affected grid sections and thereby helps prevent more serious damage. However, unselective tripping of the protection systems when there is no malfunction in the respective protection area (false tripping) interrupts regular grid operations and has negative effects on both availability and selectivity. In the past, false tripping of this kind occurred in isolated cases in the differential protection of transformers and machines operated by SBB. When looking into this, SBB realized that it was being caused by remanence effects, which were then investigated together with OMICRON and their testing equipment.

«The CT Analyzer has proven extremely valuable – it demagnetizes current transformer cores automatically and reliably.»

Michael Sudholz
HF power engineer, specializing in converter protection and instrument transformers

Premature saturation due to remanence

SBB examined fault reports and, in most cases, determined that significant saturation of the current transformers was the reason for the false tripping. However, it was not clear exactly why this was happening in the individual cases. Besides protection settings and transformer dimensioning, other possible reasons for the saturation and potential remedies were investigated, as was the case with other installations. At the ETG Protection Convention 2012, held in Mainz (Germany) in January, the engineers responsible at SBB learned that other energy suppliers were also being affected by this: in the event of a malfunction, remanence in current transformers can lead to undesired, premature saturation of the core and thereby trigger differential protection systems. Based on this, the engineers then conducted further research on the transformer types being affected.

Transformer dimensioning for transient behavior

Over the course of the research that was conducted, it quickly became clear that there was a fundamental difficulty when dimensioning current transformers and calculating the required overcurrent characteristics (ALF) as per the IEC 60044-1 standard. "A symmetrical, stationary current is used as the basis when dimensioning current transformers. However, short-circuit currents are offset asymmetrically to various degrees," explains Michael Sudholz, protection engineer at SBB. This leads to an exponentially decreasing DC component, which can magnetize the transformer well into the saturation range and lead to remanence greatly in excess of 50%. When a malfunction then occurs, a transformer with remanence quickly hits its saturation range. Transmission of the primary value is then distorted, which can lead to false tripping. "To specify current transformers for these so-called transient procedures, the new IEC 61869-2 standard must be applied, for example for TPY types," explains Michael Sudholz.

Investigations together with the manufacturer

The engineers at SBB got together with the manufacturer of the current transformers to investigate the principal behavior and, above all, the subseqent remanence in the transformers when using a DC source. It was possible to demonstrate a significant saturation of the current transformer cores even with low DC current values. The current transformers were demagnetized by applying nominal current to the primary side. However, since no suitable testing equipment was available, it was not possible to determine the remanence following the demagnetization process.

Support from the experts at OMICRON

"Over the course of our research, we read about the OMICRON CT Analyzer in the company's customer magazine. This testing device is not only capable of measuring remanence precisely, but can also reliably demagnetize the core," remembers Michael Sudholz.

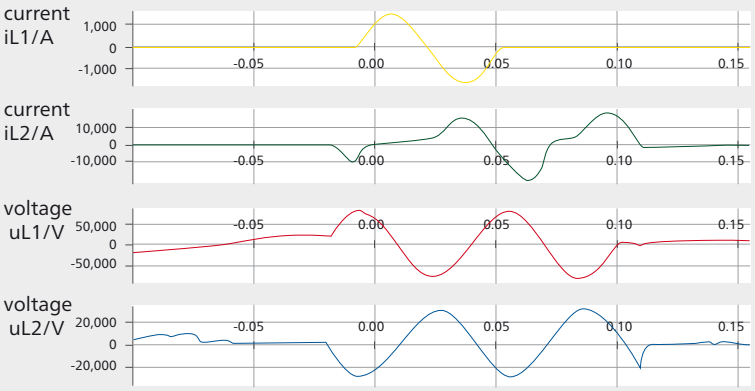
"We therefore decided to collaborate with OMICRON in our investigations." The engineers from SBB and OMICRON got together to take measurements on the six current transformers of machine 2 at the Vernayaz power plant in Switzerland.

Using the CT Analyzer, it was possible to demonstrate remanence flux of up to 66% of the saturation flux of the current transformers on the machine and up to 34% on the transformers of the 132 kV switchgear. A test was then performed to determine the effects of using a 6 V battery, such as the ones used by SBB for polarity testing of secondary wiring, on the magnetization of the transformer cores. "The results were astounding. Immediately after using the battery, it was possible to demonstrate remanence of up to 90%," remembers Thomas Stauffiger, Area Sales Manager at OMICRON. Further measurements performed at the SBB power plant in Vernayaz also showed that the primary infeed of nominal current used to demagnetize the transformers is not suitable, as the remanence is not reliably eliminated. Laboratory tests performed over the course of these measurements also demonstrated residual remanence of around 33% on an intermediate transformer which remained stable over a period of several months. Remanence in transformer cores therefore represents a serious challenge.

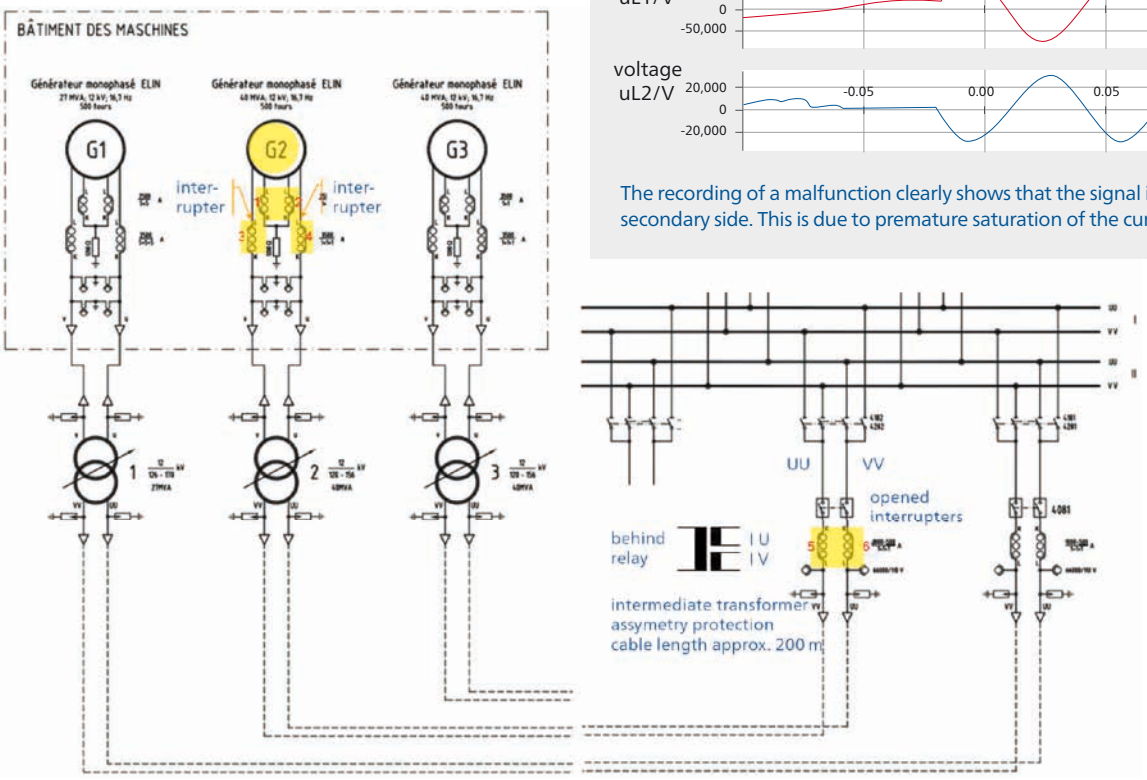
After completing the measurements in the field, the engineers from SBB demagnetized the current transformers using the CT Analyzer. This device proved extremely useful, as it completely demagnetizes the transformer core in an automated process following remanence measurement. Once all of the current transformers of machine 2 had been demagnetized in the Fall of 2012, no further false tripping was registered over an extended period of time. Following a malfunction on a 132 kV transmission line, the differential protection of machines 2 and 3 was then tripped in August 2013. The fault reports on this tripping displayed identical saturation behavior of the transformers. With the knowledge that these current transformers were demagnetized and therefore subject to the same basic conditions, it is now possible to examine the transformer design in a targeted approach and, if necessary, to replace the transformers. A corresponding proposal for replacing the current transformers is being drafted with the transformer manufacturer based on the available data.

Remote testing

Some time later, the engineers at SBB demonstrated remanence values of up to 45% on the transformers of a different machine and remanence values of up to 19% on the transformers of the testing group in the 132 kV switchgear. "To simplify handling, the demagnetization was checked remotely using the CT Analyzer, as the transformers are often difficult to access on certain machine types and the costs for grounding the machine are significant," explains Michael Sudholz. To this end, the CT Analyzer was connected to the next available disconnect terminal, which was located in the intermediate control cabinet for the machine protection / control system in the secondary room. A battery was used to first premagnetize the transformers. The remanence was then measured directly on the respective transformer and on the disconnect terminal. "The values matched up," comments Michael Sudholz with a smile. "This experiment was performed on all current transformers and it was not possible to determine any appreciable deviations between the measurement performed on the transformer and the measurement performed in the control cabinet."



The recording of a malfunction clearly shows that the signal is distorted on the secondary side. This is due to premature saturation of the current transformer.



Excerpt from the diagram of the Vernayaz power plant in Switzerland.

Collecting data as the basis for further analyses

SBB continues to rely on the knowledge and expertise of OMICRON. The CT Analyzer is used within the scope of protection testing of the current transformers at the company's installations as much as possible, first to measure and then fully demagnetize the transformer cores. "Our objective is to build a pool of valuable data," explains Michael Sudholz. "If transformer saturation is determined when a malfunction has been detected, the risk of any saturation caused by remanence can then be virtually eliminated." The CT Analyzer is also likely to see increased use during the design process for new installations and when replacing existing transformers. In this way, the CT Analyzer makes a valuable contribution to reducing grid malfunctions and thereby guaranteeing a high degree of availability and selectivity. Michael Sudholz is convinced: "OMICRON offers the right overall package, as both the service and the devices are truly unique."

Swiss Federal Railways (SBB)

Founded in 1902, Swiss Federal Railways (SBB) welcome 354 million passengers per year on its network of 3,138 km (1,950 miles). SBB Cargo uses the rail network to transport 175,000 tons of goods for its customers on a daily basis. With approximately 29,000 employees, SBB is one of the largest employers in Switzerland.

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