DTU Library

Utility survey of requirements for a HTS fault current limiter

Nielsen, Jan Nygaard; Jørgensen, P.; Østergaard, Jacob; Tønnesen, Ole

Published in:
Proceedings of 4th European Conference on Applied Superconductivity

Publication date:
2000

Document Version
Publisher's PDF, also known as Version of record

Citation (APA):
Nielsen, J. N., Jørgensen, P., Østergaard, J., & Tønnesen, O. (2000). Utility survey of requirements for a HTS fault current limiter. In *Proceedings of 4th European Conference on Applied Superconductivity* (pp. 1001-1004)

Inst. Phys. Conf. Ser. No 167
Paper presented at Applied Superconductivity, Spain, 14-17 September 1999

Utility survey of requirements for a HTS fault current limiter

J. N. Nielsen, P. Joergensen, J. J. Oestergaard
DEFU, Research Institute of Danish Electric Power Utilities, P.O. Box 259, DK-2800 Lyngby, Denmark

Ole Toennesen
Department of Electric Power Engineering, Technical University of Denmark, Building 352, DK-2800 Lyngby, Denmark

ABSTRACT: The application of Superconducting Fault Current Limiters (SFCL) in the electric utility sector will clearly dependent on to what extend needs and requirements from the utilities can be met by the ongoing development of SFCL technology. This paper considers a questionnaire survey of which needs and expectations the Danish electric utilities have to this new technology. A bus-tie application of SFCL in a distribution substation with three parallel-coupled transformers is discussed.

1. INTRODUCTION

The electric power utilities are persistently working on improvements of their networks, thus numerous different technological, environmental and economical requirements from authorities and customers can be satisfied. For this purpose, the electric power supply system will be redesigned and reinforced, even if the rate of increase in demand for electrical power is moderate. Especially an increasing focus on aesthetic and environmental considerations have caused that overhead lines are exchanged with cables and old high polluting power plants are replaced with more environmentally production units and production from new renewable energy sources. The HTS power components will be very suitable for the power utilities to meet the coming requirements to an environmental feasible and cost-effective electric power system, because they are more powerful, smaller, lighter and have lower losses than the conventional technology. The superconducting fault current limiter is a new system component with a fast and very efficient limitation characteristic, which is unknown in the conventional fault current protection scheme. Although, a full-scale and cost-effective commercial SFCL has not been presented yet it is of substantial interest to survey, which needs and expectations the utilities have to this new component.

2. LIMITATION CHARACTERISTIC OF THE SFCL

The fundamental property of any superconducting fault current limiter is its particular capability to change from one state with extremely low impedance to another state defined by substantial larger impedance. This property is in the resistive and screened-core design of fault current limiters associated by the quenching of the superconductor to a resistive limitation state. The quenching sequence is initiated when the short-circuit current is exceeding a certain transition value in the HJ-plane of the superconductors HJT-space diagram. In the resistive state power will be dissipated in the superconductor and dependent on heat capacity and cooling conditions it will be heated to a certain temperature (Gromoll et al 1999, Paul et al 1998). From an application point of view, it is the temperature of the superconductor that is decisive for whether the SFCL can be kept in operation after the fault has been cleared, or it has to be disconnected until the superconductor has cooled down and regained its superconducting state. Two designs known as the Lockheed Martin

HTS inductive/electronic current controller and the saturated iron-core FCL provide a limitation impedance, even though the superconductor remains superconducting during the fault (Leung 1997). Therefore, these devices do not have any recovery time.
The specific current limitation characteristic is obviously individual for each SFCL design and in particular of whether the critical temperature of the superconductor is exceeded during the fault sequence or not. At present, it is not clear with which design concept the first commercial available SFCL will be built. Therefore, only some few principal parameters can be used to evaluate its application potential. In this utility survey the current limitation characteristic of the SFCL is determined by the current value which is activating the SFCL, and the limitation sequence of the short-circuit current in the first few periods after the short-circuit fault has occurred.
The limitation characteristic of the superconducting fault current limiter is expected to met the following principal specifications:

Activation current:	$I_{activation} > 2.5 \cdot I_{rated}$
Limitation of the peak current value:	$I_{peak} < 10 \cdot I_{rated}$
Limitation value of the current in the first half period:	$I_{1'ste\ half\ period} < 7 \cdot I_{rated}$
Limitation value of the current in the succeeding periods:	$I_{limitation} < 3 \cdot I_{rated}$

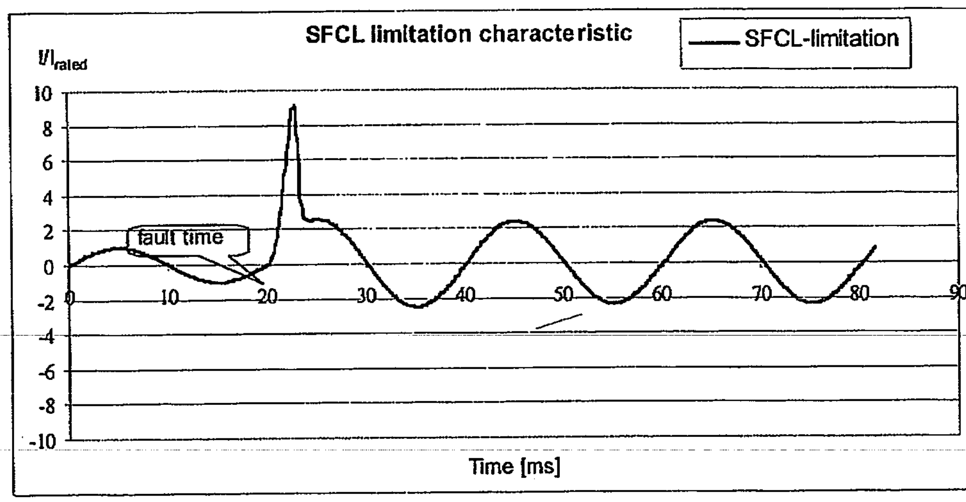

Fig. 1. Illustrative limitation curve of the superconducting fault current limiter

3. UTILITY SURVEY OF NEED AND EXPECTATIONS TO A SFCL

Based on the above mentioned specifications the Danish electric utilities were asked for their potential need of a SFCL in the transmission (400 and 150/132 kV), medium voltage (60/50/30 kV) and distribution (20/10 kV) network with concern to:

i) Increase the interconnection of the networks
ii) Avoid subdivision of the networks in future reinforcement
iii) Reduce the present short-circuit capacity if the networks are reinforced
iv) Other applications (e.g. bus-tie applications, connection of independent power production units etc.)

The utilities were further asked which investment cost is acceptable for a SFCL indicated in relation to the price for conventional relay and breaking equipment.

Finally, the utilities were asked for:

- Their knowledge about design, functioning and applications of the SFCL
- Their future expectations to use SFCL for special purpose applications in the network

4. RESULTS AND DISCUSSION

The response from the utilities operating the 400 and 150/132 kV transmissions network was 100 %. The dimensional short-circuit current value (transient and breaking value) for new 400/150/132 kV equipment is 100/40 kA. At 400 kV, none of the utilities have problems with the present level of short-circuit current and they do not expect application of SFCL in the 400 kV network. The responses from the utility survey concerning a possible application of SFCL at the 150/132 kV, 60/50/30 kV and 20/10 kV networks are shown in Table 1.

possible applications of SFCL for:	150/132 kV transmission network	60/50/30 kV medium voltage network	20/10 kV distribution network
number of utilities	5	13	87
usable respondents	5	8	29
dimensional short-circuit current value	100/40 kA	100/40 – 63/25 kA	100/40 – 40/16 kA
increasing the interconnection	40 %	50 %	25 %
avoiding subdivision	80 %	35 %	15 %
reducing the present short-circuit capacity	100 %	25 %	30 %
other applications	40 %	50 %	35 %

acceptable initial cost of SFCL	150/132 kV transmission network	60/50/30 kV medium voltage network	20/10 kV distribution network
number of responses	1	3	12
estimated price factor	2	1 – 3	1 – 3

Table 1. Applications and estimated acceptable price for a SFCL

From Table 1, it is seen that 40 % of the respondents indicated that a SFCL is an applicable solution for larger interconnection of the 150/132 kV network and 80 % find SFCL is applicable for avoiding subdivision in case of reinforcement of the network. All of the respondents find SFCL can be a usable solution for reducing the present short-circuit value in case of reinforcement of the 150/132 kV network. About 40 % find SFCL is an alternative to the conventional use of air core reactors and high-impedance transformers, protection schemes of independent power production units etc. Only one utility has responded on the question which price is acceptable for a SFCL (132 kV unit) and gives an estimate twice the price of conventional breaking equipment.

The majority (more than 80 %) of all respondents find they need more information about the design, functioning and applications of SFCL.

The utilities were finally asked about their future expectations to use of SFCL when it becomes commercial available. At the 150/132 kV level all of the utilities indicated that they expect a prospective application of SFCL for special purposes in the network. At the medium and distribution voltage level the responses were 60 and 55 % to that question.

Even though the utility survey has shown that the most obviously need for SFCL is the 150/132 kV transmission network the application potential in the present network is presumably rather limited. Today the short-circuit level is kept at the dimensional value by use of transformers with enlarged impedance and by use of air core reactors installed as series reactance in the transmission cables. The disadvantages of these solutions are the voltage drop and the power loss in normal operation. Therefore, if SFCL is to be used instead of air core reactors it is the current ratings of the transmission cable, which will set the normal and overload current ratings of the SFCL. The normal operation current value of a 150/132 kV cable is typical between 200 and 400 A with a maximum load value ranging from 400 to 1000 A.

At the 30 kV medium voltages network, air core series reactors in cables are used by one utility. The normal load current is about 200 A with a variation of the maximum ratings between 400 to 1000 A. In general, a cable is not attempted reconnected after a fault, which means that a fast recooling time is not a decisive requirement for the SFCL.

The most frequently mentioned application of SFCL in the distribution voltage network is the well-known bus-tie location of SFCL where two or more distribution transformers are coupled in parallel. Fig. 2, shows an example of a 60/10 kV transformer substation with three parallel coupled 16 MVA transformers with air core reactors installed at the bus tie. The typical current value of the outlet feeders from the substation is about 150 A at normal operation and between 260 – 340 A at maximum load. A bolted three-phase bus fault will cause a steady state short-circuit current about 14 kA without air cores. With air cores installed as shown in Fig. 2, this value is reduced to about 10 kA. For a SFCL located as bus-tie SFCL the current rating may be about 800 A at normal operation and 1200 A at maximum load. Strictly speaking, the SFCL may be able to recool itself after the fault has been cleared, carrying a steady-state current at 1200 A. Otherwise at least one additional breaker will be necessary to maintain the feeder supply during the recooling time.

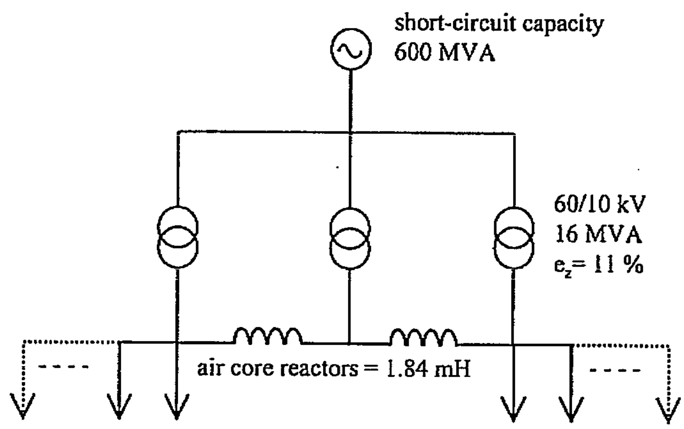

Fig. 2. Transformer substation with air core reactors

5. CONCLUSION

A questionnaire survey of the Danish electric utilities needs and expectations to SFCL has indicated a pronounced conservative assessment to its prospective application. In general, the short-circuit level is rather easy kept below the appropriated dimensional values of breakers, busses, cables etc. The most obviously applications of SFCL in the present power supply network are identified as the 10 kV bus-tie location of a 60/10 kV transformer substation and the feeder outlet location of 132 kV and 30 kV cables. The highest prospective application of SFCL is expected at the 150/132 kV transmission networks in case of system redesign or reinforcement. The survey has too shown an urgent need from the utilities of more information about its technical performance and economy before they can take specific decision on how and where SFCL may be applied in their network.

REFERENCES

Cave J, Willén D, Nadi R and Brissette Y 1999 IEEE Trans. Appl. Supercond. **9**, 2.

Cerulli J 1998 IEEE Eng. Society Winter Meeting. **2**.

Gromoll B, Ries G, Schmidt W, Krämer H-P, Seebacher B, Ulz B, Nies R, Neumüller H-W, Baltzer E, Fischer S and Heismann B 1999 IEEE Trans. Appl. Supercond. **9**, 2.

Leung E 1997 IEEE Spectrum July.

Noe M, Oswald B R 1999 IEEE Trans. Appl. Supercond. **9**, 2.

Paul W, Chen M 1998 IEEE Spectrum May.

Paul W, Lakner M, Rhyner J, Unternährer P, Baumann T, Chen M, Widenhorn L and Guérig A 1997 Supercond. Sci. Technol. **10**, 12.

Slade P G, Wu J L, Stancey E J, Stubler W F, Voshall R E, Bonk J J, Porte J and Hong L 1992 IEEE Trans. Pow. Delivery **7**, 2.