Utility Needs Survey for Fault Current Limiters

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Abstract— **In response to unprecedented restructuring of electric markets and a power delivery system in the U.S. that is not optimized to meet today's loads and customer needs, electric utility companies are undertaking a focused effort in re-assessing fault current mitigation methods. Similar efforts are underway in other countries, albeit perhaps in response to different economic drivers. Novel fault current limiter (FCL) technologies are of growing interest because of their potential to replace existing (and increasingly often unsatisfactory) methods. The superconducting FCL (SFCL) is one such technology. SFCLs attracted interest soon after the discovery of HTS materials but have only lately been seriously considered as it became apparent that coated conductors might better enable the cost and performance desired by utility companies. Cost-benefit studies as well as significant field demonstrations are still needed to determine the full potential of a significant penetration of SFCLs into the market place. A number of developers around the world are designing and testing SFCLs, or preparing to do so. As these developments proceed it will be important to understand the characteristics of the intended market – the needs of the utility industry and the desirable characteristics of a FCL.**

I. Introduction

The Electric Power Research Institute (EPRI) has recently undertaken a series of utility needs and technology readiness surveys for FCLs. The research provided an initial perspective on utility needs and prescribed ideal characteristics for FCLs.[1]

A. Utility Needs

About 28 utilities provided responses to some 18 questions in a 2004 survey that attempted to understand where FCLs would be applied and the utility's likelihood of investing in new technologies to meet their needs. Unexpectedly, utility respondents did not include the activities or needs of independent power producers (IPPs), which as it turned out could significantly affect the market size. Nevertheless, the survey found a number of key points:

- Utilities are re-assessing fault current mitigation methods and taking a serious look at needs and technologies. Emerging novel FCL technologies are seen as vital alternatives to existing methods, provided these technologies are a cost effective means of fault current management. Comprehensive cost-benefit studies are needed to better understand the potential market –from both applications and equipment design perspectives.
- There may be a modest market for novel FCL solutions for circuit breaker replacement in the next decade. It was assumed that the FCL is equivalent to the circuit breaker in all other respects (e.g., reliability, compatibility with protection, ease of installation, operation and maintenance, etc.). Survey results suggested:
  - Up to 20% of respondents expecting to replace 5 to 10% of their circuit breakers in the next 10 years would use a FCL device priced at 1 to 5 times a circuit breaker.
  - The percentage increases to 30% of respondents when the range of circuit breaker replacement need expands to from 5 to 30%. (i.e., those utilities having a greater expectation for circuit breaker replacement are even more likely to use an FCL).
- Fifty percent of the respondents would seriously consider purchase of a FCL whose cost was 2-5 times the cost of a breaker. This is particularly true in cases where breakers with the required ratings are not available, or where excessive fault current levels require more than a breaker upgrade alone (e.g., strengthening substation grounding and bus work).

Respondents were not particularly sensitized to the impact of FCLs on the protection system, and the subject was not well understood. Ongoing research in this area is limited and should be pursued more intensively in the future. (CIGRE WG.A3-16 is investigating this issue.)

- The use of superconducting cables will increase the need for FCLs, particularly in transmission applications. Mitigation of HTS cable system cryogenic system recovery time after a fault is essential to prevent an unacceptably long cable outage in the post-fault time frame. Combined cable-FCLs should be investigated more thoroughly since 60% of the respondents indicated they would consider HTS cables as an alternative to increase transmission capacity and mitigate transmission bottlenecks.
- Utility companies need technical evaluations of novel FCL technologies that focus on specific applications and the impact of the FCL on the grid. This would help to increase acceptance of the new equipment and methods. It may be beneficial to initiate representative case studies for different types of FCL applications.

B. The "Ideal" Fault Current Limiter

EPRI evaluated a range of FCL technologies as to their characteristics and how well they met utility needs. As part of this work a description of an ideal FCL was developed. While not entirely achievable in practice, the following list of ideal attributes will provide guidance to equipment developers (refer to Figure 1 for quantities in parentheses):

1) Exhibit zero impedance during normal operation (i.e. no losses, no reactive voltage drop). This requirement is straightforward. It cannot be met completely by real FCL systems but they may come close to the ideal value.

2) Provide immediate and "perfect" discrimination between a (temporary) over current situation and a true fault event. This is in fact a request for ideal protection relay functionality. Real FCL systems may come close to this ideal only if they are externally triggered. The corresponding quantity in is the minimum initiating current ($\hat{\imath}_{min}$).

3) In case of a fault, decrease the rate-of-rise of the current quickly within the first quarter cycle in order to reduce the first current peak to an acceptable level ($\hat{\imath}_{max}$). In any voltage driven circuit the only possible way to achieve this is to build up voltage across the FCL such that the remaining voltage across the system impedance is reduced or completely brought to zero. Since fault current and voltage build-up across the FCL are present at the same time the FCL effectively increases its impedance.

4) Perform the voltage build-up across the FCL such that the associated voltages do not exceed the dielectric insulation capability of the existing system.

5) Allow a follow current to flow to enable downstream protection coordination to clear and isolate the fault ($\hat{\imath}_{fol}$). However, the limited follow current must be less than the prospective (or unlimited) fault current.

6) Immediate and automatic recover under full load current, or even under over current conditions in case the system responds with such, after fault clearing. The corresponding quantity in Figure 1 is the recovery time t_r.

7) Fail safe limiting operation. This indicates whether the FCL will still limit the fault current even if its primary mechanism fails.

Items 1), 2), 6) and 7) are independent of the application attributes and are objective measures; however, items 3), 3), and 5) are not. What is considered "ideal" for the latter may vary significantly between applications. For example, if the objective is only to reduce the fault current level just enough to meet existing breaker requirements there may not be a need or desire to reduce $\hat{\imath}_{max}$ significantly below the peak unlimited (prospective) short circuit current ($\hat{\imath}_p$). In other cases it may not desired to strongly reduce the follow current in order to keep the existing downstream protection coordination.

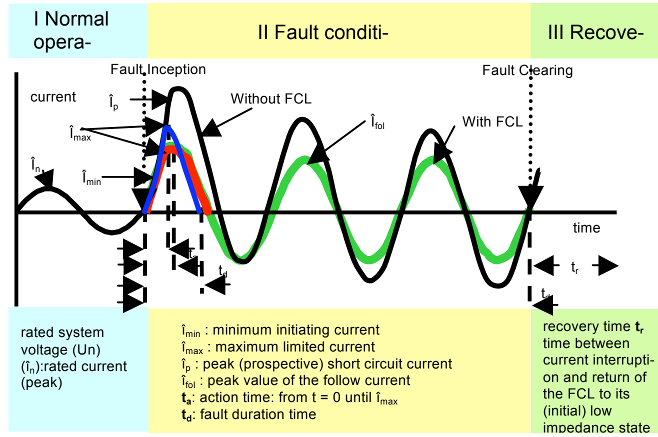

Fig. 1. FCL Perameters Graph

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References

[1] *Survey of Fault Current Limiter (FCL) Technologies*. EPRI, Palo Alto, CA: 2005. 1010760.