Integration Issues for Fault Current Limiters and Other New Technologies- a utility perspective

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Abstract--**This paper presents some issues and perspectives on the needs for fault current limiting functionality, particularly for dense urban load centers. It provides some perspective on the present conditions relative to fault currents in New York City and potential sources for increased fault currents throughout the power grid. It provides the author's perspective on some requirements that an effective fault current limiter must meet, identifies some unique requirements for special applications and provides a broad overview of current industry activities pursued to encourage the development of multiple alternatives to mitigate fault currents, and to encourage wide stakeholder participation in this effort.**

***Index Terms*--fault current limiters, fault current, generators, load management, load restoration, re-closing devices Reconfigurable architectures, superconducting cables superconducting devices, urban areas**

I. Nomenclature

CCAS- Coalition for Commercial Application of Superconductors; industry group of companies and National Labs participating in all aspects of the superconductivity community

DARPA- Defense Advanced Research Projects Agency

DOE- Department of Energy

EPRI- Electric Power Research Institute

FACTS- Flexible AC Transmission

FCL- Fault Current Limiter

GridWise- DOE initiative focused on digital information and control technologies and interoperability to enhance the value and performance of the electrical grid for all stakeholders

GridWise Alliance- a group of companies operating under a Memorandum of Understanding with DOE to promote GridWise digital information and control technologies and interoperability

GridWorks- DOE Initiative focused on hardware aspects of new grid technologies, as part of DOE's System Integration Program

HVDC- High Voltage DC

ONR- Office of Naval Research

PE-BC- Power Electronics-Based Controller

II. Introduction

Dense urban load centers like New York City have been dealing with increasing fault currents and increasing sensitivity to existing fault currents, at all voltage levels over a considerable period of time. Dense urban power systems with their N-2 redundancy also tend to have inherently higher fault current availability.

The Con Edison system already has relatively high impedance transformers since it normally operates with 2 to 4 transformers in parallel, and has installed quite a number of series reactors. While this technology and approach has in general, maintained the system below 63kA (transmission) and 40kA (primary distribution) in circuit breaker interrupting ratings, there are a number of limitations on the future effectiveness of this approach. Con Edison believes that additional fault current sources will be added and that new more flexible solutions are needed. Fault currents could be increased in the future by:

- an increase in market based transmission development,
- increased penetration of distributed generators and/or
- the addition of very low impedance superconducting cables.

In addition, energy Storage devices will be needed to take advantage of renewable energy sources that are wind or sunshine dependent and to improve asset utilization but they also can add to fault currents. For the above reasons alone FCLs are needed so that total rebuild of the existing system won't be required in addition to construction supporting new capacity. Besides mitigating the above fault current sources, fault current limiters can enhance and enable other new technologies by, for example, protecting the electronic components of line commutated FACTS (HVDC & PE-BC) devices from nearby faults. They could also make it possible for superconductors to be made even smaller in cross-section to facilitate retrofit in existing ducts and eliminate long superconducting cable cryogenic recovery times following downstream faults.

A number of specific industry projects are already underway to develop new fault current limiting functionalities. These include currently funded projects like the Solid State Current Limiter [7,8,9,13] with EPRI, Powell Industries, Allegheny Power, SDG&E, KCP&L, Georgia

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Transmission and NEISO, as well as the Matrix Type Superconducting Fault Current Limiter [5,11] with SuperPower, DOE, Nexans, AEP and EPRI.

In addition, there are multiple new market entrants, including independent developers like SCPower [2], major manufacturers like ABB [15] and new consortiums, such as American Superconductor's collaboration with Siemens [1], and Nexans [6] new effort with RWE and others.

Even China's Institute of Electrical Engineering (IEE) in collaboration with their Technical Institute of Physics and Chemistry and Hunan Electric Power Company has announced that IEE has demonstrated a superconductor-based fault current limiter [4] for the first time in a power grid in China utilizing high temperature superconductor (HTS) wire manufactured by AMSC. Since each of these designs will have operating and maintenance issues as well as performance issues for specific applications, all utilities should participate in these efforts and encourage a broad dialog between all stakeholders that would ultimately use and benefit from this functionality.

III. FCL REQUIREMENTS

In order for a fault current limiter to be fully effective in addressing the above needs, based on a review of our typical applications, it must meet at least the following requirements:

- limit fault current before the first peak,
- withstand magnetic and mechanical forces of repeated fault mitigation operations,
- properly respond to any fault magnitude and/or phase combinations
- recover automatically, so that the limited assets remain available for peak load service after the fault,
- have a very short recovery time to deal with multiple faults,
- provide and control appropriate "let through" current for coordination with other protective devices,
- provide phase independence to add inherent redundancy for many fault applications,
- have common requirements to support broad based industry demand for sustainable commercial development and deployment

In addition to the general requirements above, special requirements exist for selected applications, e.g., a compact design in urban locations or retrofit and "soft recovery" capability for applications involving generators susceptible to shaft torsional stress failure.

IV. INTEGRATION ISSUES

Integration issues include items such application specific items as:

- Existing system impedance,
- Maximum fault current,
- Potential system configurations and contingencies,
- Operation of other assets, such as gas turbines,
- Magnitude of fault current reduction required,
- Duration of fault current,
- Short term fault and reclosure sequences,
- Recovery time between faults,
- Long term expected number of faults,
- Internal protection features, including cryogenic cooling aspects, if applicable,
- Losses,
- Maintenance requirements,
- Required current and voltage ratings,
- Impacts on load flows,
- Potential operational interactions other equipment (voltage drops, generator instability, etc.),
- Space limitations, particularly for urban locations and retrofit applications,
- Control of "let-through' current for coordination, particularly as faults change state (intensity, phase and ground combinations),
- Control of "let-through" current to minimize changes to existing protection schemes and equipment.

Another potential design synergy that can help in the development of fault current limiters is the largely DARPA & ONR [10] funded development of new materials like Silicon Carbide that could greatly reduce the cost and footprint of not only the Solid State Current Limiter, but FACTS devices (both HVDC and PEB-C) in general. Ongoing work by companies like CREE and Silicon Power and research organizations at places like the Universities of North Carolina, Arkansas and Florida State [16] are advancing these technologies in different ways through materials research, device development, modeling, and unique packaging approaches to enhance cooling and device performance. Direct collaboration between these related individual developers and with user community stakeholders can provide even more synergistic benefits.

As another example of stakeholder alliance benefits, the Superconducting community is, this author believes, an even stronger proponent of fault current limiters than utilities by themselves.This is primarily due to the fact that the power system applications are fragmented, applying separately to utilities themselves, Independent Power Producers and Distributed Generators [14]. However, the much more compressed planning process, and developer control of desired interface locations increases the shared need to have a tool to selectively mitigate fault current problems as they appear more frequently, and with less predictability.

Finally, the continuing increases in power system loads, particularly in dense urban load centers demands that we provide additional capacity and this will only worsen fault current problems. Peak load in New York City and Westchester (Con Edison's service area) exceeded 13,000 MW in 2005 and is projected to reach 14,500 MW by 2012. New York City is seeing continuing classical load increases driven by increased air conditioner penetration, business development, new homes, expansion of existing housing expansions and to a lesser degree the incredible proliferation of electronic devices, computers, chargers and instant-on TVs, etc.. This does not include the potential for even more substantial load growth due to possible increased penetrations of new technologies like hybrid vehicles, lower temperature capable heat pumps and/or dis-infection equipment for air and water where larger numbers of people congregate. All of these new technologies would be electricity based.

V. CONCLUSIONS

This author believes that we, as an industry, need to accelerate and build upon benchmarking and cooperative technical discussions with many other utilities that have dense urban load centers to find ways to create new flexibilities and "smart grids" that will be key to creating the maneuverability we will need to enable the outage intensive replacement of switchgear, transformers and cable in a more cost effective manner. Some of this equipment has already served us well beyond our original expectations, largely due to substantial design margins used older equipment.

Many new technologies are needed, but each of these silver linings has a cloud we must collectively deal with, not just as utilities, but in a continuing dialog and collaborative effort with many partners such as DOE, EPRI, CCAS, GridWise Alliance, as well as our regulators and our customers, who themselves are changing the nature and character of the power system we will ultimately need to serve..

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Because multiple alternatives are needed at middle voltages (13kV to 34kV) and transmission voltages (138kV and 345kV), EPRI has initiated a new Fault Current Management Program. EPRI also recently completed a FCL needs survey and study [12] of presently known fault current limiting alternatives, as an Interim Report for funders of this project. Member utilities should encourage EPRI to add new technologies and further details to a Final version of this report, and to create a public reference version that would encourage wider engagement and participation by all stakeholders

Fault current limiting functionality is a critical enabler for many other new technologies, such as superconducting cables, and can add new flexibility to existing power system designs that would greatly facilitate required upratings due to load growth, and allow innovative reconfigurations that would also facilitate life extension and replacement efforts for existing aging electrical infrastructures.

For the above reasons all utilities and other stakeholders should actively participate in, contribute to and collaborate on industry activities for development of multiple fault current limiting alternatives..

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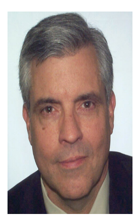

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