New York State Energy Highway (NYSEH) RFI Submission

Use of Varian Power Systems (VPS) Superconducting Fault Current Limiters (SCFCLs) to surgically mitigate excessive fault current levels that would otherwise interfere with desired elements of the NYSEH initiative

RESPONDENT INFORMATION

Paul J. Murphy, Ph.D., G.M. Varian Power Systems

Applied Materials

35 Dory Road, M/S 14

Gloucester, MA 01930-2297

Telephone: 1 978 282 7522

Email: Paul_Murphy@amat.com

Mr. Murphy obtained his Ph.D. in Physics in 1993 and has vast experience in Guidance Systems, Scientific Instruments, Space and Satellite Design and High Voltage Systems. Paul has held various senior level positions in Engineering with Varian since 1997 and is currently G.M. of Varian Power Systems Group of Applied Materials

About Varian Power Systems, a division of the Varian Semiconductor Equipment Business Unit of Applied Materials, Inc.

Applied Materials is the global leader providing innovative equipment, services and software to the semiconductor, flat panel display and solar photovoltaic industries

Applied has over 14,000 employees in 87 locations in 19 countries with annual revenue in excess of $11 Billion. Applied has the intellectual capital, financial resources and capability to help customers integrate and manufacture advanced technology around the world.

Varian Power Systems (VPS) develops and manufactures critical power system solutions for the utility market. These solutions combine the company's visionary leadership with experience in high voltage engineering design, power systems integration and systems engineering. The Varian

Business Unit has been ranked by VLSI Research as number one in customer satisfaction for 14 of the last 15 years.

NEWSWEEK Magazine's
Top Greenest Companies

Ranks No. 3 in Industry on FORTUNE Magazine's
World's Most Admired Companies List

Named one of the **Most Innovative Companies in the World**

PROJECT DESCRIPTION

BACKGROUND INFORMATION ON FAULT CURRENT LIMITERS

Fault Current Limiters (FCLs) are a new type of power equipment that protect power system equipment from extremely large mechanical, magnetic and thermal stresses that can occur when an electrical fault creates a low impedance path across other power system equipment or to ground. These stresses almost instantly concentrate, since all the electrically connected power sources on the entire power system are immediately drawn to the low impedance path created by the fault. Sometimes currents on the order of 63,000 amps occur on transmission systems (e.g. 138kV and 345kV systems) and 40,000 amps on selected dense urban distribution systems (New York City's 13kV system).

The new functionality provided by FCLs is even more critical as capacity increases to serve larger loads. This situation inherently adds to both system-wide and local fault current magnitudes. As distributed generation and energy storage proliferate, power systems must "ride through" periodic faults to provide necessary capacity and functionality during periods of peak demand.

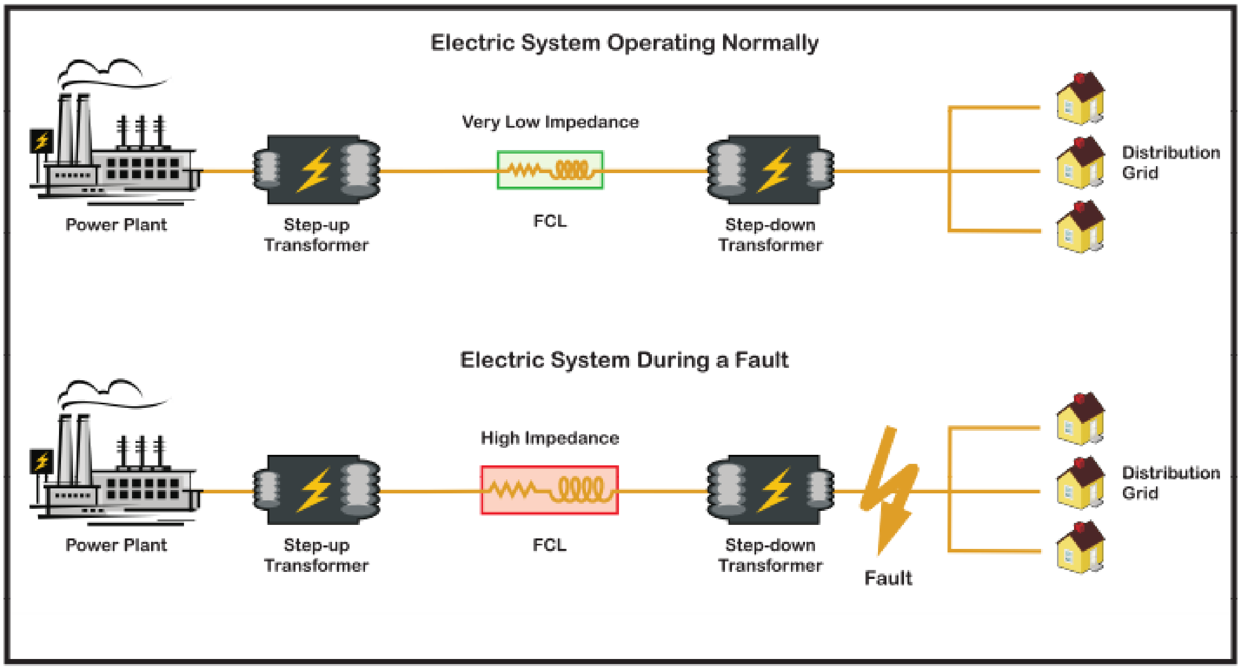
[NEXT 3 HEADINGS AND FIGURE ARE PARTIALLY EXCERPTED FROM THE DOE FCL FACT SHEET]

What are FCLs?

A fault is an unintentional short circuit, or partial short-circuit, in an electric circuit. A variety of factors such as lightning, downed power lines, or crossed power lines cause faults. During a fault, excessive current—called fault current—flows through the electrical system often resulting in a failure of one section of that system by causing a tripped circuit breaker or a blown fuse. A fault current limiter (FCL) limits the amount of current flowing through the system and allows for the continual, uninterrupted operation of the electrical system, similar to the way surge protectors limit damaging currents to house-hold devices.

Why Do We Need FCLs

The need for FCLs is driven by rising system fault current levels as energy demand increases and more distributed generation and clean energy sources, such as wind and solar are added to an already overburdened system. Currently, explosive fault-limiting fuses are utilized to limit fault current, but they require a service call to replace the fuse after it blows and they are only available for voltages below 35 kV. Series reactors are also used but they have constant high reactive losses, are bulky, and contribute to grid voltage drops. FCLs overcome these weaknesses. Additionally, rising fault current levels increase the need for larger and often costly high impedance transformers. However, in contrast to these transformers, FCLs operate with little to no impedance during normal operation which allows for a more stable system.



During a ground fault, an FCL safely mitigates the excess energy that would normally effect utility transmission and distribution equipment, preventing damage.

What Are The Benefits To Utilities?

FCLs offer numerous benefits to electric utilities. For instance, utilities spend millions of dollars each year to maintain and protect the grid from potentially destructive fault currents. These large currents can damage or degrade circuit breakers and other expensive T&D system components. Utilities can reduce or eliminate these replacement costs by installing FCLs. Other benefits include:

- Enhanced system safety, stability, and efficiency of the power delivery systems
- Reduced or eliminated wide-area blackouts, reduced localized disruptions, and increased recovery time when disruptions do occur
- Reduced maintenance costs by protecting expensive downstream T&D system equipment from constant electrical surges that degrade equipment and require costly replacement
- Improved system reliability when renewables and DG are added to the electric grid
- Elimination of split buses and opening bus-tie breakers
- Reduced voltage dips caused by high resistive system components
- Single to multiple shot (fault) protection plus automatic resetting

VPS' Superconducting Fault Current Limiter and the NYSEH

VPS' Superconducting Fault Current Limiter (SCFCL) can mitigate increased fault currents arising from additional generation and upstate/downstate transmission throughput that could otherwise increase local fault duties both within the New York City load center and in other state power systems that would be accommodating increased throughput within their service areas. Unmitigated increases in fault duties beyond current local system and equipment ratings could potentially lead to circuit breaker failures, flashovers, or physical bracing failures, which then could potentially cause multiple faults or significant loss of life to electrical power system components, as well as reliability impacts due to overtripping and/or extended equipment replacement or repair outages. In addition the restrictions on interconnection caused by fault current limitations can have direct negative impacts on the accomplishment of most of the intended objectives of NYSEH initiative. The selective application of fault current limiters can provide not only cost advantages through its relatively lower cost and losses for selective application versus Series Reactor, FACTS and HVDC alternatives, but can be more quickly designed and installed to respond to unanticipated loop flows or impacts of other changes on the power grid.

The project(s) would involve selective application of Varian Power Systems' (VPS') unique Superconducting Fault Current Limiter (SCFCL) design to mitigate generation, transmission or distribution fault currents either in a standalone project or in conjunction with any proposal accepted by the NYSEH Task Force. Many of the proposals that will be submitted to the NYSEH Task Force if implemented will exacerbate the existing fault current problems which will undermine the goals or substantially increase the required scope or cost of accepted proposals within the NYSEH initiative.

PROJECT DESCRIPTION

• **Type of proposed project:** Can be applied to generation, transmission and/or distribution or combination thereof, as needed.

• **Size of proposed project, with expected capability in energy and capacity:** will be dictated by the needs of the New York State Energy Highway (NYSEH) initiative and or any one or more of its accepted proposals, which cause fault current increases that require mitigation. Examples could include:

A. SCFCL(s) within or adjacent to a transmission substation or as an intermediate terminus along the Right-Of-Way to limit downstream fault contributions.
B. SCFCL(s) at the output of a utility scale generator to limit fault contributions from the generator
C. SCFCL(s) at either side of the transmission-distribution interface to limit additional fault current contributions that would otherwise be likely to cause damage to the distribution system
D. SCFCL(s) inserted in a bus tie, which is currently kept open due to fault current concerns, so as to achieve the operational and reliability benefits of a closed bus-tie
E. SCFCL(s) used to enable creative new power system configurations such as tying substations together, creating substation ring configurations and/or adding an additional in-service spare transformer to improve asset utilization, improve reliability, add capacity to an existing substation and/or defer the need for a new substation

• **Proposed project location(s):** to be selected based on overall NYSEH initiative and/or proposal needs. It is recognized that NYSEH projects selected may substantially impact anticipated fault currents in specific areas or locations, and our intentions would be to work with the state through NYPA or NYSERDA, developers or utilities to either directly work with new fault current problem areas, as they are identified under the NYSEH plan, or preferably to work more immediately on currently known areas of fault current concern, thus adding fault current margin to the NYSEH planning effort, allowing a more problem free development of the most desirable NYSEH Action plan elements.

• **Fuel source or availability of fuel/infrastructure:** is not required. Auxiliary power needs can be provided by the electrical infrastructure itself, since by design a project will be grid interconnected.

• **Earliest date the project can be operational:** The project can be specified, designed, fabricated, delivered and operational within 6 to 9 months of agreement on the fault current mitigation scope needed and associated user specified requirements.

• **Experience, market availability and suitability of project technology:** Applied Materials is the global leader providing innovative equipment, services and software to the semiconductor, flat panel display and solar photovoltaic industries

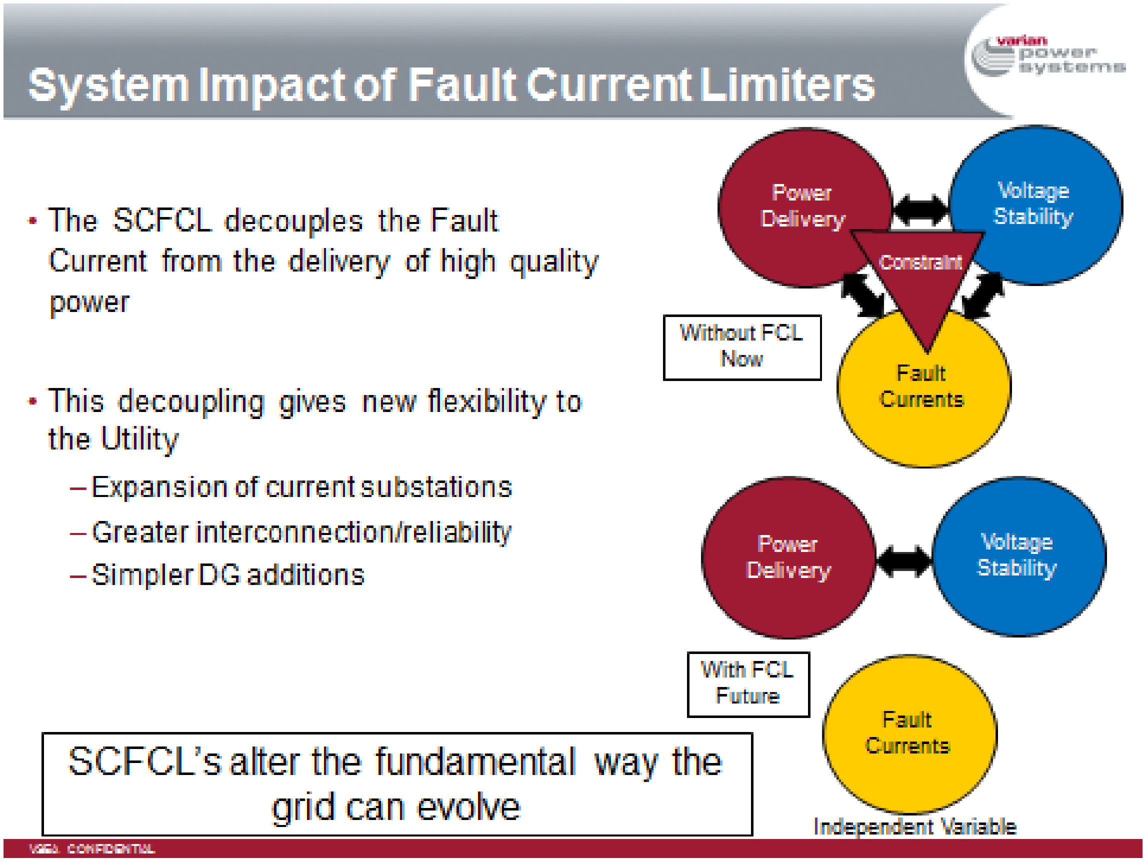
Applied has over 14,000 employees in 87 locations in 19 countries with annual revenue in excess of $11 Billion. Applied has the intellectual capital, financial resources and capability to help customers integrate and manufacture advanced technology around the world.

Varian Power Systems (VPS), a division of the Varian Semiconductor Equipment Business Unit of Applied Materials, Inc., develops and manufactures critical power system solutions for the utility market.

VPS' SCFCL uses commercial readily available components, including superconducting tape, which is commercially available from multiple manufacturers.

Equally important is both Applied Materials' corporate commitment to the reliability, flexibility and maintainability of its process systems, and its demonstrated manufacturing capabilities that will be vital to achieve a scale-up of FCL production, deployment and support.

FCL development at VPS included a careful assessment of the strengths and limitations of all currently available fault current limiting technical approaches. It was concluded that a superconducting FCL, enhanced by our unique techniques and design features and successfully KEMA and Doble tested, is the best solution for the utility industry's FCL needs. Its suitability to the grid – small size, scalability and cost avoidance as well as proven technology make it not only a very suitable solution, but a critical enabler for the capacity increases that will be required for both the transmission grid and local infrastructures.



FLEXIBILITY- Varian Power System's SCSFCL can be scaled to meet needs in generation, transmission and distribution up to 400kV and fault currents greater than 100kA. Can be installed in any location, or interconnection point, where this type of mitigation would benefit the overall cost effectiveness and benefits of the overall NYS Energy Highway program, or one of its accepted proposals. See examples A. through F. on above page 6.

OPERATIONAL CHARACTERISTICS- Varian Power Systems (VPS), a division of Applied Materials, Inc., has completed KEMA and Doble testing for its newly developed Superconducting Fault Current Limiter (SCFCL). This modular compact platform can be used for distribution and transmission applications. These devices insert no significant impedance during normal operations. In a fault condition the system inherently responds instantly adding sufficient impedance on the line to reduce the first peak and subsequent peaks to customer specified fault current reductions in the range of 20-80%, depending on the specifics of the application and the specified design.

The successful KEMA and Doble tests used the following test conditions:

Testing Parameters:
- System voltages from 10kV to 125kV
- Prospective Fault currents up to 56kA
- Subjected to 50 high energy faults
- Tested to the limit of KEMA (US) capability.

Testing Results
- Demonstrated <1ms response for first peak reduction
- Demonstrated > 60% fault reduction at 13.8kV
- Fault reduction at 125kV
- No functional degradation after more than 50 faults
- Passed 220 kV single phase to ground (Satisfying IEC and IEEE standards for transmission line systems up to 200kV).
- Passed Life testing and Customer Validation (>200 Fault Tests)

Fault Current Limiter Operation

Normal operation
• Load current flows through superconducting unit
• SCFCL introduces no significant impedance and zero voltage drop

Fault condition
• Superconductor inherently senses fault current, quenches, inserts high resistance
• Current transfers to shunt and limits fault current

Recovery
• Superconducting unit recovers superconducting state quickly in seconds

KEMA Short Circuit Test Capability
• Voltage – single phase up to 72 kV (125 kV Line-to-line)
• 3 circuits from transformer at 22 kV, 44 kV and 72 kV
• Directly connected to generator – up to 12.5 kV single phase (21.65 kV Line-to-line)
• Short circuit Current – 8 kA at 72 kV to 63 kA at 10 kV

High Voltage Test Capability
• AC High Voltage tester – up to 220 kV (single phase)

PROJECT JUSTIFICATION

How the proposed project could address the State's objectives and goals: VPS's SCFCL can help assure that the intended New York State Energy Highway Objectives are met in the following ways:

SCFL IMPACTS ON ENERGY HIGHWAY OBJECTIVES

Reduce constraints on the flow of electricity to, and within, the downstate area; and expand the diversity of power generation sources supplying megawatts downstate by reducing fault current restraints on the flow of electricity to and within the downstate area, and reducing fault current contribution restrictions that could otherwise limit interconnection acceptability of some generation alternatives.

Assuring that-long term reliability of the electric system is maintained in the face of major system uncertainties not only by mitigating potential immediate impacts of fault currents on severe fault equipment damage and on zonal coordination of relay protection, but on long term life and reliability of equipment that is subjected due to the mechanical, magnetic and thermal forces of periodic faults on the power system. Examples include impacts on transformer and bus bracing, both of which may be hard to access for repair, and if allowed to fail in service would possibly cause serious faults themselves. These same fault stresses affect other components, as well, and could make them more susceptible to in service failures such as moisture migration into underground components or cracked insulators.

Encourage development of utility-scale renewable generation resources throughout the state by facilitating access to the market, and increasing stability by allowing simultaneous interconnection of both renewable resources and alternative supplies needed to maintain stability in case of unanticipated losses or reductions of intermittent capacity. The inherent volatility of utility scale renewables at higher penetrations may require additional spinning reserve allocations and/or energy storage to cope with unplanned reductions in renewable capacity. This may further increase fault currents, which can be mitigated by SCFCLs. Overall reductions in available fault currents may also increase the likelihood of smaller residential and commercial renewable generation resources "riding through" nearby faults, and remaining available to serve peak loads after this kind of contingency.

Increasing efficiency of power generation, particularly in densely populated urban areas, by reducing the need for or improving the performance of alternatives such as series reactors, high impedance transformers and less surgical and more expensive FACTS devices and HVDC terminals, which, if line commutated can be damaged themselves by close-in faults.

Create jobs and opportunities for New Yorkers. Several major components of VPS' SCFCL are currently sourced from New York Manufacturers. Creating jobs and opportunities for New Yorkers by helping to sustain the increases in electrical power needed to maintain U.S. and New York technology based economic competitiveness, providing a market for New York based component suppliers and helping to maintain sustainable electric rates for consumers, and enabling continued economic development and construction within New York.

Contribute to an environmentally sustainable future for New York State by reducing fault currents and in turn facilitating market access for both more remote renewable power supplies, and improving local conditions effecting both the ability to interconnect of smaller local distributed generation and renewables, and the "fault ride-through" availability of these smaller assets to help meet peak load following a near-by fault on the local power system and allowing more freedom in the selection of some NYSEH alternative proposals that might otherwise be precluded due to fault current concerns. The SCFCL creates no environmental concerns as a technology in itself, and by allowing interconnection of both utility-scale and smaller renewables and supporting more resilient smart grid interconnections it enables many other environmentally beneficial technologies to more easily be added to the grid.

Apply advanced technologies that benefit system performance and operations. Fault Current Limiters are in themselves an advanced technology that can benefit overall system performance.

Maximize New York State electric ratepayer value in the operation of the electrical grid. VPS' Superconducting Fault Current Limiters can be selectively installed to mitigate fault current increases on transmission or distribution systems, and can cost effectively enhance other project proposals that would otherwise increase the potential for the types of problems listed within the Project Description. As discussed in many of the sections above SCFCLs can be used to avoid and reduce the expense of in service failures, improve asset utilization and maintain reliability, while deferring more expensive alternative infrastructure upgrades. This leads to reduced associated installation, cable routing and overhead and/or under-street work and simplified coordination with municipal development plans.

Adhere to market rules and procedures, and make recommendations for improvement as appropriate. VPS' SCFCL broadens available market choices by mitigating restraints on some otherwise viable project proposals, allowing more freedom of strategic choices that can be considered in the resulting action plan.

Other Reasons Why Fault Current Limiters are critical to business plans and strategies in the utility industry and in New York State

The pressures and demands on utilities are at an all-time high. Contradictory requirements and restrictions have not only undercut traditional utility approaches to meet their unique "obligation to serve" as the provider of last resort, but have made meeting that challenge even more difficult. Today's utility providers have to take the following into consideration:

- Maintain low rates for utility customers
- Improve efficiencies
- Meet new reliability standards
- Increase cyber security
- Accommodate intermittent power sources
- Deal with real estate unavailability in urban centers
- Survive continuing transmission gridlock
- Anticipate fuel supply uncertainties and volatilities
- Prepare for new transportation, smart grid, entertainment and communication technologies' loads
- Hope for economically feasible energy storage

- Provide for infrastructure additions and life extension.

Utility planning has also become much more time compressed and reactive since decisions on timing placement and characteristics of new power sources are increasingly in developer's hands and impacted by environmental and governmental decisions. What is needed is a new way to deal with some of these problems in a more focused and quickly deployable way. Utilities need improved asset utilization. They must make better use of existing redundancies, and extend the life of all assets. This can be achieved by limiting mechanical, magnetic and thermal stresses that reduce equipment life and cause catastrophic failures.

Fault Current Limiters can enable more assets to be connected together, increasing reliability and asset utilization and allowing deferrals of requirements for separate new substations. This leads to reduced associated installation, cable routing and overhead and/or under-street work and simplified coordination with municipal development plans. Within the context of the New York State Energy Highway plans, increases in power capacity are vital to the economic future of New York State:

- to support increased business activity and community commercial development loads following the current economic downturn,
- to accommodate new consumer loads such as flat screen TVs, multiple TV top appliances, smart grid home devices, mobility, communication and entertainment devices and chargers,
- to support continued development and deployment of technologies necessary to maintain and increase competitive advantages within New York State and
- to encourage increased business migration and retention within New York State

Unfortunately these very necessary increases in power capacity carry with them associated increases in fault currents, which, if unmitigated, could negatively impact the achievement of the desired benefits, and lead to significant negative impacts on electric infrastructure life, increased repair and replacement costs and disruptions to commercial activities and the daily lives of the people who live or work within New York State.

FINANCIAL

Project costs vary greatly depending on voltage, current and number of Fault Current Limiters required to mitigate the specific fault current problem. Project cost estimates at distribution voltage $4M - $20M at transmission. This estimate would be inclusive of site work required by host utility or developer for retrofit applications. Greenfield opportunities would be less.
VPS is open to various cost sharing scenarios in order to demonstrate and validate product capabilities.
VPS is open to private-public partnerships, although research, development and commercialization to date have been fully funded from internal resources. VPS is also very willing to discuss pricing and payment alternatives with the either developer of the proposal to be fault current mitigated and/or the host utility. Simply stated VPS has the financial resources to contribute a significant amount to overall cost for an early adopter, and with a modest cost share, as well as utility receptivity and commitment of financial resources could undertake a project in short order.

PERMIT/APPROVAL PROCESS …

Only routine local and building permit processes are anticipated.

OTHER CONSIDERATIONS

The SCFCL design is well understood and exhibits close correlations with device and system modeling.

The entire NYSEH initiative action plan will require a substantial financial commitment by New York State utilities, which could be greatly delayed by utility internal budget and rate case timing and support considerations. Any accommodation that the NYSEH Task Force could recommend to the NYS DPS could be very helpful to achieving the overall strategic plan that the NYSEH Task Force recommends.

ADDITIONAL INFORMATION

If desired VPS can provide further non-proprietary details with regard to the information provided above, or address any other questions that the RFI reviewers may have.