INTRODUCTION TO SPECIFYING SURGE PROTECTION

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I. INTRODUCTION

Surge Protective Devices (SPDs) can protect electrical equipment from harmful surges. Frequently, consulting engineers have to explain to their clients the advantages and trade-offs of utilizing an SPD within their system. This Tech Topic describes the overall considerations when applying SPDs to a client's system.

II. PROBABILITY OF SURGES APPEARING:

The history of lightning strikes is well recorded and isokeraunic maps detail the strike history throughout the world. For instance, Florida and some areas of the Gulf Coast have the highest levels of lightning activity in the US, whereas the West Coast has the lowest average activity. Specific information is available for the client's location from sources such as Vaisala.

Lightning tends to strike the taller objects. If the client's facility is prominently higher than surrounding buildings or terrain, it is more susceptible to lightning activity. However, if the building is undergoing a renovation, there could be an available history of surges that should be taken into consideration.

Some buildings are designed to have a lightning protection system complying with UL96A or NFPA 780 standards. These systems are justified for the protection of the building structure, not the internal electrical power distribution system. As an unwanted side effect, they increase the lightning activity for the building. The increased activity generates more surges in the building power distribution system. Because they are not direct strikes to the power distribution system, the surges have a much smaller magnitude.

Machinery and other devices can also cause surges within the building. Many surges are unrelated to lightning activity. Startup or shutdown of devices with inductance or capacitance can create a transient overvoltage. For example, motors have inductance and create surges when they are cycled. Power factor correction capacitors likewise create surges. Building equipment usually generates more surges than lightning, albeit with a lower amplitude. Solenoids and arc-welding equipment are common sources.

III. INTENSITY OF LIGHTNING SURGES:

About 95% of all lighting strikes are less than 60kA and about 99.9% are less than 200kA as shown in figure 1. When a strike discharges on a power line, it spreads out in all directions based upon the relative impedance of the different available paths. The surge is split up so that an initial extreme surge of 200kA would only supply 100kA or less to the building. The rest would back feed the utility system and go to ground.

IEEE Standard 1100-2005 depicts the frequency spectra of the standard 8/20 impulse distributed up through 100 kilohertz. Because the impedance of inductance and capacitance varies with the effective frequency, a low impedance connection at 60 hertz can be high impedance at 100 kilohertz. As a result, the earth acts like a large shunt filter capacitor to the high frequency waveform and decreases the amplitude with distance.

It is important to note that surges are high frequency waves that require much more voltage to drive the same amount of current as compared to 60 hertz power. A surge amplitude in kA is unrelated to the available fault current at 60 Hz also rated in units of kA.

IEEE C62.41.2-2000 also shows that in the event a surge current of 100kA were to enter a building, it would cause a flashover on a system with 600 volt rated equipment. This is due to the clearances between live parts, which 600 volt rated equipment must abide by. The standard air gap for 600 volt rated equipment is 25 mm; this would effectively prevent any more than a 100kA surge from entering the equipment due to the tremendous voltage required to drive it with a short rise time and high frequency effects.

Many SPD installations have surge ratings of 100kA or 200kA in the 480 volt service entrance, although much higher ratings are also available. The 100kA is adequate for many locations but the 200kA rating adds some redundancy capability. Special applications may be supplied with higher ratings. Higher surge ratings substantially increase the cost of the SPD.

Lightning Intensity Selection Considerations:

- Service connection underground or open air
- Higher resistance to true ground in the surrounding soil area
- Location of building and surroundings
- Building lightning system
- Client's budget for redundancy
- SPD surge rating

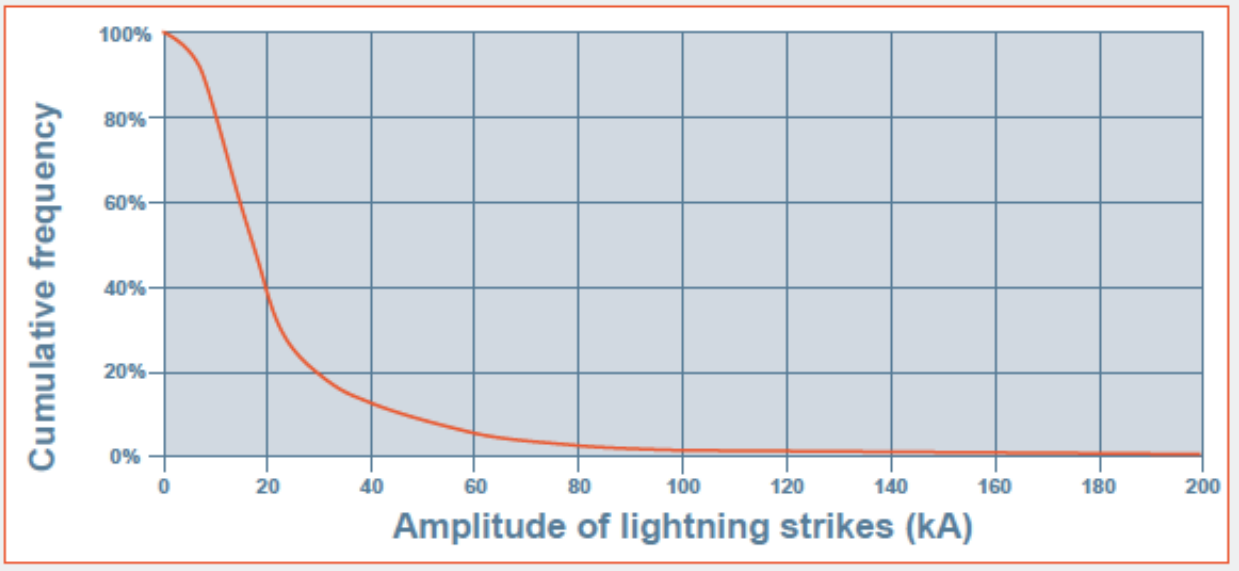

Figure 1-Cumulative frequency of lightning strikes — positive and negative — versus their amplitude. Data from Meteorage. Measurement campaign on 5.4 Million strikes between 1995-2005

IV. EQUIPMENT

The longer a surge travels, the more the surge magnitude is reduced due to the high frequency effects. If susceptible equipment is closer to the source of the surge, the surge will transmit more energy to the equipment.

SPDs listed to UL 1449 4th Edition have a Voltage Protection Rating (VPR) that indicates how much of the original surge will remain after the SPD. A lower VPR will protect the susceptible equipment better, whereas a higher VPR will allow undesirable higher voltages to reach downstream loads. If multiple SPDs are used and the surge passes by them, then this cascaded configuration will provide the best protection. When multiple SPDs are applied throughout the distribution system, it protects better than a single premium SPD.

SPD Location Considerations:

- Distance from service entrance to utility transformer
- Distance from conductors connected to outside metal
- Distance from the building equipment or machines generating surges
- Distance from other surge protection
- Cascaded protection for critical equipment

V. SENSITIVITY OF PROTECTED EQUIPMENT

Sensitivity of equipment to surges varies significantly. Electro-mechanical relays and motors are more resilient than electronics. A surge can be large enough that the equipment disrupts operations, suffers erosion of its insulation, or outright fails.

IEEE C62.41.2 Section 1.1 describes damage from surges resulting from applied voltage, and duration. The CBEMA Curve is commonly referenced for electronic equipment surge tolerance. The ITI (CBEMA) Curve was published by Technical Committee 3 (TC3) of the Information Technology Industry Council (formerly known as the Computer & Business Equipment Manufacturer's Association).

If the client's equipment is subjected to surges in excess of these industry recommendations, the manufacturers consider this an out-of-warranty failure and the client should be prepared to buy replacement equipment. Choosing an appropriate voltage protection rating can give protection to downstream equipment.

Some Equipment Sensitivity Considerations:

- Data centers
- Process control
- Delicate electronics
- Communication centers

VI. PARALLEL OR SERIES

Power distribution SPDs are normally wired in parallel to the load. This allows surges to be diverted between the connected wiring, preventing surges from traveling downstream to the load. If a parallel SPD wears out or fails, and so disconnects itself, the load will stay in operation. Many SPDs have optional alarm contacts to notify maintenance of needed replacement.

A series SPD is sometimes used for low power circuits, but the entire load current has to pass through it. When the SPD wears out or fails and self-disconnects, the power to the load is lost. Some series SPDs rely upon upstream overcurrent protection. This may also interrupt power to the load. This causes Selective Coordination issues and is not recommended on critical loads. In many cases, series SPDs employ parallel connected suppression components. Close attention to short leads on a parallel connected SPD usually yields comparable results without coordination or outage problems.

If continuous power is most important, people choose parallel. If loss of power can be tolerated but not loss of surge protection, people choose series SPDs. The cost of a series SPD is proportional to the load current, unlike a parallel unit.

VII. UNDERSTANDING CLIENT COSTS

Many clients trust their engineers to make economic trade-offs to protect their equipment from surges. In those cases, a review of the potential client costs versus the benefits of the SPD system indicates the correct level of protection.

Although the SPD system is a small percentage of the electrical system cost, if it has too little protection for the client's needs, the client could be dissatisfied with the design. Clients can be encouraged to reveal what their risk tolerance is for the equipment. If clients don't understand their risk exposure, they may see no value for surge protection.

Client Potential Cost Considerations:

- Potential loss of life from surge damaged equipment of fire alarms, security systems, and life support systems
- Replacement cost of unprotected equipment
- Costs of downtime of the facility
- Disruption of Process Control
- Legal liability of security and fire system outage
- Design to worst case or typical case protection?

VIII. CLIENT MAY DICTATE PROTECTION LEVEL

Some clients take a more proactive role in determining the system capabilities. They might have different needs than a long term lower cost to operate the facility.

Client Dictated Level of Protection Considerations:

- Client identifies and limits equipment to be protected
- Large motor protection?
- Drives protection?
- Electronics and computer protection?
- Communications protection?
- Process control immunity?
- No unplanned outages allowed?

IX. EXAMPLE APPLICATIONS

An office building has a 480/277 volt 3-phase grounded wye service entrance, 30kA fault current available, and a utility service fed from underground. There is moderate lightning activity in the area, one computer room, parking lot lighting, an outside emergency generator, no especially expensive electronics, and no special continuous process requirements. The building HVAC computer and main business computer operate from 208/120 volt 3-phase grounded wye transformers supplied by the 480/277 system.

Example Main Switchboard Selection Mersen STXT480Y20

• Type 1 for self-protected SPD
- Incremental cost difference versus Type 2
- Saves engineering time and liability versus Type 2

• 200kA SCCR is more than the 30kA available fault current
- Incremental cost difference versus low rating
- Assures meeting NEC 285.6 requirements

• VPR values of 1200V L-N, 1200V L-G, 700V N-G and 2000V L-L are good for this 480 system because it's grounded.
- No additional cost difference versus undesirable higher VPRs
- Lower values protect the equipment better than higher values

• MCOV ratings 320 volts L-N
- Should be at least 115% of normal voltage to prevent premature wear out under normal conditions
- 277V x 1.15 = 319 Volts
- Higher MCOV ratings are associated with undesirable higher VPR values

• One-time Surge Rating of 200kA will have extra reserve to prolong the life of the SPD
- Increased one-time surge ratings can drive the cost up significantly
- Consider the total rating the sum of the component MOV ratings instead of based on individual manufacturer testing outside of UL

• I Nominal rating of 20kA ensures that the unit is documented by UL to withstand 15 tests of 20kA and still provide protection
- This is the highest rating available. Other ratings are 10kA, 5kA, and 3kA
- Standard three-phase grounded systems have incremental cost difference versus a 10kA rating
- Ungrounded, delta, or CSA listed systems are normally 10kA
- UL 96A Master Labels require a 20kA rating

• UL listing of the SPD to UL 1449 Revision Four
- Ensures compliance with NEC 285.5
- Engineer has the ability to verify SPD manufacturer claims against the UL website except the One-Time Surge Rating
- UL 96A Master Labels requires a "UL" listing on the SPDs

• Externally Mounted SPDs are preferred
- They can be isolated from the switchboard for maintenance or repaired without a switchboard shutdown
- In the event of a SPD burning failure, it won't destroy the switchboard and require extensive client downtime

• Various features such as filtering, alarms, and alarm contracts are available

Example Panel SPD Selection Mersen STXP480Y10

For panels that feed outdoor circuits and a computer room, or at the load side of an automatic transfer switch.

- Type 1 for self-protected SPD
  - Incremental cost difference versus Type 2
  - Saves engineering time and liability versus Type 2
- 200kA SCCR is more than the 30kA available fault current
  - Incremental cost difference versus a lower rating
  - Assures meeting NEC 285.6 requirements
- VPR values of 1200V L-N, 1200V L-G, 600V N-G and 2000V L-L are good for this 480 grounded system
  - No additional cost difference versus undesirable higher VPRs
  - Lower values protect the equipment better than higher values
- MCOV ratings 320 volts L-N
  - Should be at least 115% of normal voltage to prevent premature wear out under normal conditions
  - 277V x 1.15 = 319 Volts
  - Higher MCOV ratings are associated with undesirable higher VPR values
- One-time Surge Rating of 100kA will have reserve to prolong the life of the SPD
  - Increased one-time surge ratings can drive the cost up significantly
  - Consider the total rating the sum of the component MOV ratings instead of based on individual manufacturer testing outside of UL
- I Nominal rating of 20kA ensures that the unit is documented by UL to withstand 15 tests of 20kA and still provide protection
  - This is the highest rating available. Other ratings are 10kA, 5kA, and 3kA
  - Standard three-phase grounded systems have incremental cost difference versus a 10kA rating
  - Ungrounded, delta, or CSA listed systems are normally 10kA
  - UL 96A Master Labels require a 20kA rating
- UL listing of the SPD to UL 1449 Revision Four
  - Ensure compliance with NEC 285.5
  - Engineer has the ability to verify SPD manufacturer claims against the UL website except the One-Time Surge Rating
  - UL 96A Master Labels requires a “UL” listing on the SPDs
- Externally Mounted SPDs are preferred
  - They can be isolated from the panelboard for maintenance or repair without a panelboard shutdown
  - In the event of a SPD burning failure, it won’t destroy the panelboard and require extensive client downtime
- Various options such as remote indicators, alarms, and alarm contacts are available

Example Remote End Use SPD Selection Mersen STXR208Y05

For the critical loads such as the building HVAC computer and the business computer operating at 208/120 volt grounded wye, the SPDs should be mounted at the end use equipment location.

- Type 1 for self-protected SPD
  - Incremental cost difference versus Type 2
  - Saves engineering time and liability versus Type 2
- 200kA SCCR is more than the 30kA available fault current
  - Incremental cost difference versus low ratings
  - Assures meeting NEC 285.6 requirements
- VPR values of 700V L-N, 1200V L-G, 600V N-G and 1200V L-L are good for this 208 grounded system
  - No additional cost difference versus undesirable higher VPRs
  - Lower values protect the equipment better than higher values
- MCOV ratings 150 volts L-N
  - Should be at least 115% of normal voltage to prevent premature wear out with normal conditions
  - 120v x 1.15 = 138 Volts
  - Higher MCOV ratings are associated with undesirable higher VPR values
- One-time Surge Rating of 50K will have sufficient reserve to prolong the life of the SPD
  - Increased one-time surge ratings can drive the cost up significantly
  - This location is considered protected from highest surge currents by distance
  - Consider the total rating the sum of the component MOV ratings instead of based on individual manufacturer testing outside of UL
- I Nominal rating of 20kA ensures that the unit is documented by UL to withstand 15 tests of 20kA and still provide protection
  - This is the highest rating available. Other ratings are 10kA, 5kA, and 3kA
  - Standard three-phase grounded systems have incremental cost difference
  - Ungrounded, delta, or CSA listed systems are normally 10kA
  - UL 96A Master Labels require a 20kA rating
- UL listing of the SPD to UL 1449 Revision Four
  - Ensures compliance with NEC 285.5
  - Engineer has the ability to verify SPD manufacturer claims against the UL website except the One-Time Surge Rating
  - UL 96A Master Labels requires a “UL” listing on the SPDs
- Various options such as alarms, and alarm contracts are available