Good afternoon my name is Bob Talley, PE; Level 3 Elec Inspect and PM
Welcome to the session entitled “Can I blame the electrician?” Welcome to the session entitled “Can I blame the electrician?” Apparently blame is a big issue in our society. A friend of mine offered me the following quote: “its not whether you win or lose ... its how you place the blame.”

Just so you know, I don’t have anything against electricians. A few years ago I started reminding designers that the electrical engineer and electrical contractor really hold the success of the final inspection in their hands. The building must pass the SCO life safety inspection or the owner typically cannot obtain a Beneficial Occupancy of the facility. The life safety inspection involves the proper operation of the Fire alarm system, emergency lighting, illuminated exit signs and a functioning sprinkler system that correctly interfaces with the fire alarm system. If the building has electro-magnetic locks we will check to see that they were wired and installed in accordance with the building code. If the electrical engineer has prechecked the operation of all those systems we have a high chance the building will be accepted. Thus the title of this session ....
Our session will actually cover many construction issues that can surround the work of the electrical trade including: elevator controllers, UPS units and LED lighting which are all forms of power conversion equipment. That will lead us look at “Harmonics and Wave form distortion.” And we will talk about Third Party Approvals, Security Systems and Life Safety Inspections.
Today’s session is a continuation of last year’s presentation in the sense that we are still looking at construction problems, but this time want us to look deeper into the nature of the problems.

So let's start with the big picture.

New products are constantly coming to the market. Our owners, designers, suppliers and contractors are all being pushed by market forces to deploy these new products. For that reason today’s session will cover some basic electrical concepts. I just want to remind all of us ... that electrical characteristics of new products can impact the entire building. Since all most all of the design disciplines, A,C,P,M,E,F and sprinkler are deploying electrical products, we all need to remember that these products can interact.
Architects are writing specifications that often include electromagnetic door locks and door holds, elevator controllers, specialty lighting, security systems and kitchen equipment.

Mechanical engineers write specifications for motors, starters, variable frequency drives, automation system and electronic control systems.

Plumbing engineers write specifications for pumps, electronic valves, automatic valves and 24 volt transformers.

Sprinkler designers are now tasked with interfacing with the fire alarm systems and layouts. Even the new fire pump controllers can have VFDs if the owner has the need and the budget.

Civil engineers are specifying lift stations, hot boxes, pumps and control systems.

The proliferation of electronic products has been a blessing; but, we are starting to see some problems that have been long predicted as electronic components interact.
Now for a little background … Our electric system is based on the work of Nikola Tesla and the financing of George Westinghouse.

Tesla was a mathematician, electrical engineer, mechanical engineer, futurist and the inventor of alternating current machinery. In this system the voltage alternates back and forth across the zero mark. Tesla realized there was usable power in the relationship between rotating electric fields and rotating magnetic fields. Created by generators, the sinusoidal wave form is very elegant and literally provided the horsepower to change our world. They deployed a three phase alternating power system and it changed the world.
Let's talk about Voltage
Single Phase ... Three Phase
Voltage and Current - when current track with the voltage it is called a linear relationship, as this graph demonstrates.
Then came the 1960s - Until the 1960s the electrical utility system primarily supplied linear loads. That means the current wave form tracked with the voltage wave form. Incandescent bulbs, well pumps, ceiling fans, air conditioning units, electric stoves and ovens all used alternating current to make life more pleasant for Americans. But the 60's brought significant change to our world. The advent of the transistor and proliferation of small electronic devices that followed led to changes in the way electric power was used.
IEEE 519 was written to offer a Standard on Harmonic limits or how to be a good neighbor - By the 1970s the writing was on the wall that change was coming. IEEE 519 was first issued in 1981 placing the responsibility for clean power on the utility. They were not happy and IEEE 519 was revised and reissued in 1992 with an emphasis on shared responsibility for clean power. Now the document has been revised again and a 2014 version is available.
Now in 2015 ... the new technologies now include elevator controllers, variable frequency drives (VFDs), UPS units, LED lighting, Power conversion equipment, and security systems.
In the past the loads were primarily linear. But now the majority of the electronics in my house (except for the stove, oven and AC unit) all have small transformers attached to the cord. The laptop, the phone charger, the flat screen TV, the LED Christmas lights and the clocks all need small power.
The cheapest way to convert AC power to a suitable source for electronic equipment is to use a Switch Mode Power Supply (SMPS).
Voltage and current interact. The higher the current the higher the voltage drop, for a given conductor size. To reduce the impact we increase the conductor size. That is a well known relationship.

Now most of the new electronic equipment comes with some type of power conversion system to convert from the 120 volt supply to the 3, 12 or 24 volts it needs to operate the equipment. The same is true in principal for the big equipment like UPS units and Variable Frequency drives. The basic power conversion form uses a concept that charges a capacitor once the wave form is two thirds of max height and stop charging once the wave form drops below that value. This leads to a pulsing current draw. (See the example). This is called a Switch Mode Power Supply. I am over simplifying here but you can get the concept. That sudden pulse can cause nonlinear voltage drops on the system. The non-linear voltage change … distorts the voltage wave form.
SMPS

The non-linear load (ie the current) is only a problem once it gets large enough to start interacting with the voltage waveform. When voltage and current interact we call the interaction either Harmonic distortion or Wave form distortion. Harmonic distortion can be evaluated and broken into component parts. Repeating distortion is harmonic. Non-repeating distortion is the single event type.

If the advantage of SMPS is that it is cheap what is the draw back? Well the SMPS can create problems for the power system. As long as the current draw is small compared to the system the pulse will have limited impact on the system. Remember it is not just your computer that uses current in that window. Ever device attached to that phase of the panel board uses power at the same time. The total result can be rather large.
Distortion evaluation

Voltage Distortion can be evaluated by assuming we have multiple frequencies that add together to create the condition.

If the distortion is repeatable then it can be evaluated as a harmonic of the fundamental frequency.
This is another example showing the fundamental and two harmonics. You see how they add together.

Why is this important? Because if we can understand what is happening we can find a way to mitigate the associated problems. We might add filters, traps, transformers, etc.
Single events are not considered “harmonic distortion”. Combine a single event with a distorted voltage wave and very odd things can happen.
There are a number of resources available on the web and in the library for helping you better understand Harmonic Distortion. This picture is just one sample of what is available. Each manufacturer will provide a slightly different understanding and do their best to explain why their product is best.

OPTIONS:
Look at the “big project picture”... Specify appropriate equipment... Evaluate conversion equipment
Determine line reactor needs ... Evaluate cost impact ... Make sure you are informed.
Not a problem until it’s a problem
This is one manufacturers explanation of available product.
6 pulse, shown, is the simplest version, These devices use two pulses per wave, since there are 3 waves that yields a 6 pulse device.
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The 24 can be made from two 12 pulse units
Take Away, Electrical Distortion
Harmonic – Repeatable
Distortion – single event
Distortion be mitigated
Line reactors
12 pulse, 18 pulse, etc.
Phase shift transformers
More robust supply
Add linear loads

Designer - cannot put the responsibility on the manufacturer
So the phone rings ....
With that background let’s look as some of the phone calls we have received the last couple of years. Removed 5,000 kva of unit sub stations on a job site. Yes it was over designed – we had Progress Energy install a 500 kva utility transformer to serve the building. Suddenly all of the new LED lighting in the facility was flashing. Answer - replaced the lights.
Picture of the 4160 volt gear – new opportunities to succeed
So the Phone Rings ...

- Elevator keeps “trapping” people:
  - 20 story tall elevator
  - Recently modernized - new VFD controller
  - No posted VFD settings or Elev settings
  - Elevator is 80% of the power used at site
  - Emergency lighting turns on every time the elevator starts
  - Replace the feeders and decrease length
Three Phase Voltage and Current
Cycle-by-Cycle Readings
Max, Min, & Average Over Consecutive 10 Second Intervals

**Voltage and Current Interaction**
This is a 10 day chart. Current goes up and voltage goes down.
Voltage and Current Interaction

Enlarged view over a 24 hour period
Elevators are turning off trapping people

- 4 story building with 4 new elevators
- VFD type controllers, each with a separate isolation transformer
- No posted variables or settings for the drives
- Ran all the elevators until one would stop.
- Proved equipment was interacting
- Manufacturer replaced the controllers
New building with roof top AHU keeps turning off and requires tech to reset
- 60 HP Supply and 20 HP Return
- Feeders are sized per NEC
- Drives are 6 pulse type with 3% Line Reactors
- No posted variables or settings for the drives
- Fault code indicates trip on OC during start
- Changed VFD parameters
Owner complains that generator is broken

- New building with ducted hood exhaust manifold and 60 hp fan periodically shuts off
- 3% line reactors are installed
- No posted variables or settings for the drives
- Owner wants to know why generator is not running to keep the fan operational
- Changed parameters - Still under review

Owner complains that generator is broken

New building with ducted hood exhaust manifold and 60 hp fan periodically shuts off
3% line reactors are installed
No posted variables or settings for the drives
Owner wants to know why generator is not running to keep the fan operational
Changed parameters - Still under review
Boiler plant manager complains of random activation of Emergency Stop System
- Building has four 60 hp fans
- New VFDs were specified with line reactors
- No posted variables or settings for the drives
- Opened the VFD and saw a large empty spot
- Add line reactors and problems ceased
GS 66-23  sale of goods - regulated
GS66 24 manufacturer marks are required - I recently turned a project down because the manufacturer could not figure out what they wanted to provide. Their system drawings did not match the equipment they shipped. The labels on their equipment did not match the equipment provided.
GS6625 Listing is about suitability - 
Most contractors believe an inspector should tell you what to fix. That is true when I have a NEC code reference. But when the issue is with the electrical construction of the equipment it is not so clear. – When we see real problems the best thing to do is to tell the manufacturer or the contractor who purchased the equipment to get it third party approved. It is amazing what they can find.
50 year old equipment served by bus duct from the utility vault. The engineers drawing say to remove the bus duct and refeed the gear from a new 1500 amp switch.

The contractor did not order an interior bus termination kit. That kit which would have been factory built, third party listed and come with instructions would have prevented the mess we had.
The electrical contractor took a sawzall and cut the bus bars off – evidenced by this photo. He then drilled nonsymmetrical holes in the bus and attempted to attach lugs. It did not look right to me. I don’t build switchboards for a living. I told the contractor they had created a problem and modified the SWBD outside if it listing. It took months for him to find the right company who could tell him how to bring the board into compliance with the UL standard for switchboards.

I also learned a new term. “Angel dust” that is what is created by copper shavings in an electrical switchboard. Because if there is a problem the next thing you see is angels
Another view
It took months to get the right third party inspection department on site. This is photo is from the third party report detailing what was needed to fix the switchboard. Someone knowledgeable in the area of switchboard construction and willing to work with the contractor to fix the situation.
These are sample pages of the report.
How to brace the bars
Then we were provided a final report by the third party agency and their label went on the equipment.

**Listed Equipment with Label**

This is the view after the nylon ties were installed and the bus bars supported.

Our inspectors are not prepared to tell a contractor how to modify a switchboard.

Now it gets a Third Party Label and is approved by inspector.
Seems like everyone wants to use magnetic locks these days. The building code is very specific about the use of a magnetic lock. The rules change with the occupancy and the tenant. Please don’t expect your hardware specifier to get the code right on these devices. Because of the use of power to the locks and the access control system your site electrician will be involved. If his boxes are not installed in the code required location you could spend significant time making repairs; because this system does impact LIFE SAFETY.
This is a look at the locks back side – also used in the previous picture. It has a momentary trigger. I think that keeps it from being the ON/OFF type of lock required by the NC building code.

Additionally this lock is not Third Party Listed, we talked to the factory. Based on the way it operates I suspect it can not be listed to meet the UL standard for Special Locking Arrangements.
Conduit support device called a “Helicopter” – I am learning to hate these things. Primarily because they are so often misused. They are not supposed to be bent or broken and are supposed to use two screws. Read the instructions.
I can almost understand the logic on the last picture but this one is an attempt to deceive the inspector. From the floor it looked pretty good.
Let's look at another new fixture type. It has a third party label but this is going to be a problem if you buy it.

I found this on a recent project. The manufacturer never thought about how to meet the NEC.
Better view of the fixture
This is a 4 inch opening. I cannot put my hands on the wiring to install wire nuts. The contractor did not leave enough wire to meet the NEC requirements.
It can be listed and labeled but it still has to meet the NEC requirements.
So the Phone Rings ...

The fire dampers on a new building won’t reset after a fire alarm system test

- Building was specified with 120 volt dampers
- Apparently 24 volt dampers were installed at the end of project
- Someone added 2 KVA, 24 volt transformers
  - Capable of 80 amps on the secondary
  - But the 20 amp, 120 volt wire was provided by electrician
  - Fuses were added to the wiring compartment – then disabled
- A problem was found with dampers at the Final Inspection but GC had it “fixed”
This 2 kva transformer is Listed and Labeled
It was never inspected
Someone added fuses in the compartment (wrong size)
All fuses were bypassed
The 12 AWG wire was heat damaged
The fix ... the contractor is removing the 2 kva transformers and installing 75 VA transformers at each damper ... working nights and weekends.
Security – Like elevators, access control, lighting, data and kitchen equipment there are now “Specialist” who want to design security camera systems. Just because someone is good at figuring out some part of a system it does not make them the best at specifying the actual equipment. For the camera equipment currently being sold you need to cross check the design with a “data” guy.
A performance specification for security equipment yielded this installation. If the final product looks like this photo for security installation, beware.

One problem on this project - the security designer did not see IP cameras as a data issue or require the installation to be built in accordance within typical data specifications.

The system problem as described to me: “what you have is like trying to shove an elephant down a fire hose … what comes out don’t look much like elephant”
The following is from 907.1.2 and details the requirements of the shop drawings. It is not a small list. And it might require significant work for both the designer and the contractor. Let me enlarge it for you.

Remember designers – SCO does not review the fire alarm shop drawings – we have contracted with you to review the drawings prior to installation. We then back check at the final inspection.
The list also include items 10-13 as listed.
Note that all systems and components must be listed and approved for the purpose installed.

Now assuming you know to use Chapter 9, NFPA 72, For Accessibility use Chapter 11 and ANSI 117.1 (2009) then you have a good start at understanding the minimum requirements. It does not mean you system will work that is just the minimum.
Lets build a model 4 story building with a center fire wall and rated stair wells.
Rated stairs and an atrium type area
Add sprinkler and

Let's put speaker zones in the facility.

For simplicity let's assume we will only move the people in the actual fire zone.

YES .... I am oversimplifying to help make a point regarding the coordination of fire alarm zones with sprinkler zones.

Let's add flow switches to find the fire.
Activate the sprinkler flow
See the zone in alarm
That is a problem the atrium is in a different section.
This coordination problem is real, though greatly over simplified.
This is the fix.
Generator requires service from both sides – hate to be checking this on a snowy night. We are ordering an access platform.
Frozen - HVAC renovation:
Received new control system
Freeze stat tripped but was not hard wired to the dampers.
The control system was programmed incorrectly and opened the dampers to 100%.
Coils froze and flooded the building.
You can do something for an item to lose the approval for use.
In this case you cannot blame the electrician. When he left the site there was a building. The electrician did not remove the building.
Summary
Expect to see more “new technologies”
Harmonic distortion must be considered
Large non—linear loads can interact
Specify Listed and Labeled Equipment
Equipment must be suitable for the conditions
Delegate Design at your own risk
- “Specialist” may not understand the NC codes
- Still need to coordinate electrical characteristics
Designer must review the installation

QUESTIONS
Are there any question on the material or on some issue we should have covered?