Electric Substations
Overview, Hazards and Response Tactics

by Battalion Chief Frank C. Montagna and
Anthony J. Natale, Emergency Response Group, Con Edison

You are a covering Captain working in a ladder company. At 0340 hours, you find yourself responding to a report of an explosion near the South Street Seaport. The dispatcher states that there were numerous calls. As you arrive, you see heavy smoke rising over the roof of what appears to be a garden-variety, five-story, brick commercial building. (See Photo #1.) You transmit the 10-75 and provide the address of the fire to the dispatcher. The dispatcher informs you that there is CIDS information available and it turns out that this two-story commercial building is actually a Con Edison electric substation.

Currently, your forcible entry team is sizing up the front door for entry. Do you let them force the door? What hazards are waiting for you inside the building? Will you encounter PCBs? What actions do you take to protect yourself and the Firefighters? Is there a life hazard inside? Since you've arrived, conditions have deteriorated and the smoke is heavier. The engine is stretching a $2^1/_2$-inch line to the front door. Do you want them to put water on the fire? Can you confidently answer the above questions?

This article will provide vital information to help keep you safe when responding to fires and emergencies at electrical substations. It includes a substation overview, points out the hazards you may encounter and offers the recommended tactics for incidents at these facilities.

Substation overview

Electricity is produced at steam- or gas-fueled generating stations and is routed to electric substations for distribution to the areas they support. (See Diagram #1.) There are two types of substations--transmission and distribution--and both act as a transportation hub for power. The difference between a transmission and distribution substation is the voltage present and to whom the electric supplies go.

Photo #1--From the exterior, the Con Edison substation appears to be a five-story building.

Photo #2--Exposed electrical conductors.

Transmission substations typically receive a 345,000-volt feed, which is stepped down or reduced through a transformer to 138,000 volts. Following this voltage reduction, power then is routed to a distribution substation. Distribution substations receive the 138,000-volt feed and continue to step it down further to supply the various distribution networks. When power leaves a distribution substation, voltage is proportionate to the requirements of the network it supports.

Brooklyn and Queens are supplied with 27,000 volts. Manhattan and the Bronx receive 13,000 volts. Staten Island is supplied with both 13,000 and 33,000 volts. To accommodate the end user, further voltage reduction occurs on the pole and/or underground transformers in the field. Commercial voltages range from 277/460 volts, while standard residential voltage is 120/208 volts.

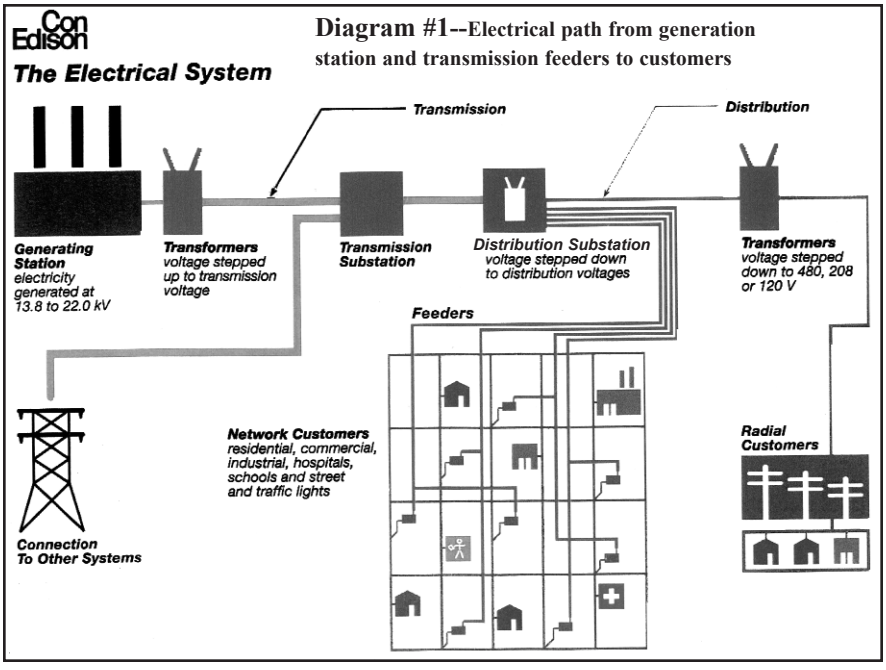

Diagram #1--Electrical path from generation station and transmission feeders to customers

artwork courtesy of Con Edison

Overhead clearance and exposed conductors

- What most of us know about electrical safety is related to what we've learned in our homes. As a result, many of us think we have to touch a conductor to get hurt. In the home, electrical conductors are insulated in a plastic coating and run in a plastic jacket--Romex--or in a metal jacket--BX. In some applications, these plastic-coated wires are run in conduit. If you were to come in contact with these wires or the conduit, the insulation would protect you from the electrically charged wire. This is not true in a substation, however.
- Substations use open-air conductors--called bus--which resemble three-inch conduit pipe. (See Photo #2.) *This is not conduit.* These metal pipes running through the overhead areas of a substation are the conductors. Electricity carries on the skin

Photo #3--Capacitor banks reside in cages that provide a buffer zone between you and the exposed electrical conductors.

Photo #4--Circuit breakers are housed in locked cubicles to eliminate the chance of anyone casually entering these areas.

Photo #5--Lightning arrestors are found behind fences. Remaining outside of these fenced areas ensures your safety.

Photo #6--Signs indicating the hazards are posted and they should be followed.

Voltage	Clearance
15 kV	10 feet
27 kV	10 feet
33 kV	10 feet
69 kV	10 feet
138 kV	10 feet
345 kV	18 feet

of the pipe. There are no internal wires.

- Just knowing what the conductor looks like is not enough to keep you safe. Many believe that they are safe from electricity as long as they do not come in contact with the bus. *This is not true.* Due to the extremely high voltage carried on bus, clearance of up to 18 feet may be required between you and the conductor to ensure safety.
- The proper clearance from overhead bus has been calculated for each station. Conductors have been positioned accordingly, using a conservative distance to ensure the safety of anyone walking through a station. *To stay safe inside a substation, do not climb and do not carry tools above your shoulder.*

Ground level clearance and exposed conductors

- Overhead bus is not the only electrical hazard present. Many electrical hazards can be found at ground level. However, access to these hazards is restricted through locks, cages and fenced-in areas.
- Capacitor banks reside in cages, providing a buffer zone between you and the exposed electrical conductors. (See Photo #3.)
- Circuit breakers are housed in locked cubicles to eliminate the chance of anyone casually entering into these areas. (See Photo #4.)
- Lightning arrestors and various other electrical components may be found behind fences. *Remaining on the outside of these fenced areas ensures your safety.* (See Photo #5.)
- Please note that signs indicating the hazards are posted and they should not be ignored. (See Photo #6.)

Chemical hazards

The five basic chemicals, which can be found in substations, include dielectric fluid, transformer oil, Edisol XT, sulfuric acid and sulfur hexafluoride. Excluding sulfuric acid, these products serve to insulate and cool the electrical conductors.

- Dielectric fluid is an insulating oil used in underground transmission feeders. (Photos #7 and #8 show underground 345kV feeders.) This non-PCB oil resembles cooking oil, has a flash point of 350 degrees Fahrenheit and an auto-ignition temperature of 795 degrees Fahrenheit. Note that electrical arcs can produce temperatures up to 7000 degrees Fahrenheit.
- Transformers also use insulating oil, which is simply classified as transformer oil. The flash point is approximately 300 degrees Fahrenheit.
- Historically, this is where PCBs have been found. Over the years, Con Edison has successfully worked to remove PCBs from its system through a process called retro-filling. This is somewhat similar to changing the antifreeze in a car; the old product is drained and the new product is put in. Unfortunately, there are certain oil-filled components that cannot be retro-filled and have no sampling ports. (See Photo #9.) Their PCB content is unknown. As a result, when we respond to fires or other emergency conditions, we assume the oil contains more than 50 ppm/PCB until sampling proves otherwise.
- Oil involved in fire will be sampled to identify the existence and quantity of PCBs. Representative samples are obtained once the area is made safe. Results usually are available in six to eight hours. (See AUC 266, PCB Incidents.)
- PPE should be worn to protect members from potential dermal and respiratory exposure to PCBs.
- Edisol XT is a viscous-type of insulating oil used in capacitor banks. (See Photos #3 and #10.) It is non-PCB oil and has a flash point of 284 degrees Fahrenheit. MSDS information indicates that dermal exposure results in skin irritation, consistent with most petroleum exposures.
- Sulfuric acid is contained in the lead/acid batteries used in the back-up power source for the facility. Each substation has two

Photo #7--Exposed underground feeder lines.

Photo #8--Cutaway of underground feeder line.

Photo #9--Oil-filled bushing.

Photo #10--Edisol XT is a viscous-type of insulating oil used in capacitor banks.

Photo #11--Each substation has two battery rooms, with each room holding 30 to 40 car-type batteries.

battery rooms, each of which contains 30 to 40 car-type batteries. (See Photo #11.) Each battery contains five to 10 gallons of acid with a 30 to 40 percent concentration. Exposure to sulfuric acid under normal conditions presents a dermal hazard, but more significant issues arise when the product is exposed to heat. Sulfuric acid mist can produce serious, if not fatal injuries, to responders who fail to protect against respiratory exposure.

- *It should be noted that the carbon monoxide detectors used by the fire service have shown false CO readings in battery rooms.* The sensors in these units are cross-sensitive to the hydrogen produced when the batteries charge. In one case, personal monitoring devices indicated 50 ppm of carbon monoxide. Additional testing revealed that it was actually hydrogen with a concentration of 1500 ppm. (The LEL for hydrogen is 30,000 ppm.)

Photo #12--Sulfur hexafluoride gas is used to insulate and extinguish arcs in electrical components, such as circuit breakers.

- Sulfur hexafluoride gas is used to insulate and extinguish arcs in electrical components, such as circuit breakers. (See Photo #12.) Under normal conditions, it is an odorless and colorless gas that is five times heavier than air and presents an asphyxiation hazard in below-grade confined spaces. Additionally, thermal decomposition of the product produces two hazardous by-products: One is hydrogen fluoride gas (HF), a respiratory hazard that when mixed with water, produces hydrofluoric acid. Hydrogen fluoride gives off a rotten egg smell. The product is a desensitizer and continued exposure to it may make it seem as if it has dissipated. The other is metal fluoride, which resembles a white talcum powder. Dermal exposure to this substance produces a sunburn-type effect on the skin. The ions in fluoride are a calcium scavenger and will eat through the skin and aggressively attack the bones. The key to successful treatment is early recognition of the symptoms of exposure and obtaining medical attention in a timely manner. MSDS information recommends the use of calcium gluconate, a gel that impedes the effects of the process.

Photo #13--Identifying logos are placed at the main entrance for each site and have been entered into the CIDS program.

Response tactics

Because of the hazardous environment found in substations, Firefighters must resist their natural tendency toward aggressive tactics. These incidents require specialized knowledge, close control of operating personnel and a heightened sense of caution. The first-responding Officers must closely supervise their Firefighters to ensure their safety. All members operating at the scene must be aware of the potential dangers and act to safeguard themselves from such dangers. The Con Edison "white hat" will provide the specialized knowledge required to safely operate at a substation incident.

- The FDNY and Con Edison have worked together to develop safe operating guidelines for substation and generating plant fires and emergencies. This plan is outlined in AUC 266 (which will be revised to include substations) and dictates that the utility will provide a "white hat" to meet the Fire Officers at a predetermined muster site. The "white hat" is worn by the Con Edison Incident Commander and is meant to identify him to responding Firefighters. Other Con Edison employees will wear a blue hat. Identifying logos have been placed at the main entrance for each site and entered into the CIDS program. (See Photo #13.) This logo indicates the central meeting location for first-arriving units and the Con Ed "white hat" at substations.
- In the event that the "white hat" is not immediately available to you, wait for him. (See Photo #14.) On arrival, FDNY members must never force entry to a Con Edison substation. Entering and moving around in the substation unescorted exposes Firefighters to the hazards mentioned above. Here are some guidelines:
- If the "white hat" does not come out to meet first-due companies in a reasonable amount of time, he may be engaged in an operational function to eliminate or mitigate the hazards members may face. Or, the site may be unoccupied at the time of the incident and the "white hat" may be en route from a neighboring station.
- If the "white hat" is not present, call the Con Edison Control Center at the number posted on the sign adjacent to the "white hat" logo. (See Photo #15.) The operator will be able to provide you with current staffing at the station or the estimated arrival time of the responding "white hat." As Con Edison routinely electronically monitors these facilities for problems, it is likely that a "white hat" already will be on the way by the time you arrive and call.
- Inside the substation gate, Con Ed maintains a lock box for FDNY responders. (See Photo #16.) It contains a book, featuring a map and overhead photograph of the substation and PCB information for the substation's equipment. This information can be extremely useful to the

Photo #14--Wait for the "white hat" to arrive.

Photo #15--If the "white hat" is not present, call the Con Edison Control Center.

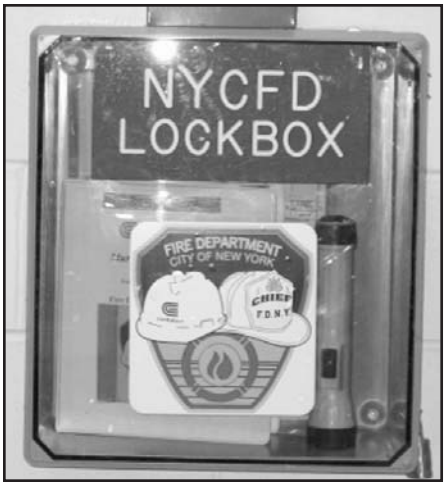

Photo #16--Con Edison maintains a lock box inside the substation gate for FDNY.

Photo #17--A sign at the siamese indicates the appropriate pressure.

Incident Commander and should be requested from the "white hat." Do not force entry into the substation to obtain the book. Wait for the Con Edison "white hat" to obtain it for you.

- For a fire inside the substation, a decision must be made about the proper extinguishing agent, safe positioning of the apparatus and the required standoff distance for stream application. Once again, the Con Ed "white hat's" expertise will be invaluable.

Note: *Currently, joint testing is being conducted by Con Edison and the FDNY to determine safe standoff distances for the use of water in the vicinity of live, high-voltage electrical equipment. This evolution will be initiated on the orders of a Staff Chief.*

- If a substation fire is exposing residential or commercial neighbors, set up lines and/or large-caliber streams for exposure protection. It is safe to put water on the threatened exposures, but do not apply water directly on electrical equipment without first consulting the "white hat." He will tell you what is energized and where you can safely apply water.
- Substations have a deluge sprinkler system, with coverage limited to the transformers. Stretch and attach a $3^1/_2$-inch line to the sprinkler siamese, but do not charge it until requested to do so by the "white hat." Con Edison would request the line to be charged only in the event of a water main break or as a result of a fire pump failure. There will be a sign at the siamese, indicating the appropriate pressure. (See Photo #17.) Excess pressure could rupture the sprinkler piping, rendering the system useless.
- Avoid exposure to PCBs and other contaminants.
- Because of the possibility of a PCB spill and PCBs in the smoke, as well as other types of contamination, wear full PPE and attempt to operate out of the smoke if possible. Use your SCBA, even in light smoke, which may be PCB-contaminated.
- Operate from uphill and upwind if possible.
- Stay out of the water run-off and any liquid spills.
- Attempt to contain the water run-off or liquid spills and channel it away from civilians and Firefighters.
- Keep Firefighters and civilians out of possibly contaminated smoke and evacuate exposures as needed.
- Consider decontamination after being exposed to smoke, oil or possibly contaminated water run-off. Do this rather than take the chance of spreading the contamination to the apparatus, firehouse or your own home. (Refer to HMO 2 for decon procedure.)

Safety precautions

The basic rules for enforcing electrical safety in a substation are simple.

- Don't climb and you will maintain the necessary clearance from the overhead conductors. In other words, stay on the ground and you'll stay safe.
- Don't cut through fences or cages or force locks. They exist for your safety. Ground-level electrical hazards have locks, fences or a cage surrounding them in order to provide a buffer zone between you and exposed electrical conductors.
- Avoid bringing metal or partially metal tools into the substation and do not carry tools projecting over your shoulder. All tools must be carried below the shoulder. Remember, you do not want to reduce the allotted clearance. ***Note:*** *Even a wooden or fiberglass hook can conduct the high voltages found in substations.*
- When raising aerial ladders and tower ladder buckets, maintain an 18-foot safe clearance horizontally from the substation's exterior fence line.
- Since there is no safe action you can take inside the substation until the "white hat" arrives, it may be best to leave the aerial devices bedded until after consultation with the "white hat."
- After consulting with the Con Edison "white hat," only a Chief Officer should make the decision to put water onto or near electrical equipment inside a substation.
- Always operate as if PCBs or other contaminants are present in the smoke, oil and water run-off.
- Consult with the "white hat" on hazards and safety of proposed tactics.

Substations pose serious safety risks to Firefighters. However, we can work safer and smarter when mitigating these incidents by following the above safety rules and working together in a partnership of safety with the Con Edison "white hat."

About the Authors...

Battalion Chief Frank C. Montagna *(left) is a 36-year veteran of the FDNY, the past 19 years of which have been as a Chief Officer. He is assigned to Battalion 58. Currently, he is working in the Bureau of Training, where he is responsible for curriculum development. He holds a degree in Fire Science from John Jay College, where he has taught fire science courses. He is a member of the editorial advisory board of* Fire Engineering *and has published articles in that publication and contributes frequently to* WNYF. *He is the author of* Responding to "Routine" Emergencies. ***Anthony J. Natale*** *(right), Senior Specialist, is a six-year veteran of Con Edison. He is assigned to the Emergency Response Group. He teaches FLIPS, new Battalion Chiefs, the 80-hour haz-mat and infrastructure emergencies courses at the Fire Academy.*