Electrical Distribution Mitigation
A Handbook for Public Facilities
Introduction

A vital strategy in the delivery of community response and recovery is the reduction in the vulnerability of public electrical distribution systems from hazards, such as hurricanes, wildfires and ice storms. This Handbook provides local units of government and electrical service providers, especially electric co-operatives (co-ops), suggested mitigation measures that will lower their susceptibility to hazard events that often lead to system failure.

The mitigation actions suggested in this Handbook were developed to help identify and define strategies that local officials and providers should consider and implement during repair and/or rebuilding to reduce or prevent damages from future hazard events.

The Challenge:
An increase in the frequency and intensity of severe weather events, combined with growth in infrastructure development, has escalated disaster response expectations and recovery costs to unsustainable levels.

The Goal:
To reduce excessive and foreseeable losses from severe weather events through preparedness and mitigation.

This can be achieved through three objectives:

**Objective #1:** To incorporate mitigation actions into the repair and rebuilding of damaged electrical infrastructure, to reduce or prevent future damages to the infrastructure.

**Objective #2:** Harden and/or strengthen existing electrical infrastructure facilities to more effectively withstand severe weather events, such as hurricanes or winter storms.

**Objective #3:** To ensure that local units of government address natural hazard through comprehensive planning, which will identify significant hazards and steps to eliminate the risk and vulnerability.

The Results:
Achieving these objectives will substantially enhance community resiliency and economic sustainability in future disasters.

Target Audience:
Owners and operators of rural and municipal utilities, and recovery specialists dealing with federal reimbursement during major hazard events.
Mitigation – Worth the Investment?

Each year, hazards and disasters result in millions of dollar in direct damages to the nation’s built electrical distribution system, and as much or more in indirect damages and economic losses, especially to their customers/clients. As our country’s population continues to grow and the demand for electricity continues to increase, disaster- and hazard-related damages to the electrical infrastructure will continue to escalate.

How can owners and operators protect their equipment and investment from disaster-related damages? Is doing so worth the financial and resource investment? A major promise of this handbook is that mitigation works. The Federal Emergency Management Agency (FEMA) has published a loss avoidance study of electrical distribution systems, titled, Electrical Transmission and Distribution Mitigation: Loss Avoidance Study. This report assesses the effectiveness of completed electric system mitigation projects in Nebraska and Kansas affected by ice and wind storms in the winter of 2006 - 2007.

FEMA developed the loss avoidance study (LAS) methodology to provide a quantitative approach to assess post-construction performance of mitigation measures. FEMA has performed loss avoidance studies on a variety of project types, and the return-on-investment (ROIs) for these projects has been impressive. The Electrical Transmission and Distribution Mitigation: Loss Avoidance Study was performed for electrical distribution mitigation measures. It focused only on losses avoided from ice and wind storm mitigation, but it is expected that LAS for mitigation from other natural disasters - earthquakes, flooding, etc. - would show positive ROIs as well.

Damage analyses were conducted for each project, to calculate the damages that would have occurred had the mitigation project not been completed. These analyses calculated the dollar amounts from physical damage and loss of function for pre- and post-mitigation conditions. The total project investment (based on the original project costs) for the three projects was $1.15 million. The total losses avoided were estimated at $1.33 million. As a result, the overall ROI for these mitigation measures was 115%.

Note that this study focused on a single series of events, namely winter storms. As future disasters occur, and the system does not fail, the ROI percentage will only increase.

Effectiveness:

- Mitigation projects provide significant ROIs
- Mitigation reduces the impacts to society from disasters and hazards

Limitation:

- Lack of awareness on positive benefits of mitigation
- Old habits are hard to break
Pre-Event Response Planning

More than a decade of experience in responding pre and post event to some of the most significant major natural and man-made disasters in the history of the United States has initiated the activities and thoughts described here. The strategy discussed surrounds the genesis and evolution of pre-event planning necessary to meet most any scale of electrical power outage. It is important to note that even those events which may be considered minor by emergency management standards and by most response/recovery practitioners are in many cases potentially devastating or even catastrophic to those entities suffering the loss.

The focus of this planning effort is

- effective and generally comprehensive preparation;
- development or enhancement of functional and response oriented procurement tools;
- efforts leading toward maximum effective use of portable power sources in order to quickly initiate recovery from any catastrophic event.

Where possible, this effort can also help to prevent the potential cascading negative effects of not having a functioning electrical system. A key in the planning effort is to identify and prioritize the prime power needs in any given jurisdiction (city, county, state, authorized agency, or non-governmental organization).

In our experience, the primary planning method is to engage in conference and consultation with those groups or agencies identified by the emergency management community as having critical demands for energy that must be met with a robust response post event or interruption prevention plan pre-event (or both). While this notion may seem inherently self-evident, the experiences over the decade have lent themselves to the discovery that in every catastrophic event there is something new to be learned, and that as much as we vision and imagine and project, we do not yet know or account for everything. It is also important to note that in many cases, considerations must be made by the emergency management community for those enterprises which do not have the inherent capability or problem recognition skills to know when there may be a potentially problematic situation with a cessation of power of unknown duration to their facility.

**Genesis**

In 1998-1999, winter ice storms dropping temperature into the -30+ range in Upper New England generated a request for prime portable power by NYSEMO (New York State Emergency Management Office). In coordination with NYSEMO and Air Force Reserve Airlift, 76 generators were shipped by C-130 out of Ellington Field south of Houston to Stewart Air Force base in New York State and disseminated for use from there. Aside from the numerous individual gen-sets that had previously been dealt with on other disasters, this was the first time such an initially robust thrust of prime portable power had been requested for a situation in which lives and economies were threatened (other than by the Federal Government). The generator sizes ranged from 25 kW to 100 kW. In the ensuing response equation, several issues were dealt with on the fly and not necessarily as well planned or well executed as they could have been. Electrician availability, variable power cable size/connection availability, diesel fuel, and generator delivery transportation were cobbled together and addressed as the response gathered momentum and the equipment was mobilized. Prioritization for use of the portable power units was being assessed as the equipment was mustering and mobilizing.
Pre-Event Response Planning (continued)

The contracting portion of the NYSEMO driven event went well due to the latitude and flexibility given New York by its own Department of General Services (DGS) to deal with this event in a speedy, timely and expeditious manner. By utilizing a private sector contractor, NYSEMO did not have to wait for the mobilization and response from Federal Agencies and assets in moving prime portable power to the site and getting them prepared and under way. The initial response package of portable power had much to deal with in the way of flexibility in the executed response mission, but it was done successfully and helped to mitigate longer term deleterious effects of the disaster.

Based upon this event and others leading up to and through the hurricane seasons of 2004-2005, pre-event packages were established with Florida, Virginia, South Carolina, Louisiana, Virginia Beach - VA, Port Arthur - TX to name a few entities. They were based upon historical precedence, disaster event characteristics, and the experience of those survivors who had been through it and responded to it, in the form of Lessons Learned.

**Evolution**

The most successful iteration of the pre-planned portable prime power response to date has taken place in Florida. In consult with the FDEM (Florida Division of Emergency Management) Chief of Logistics, a group of pre-equipped, pre-staffed and pre-identified task forces were established that were called “Typing” or “PUSH” packages.

(The term “PUSH” package was coined because of Florida’s pronounced proactive response posture in which the state DEM was more likely to PUSH equipment and relief supplies to an affected area rather than to have them PULLED in by request, knowing that the affected areas may have communications issues to resolve and may not yet have a handle on the complete assessment of damage and destruction.)

This allowed a phone call to be made prior to hurricane landfall or post traumatic event, and an order for (you insert number) TYPE I through TYPE VI packages to be mobilized. By collaborative agreement between the State DEM, the experienced contractor/consultant, and based upon historical perspective of dealing with past storms and events, four sets of Typing or PUSH packages were created to deal with fairly robust (TYPE I Heavy package) events to fairly small (TYPE IV packages) events. These packages could also be customized based upon experience, intuition and type of hurricane or storm event to be encountered. A fast moving high speed storm was going to wreak havoc on the power system, thus necessitating more prime power be put in the package, rather than a large wet slow moving event which mandated more pumping capacity. An initial Package TYPE was sent to the client to inform and get their approval and/or input for adjustment even as mobilization was begun.
Pre-Event Response Planning (continued)

The Package was in essence a self-reliant Task Force sent in immediately post-strike, post-event, to address the priorities established by the state in dealing with portable power distribution. The prioritization was established by the State as

1. Life Saving
2. Life Sustaining
3. Life Enhancing.

Thus medical facilities, dialysis clinics, 911 dispatch centers, fires stations, etc. fell into the ranks of those facilities that had a priority for the portable power brought to bear in a disaster event.

A Task Force consisted of a variety of equipment and personnel, including

- Portable Prime Power Units from 25 kW to 2.5 MW generators;
- every manner of Material Handling Equipment (MHE to include cranes and 30 ton forklifts among the pallet jacks and extended reach forklifts);
- Light plants;
- Mobile Emergency Ops Center;
- 4", 6", 8" and larger pumps and pipe and hose;
- a fleet of trucks designed to deliver generators and MHE to all sites; and
- a cadre of electricians, technicians, certified operators, managers and mechanics.

Size depended upon Type (very similar to NIMS typing) and necessity, but the essential capabilities were similar, size and overall capacity the difference.

In the response to hurricanes, the ability to move quickly pre-event and stage on the periphery of the strike zone prior to landfall was enhanced by the creation of these packages. All parties were fully versed and apprised as to what the packages were comprised of and their roles in the marshalling and mobilization of all equipment and personnel. Complete coordination with, and integration into, the State EOC provided the ability to move through secure zones with correct credentials, special permits for interstate transport of oversized loads, information sharing for a common operational picture, and the flexibility to change to meet requirements as the information gathered in preliminary damage assessments (PDA’s) flowed in.

One of the single greatest capabilities established within the State of Florida DEM was the complete integration, coordination and cooperation of the Finance and Administrative branch of FDEM. With every Task Force or TYPING Package came the cost estimate based upon the total size of the package (and within FEMA allowable reimbursable rate structure). This allowed for a projection of costs over time and an encumbrance for weeks based upon the projections. Invoices would reflect the actual types and amount of personnel and equipment utilized. This gave the agency the ability to project costs over time, and yet also be flexible within the construct of the Typing Package to address additional needs and demobilization issues. This speaks directly to the issue of having an integrated and flexible approach within the relationship between client and service provider.
Florida also insisted upon the coordination with the federal portable power team (FEMA and USACE) to form the State of Florida Prime Power Team. The state contractor along with members of the 249th Engineer Battalion and the USACE Contractor coordinated the portable power mission requests from the inception of the 2004 hurricane season. Missions were discussed and assets disseminated based upon proscribed and assessed needs and whichever piece of the response matrix could handle and answer the mission request faster then undertook the mission performance. This alleviated redundancy in mission assignment and resulted in an overall broader coverage of power requests in the stricken area. While extremely successful over the life of four major hurricane response events in 2004, the single biggest drawback was slow speed at which the federal teams (249th excluded) moved to mobilize and fulfill missions. In the comparison of performance of the private sector contractor and the federal team, there was no comparison. The federal team could bring a robust power hammer from their tool kit, but it was slow to move and very difficult to swing. This as it turned out was a result of the contracting mechanism used by the USACE in the performance of their mission assignment from FEMA. It was created to follow the FARS and low cost accountability was the focus, not mission critical completion.

The importance in this federal response relationship is placed upon the contract vehicle in the main, and not the speed and flexibility necessary to accomplish the mission in the most expedited fashion in an emergency response (and often life threatening) event.

By way of example, in 2005, in response to Hurricane Wilma, 108 portable prime power units were placed in theater in Miami and surrounding area in the initial 6 days by the State’s power contractor. During this same time, USACE and their contractor placed 6 FEMA portable prime power units into theater. Ultimately, much of what was transported into theater for use was too late to be effective and remained on the trucks, unused and largely unneeded as the power grid was returned to some semblance of normalcy. The single biggest factor in the disparity of availability and use of FEMA equipment, however, was the contract mechanism and integration used by the USACE with its contractor. It was simply too cumbersome and not client-centric enough to generate an overwhelming fast response necessary to mitigate the negative effects of power loss in the earliest part of an emergency response.

It is not enough to simply plan and prioritize for the use of portable power. Providers and responders must have an effective contract mechanism designed for maximum speed and flexibility with maximum effective accountability. Focusing solely on accountability sacrifices the speed and flexibility necessary to focus on the mission and mitigate immediate deleterious and negative effects for the survivors.
Other Experiences and Applications

It is imperative that jurisdictions are diligent in canvassing the community as to portable power needs. This would include state, county, and city, NGO, any other qualifying agency, and even some critical private sector entities that may not be able to provide for themselves, but without which there is a measurable and sometimes dramatic shortfall of response, recovery and economic resilience means. Database inventories have been and are being created which allow for the easy application of a prime power source of a known type to a known location. In Florida in 2004, owing to the closure of ports and the subsequent non-delivery of fuel coupled with the mass evacuation exodus ahead of the storms, the diminishing fuel availability for those escaping potential wrath and destruction reached critical mass. This was exacerbated post-storm with large scale power outages, thus rendering even those fuel distributors and providers with fuel stocks available helpless to supply fuel for responders, aid workers and citizens remaining or returning.

This resulted in an immediate short term response with specially crafted “Fuel Trains” (emergency tank cars of diesel and gasoline specifically designated and scheduled to carry fuel to sidings in Florida with the capability to offload fuel with special portable pumps at sidings, thus enabling tank trucks to be filled for delivery into distribution sites in theater). The problem of loss of power post-event at these distribution sites resulted in subsequent proposed state-wide legislation (in Florida), which mandated portable power in residence at newly constructed stations, or at least the capability for portable power via manual switches and ‘plug n play’ capacity at those fuel distribution sites along major travel and evacuation corridors. Portable Power capability was also legislated (again in Florida) for special needs designated shelters as many of these sites prior to the 2004 and 2005 hurricane seasons had not considered and did not know their portable power requirements, or could not access portable power necessary to provide for their particular population needs.

Also in Florida, hospital insurance legislation has previously provided a mandate that all hospitals must have backup power and an evacuation plan in order to qualify for necessary insurance, thus shifting the burden from the state or region to the service provider.

In South Carolina after the 2004 hurricane season, and resulting directly from the visitation of a South Carolina contingent to Florida during their record-breaking hurricane season, the SC legislature mandated the retrofitting of all designated and approved shelters in the state with a pre-wiring manual transfer switch box with lockout/tagout design. This program was designed, promoted and pushed by the SCEMD (Emergency Management Division) and coordinated with the American Red Cross, the County and School District Boards and Superintendents, the State and local Fire Marshals, and the State Department of Education School Re-design Review Board. It was a massive, three year undertaking, with more than 150 shelters prioritized, first from the coast to I-95, and then west of I-95. All new schools designated as shelters which were constructed after this period were to be designed and constructed with manual transfer/lockout capability.
Other Planning Considerations

For those sites or services designated as critical and/or life-saving which require a priority power application and must have it restored immediately, natural gas is an alternative fuel source to an intermittent or threatened diesel supply. This is not a necessarily cheap or preferred alternate strategy, but one that should nonetheless be considered in a priority power application.

These Typing or “Push” Packages are not immutable, but flexible. The notion that a task force or push package is a fixed and rigid structure consisting of a set number, type and amount of personnel and equipment flies in the face of a fast, measured, flexible response. The notion of tweaking a task force or push package based upon storm or event type, duration, and time since last event is not only acceptable, but preferable. Slow moving wet storms generally require more pumping capacity with less portable prime power source, while fast moving high speed strong wind field storms require much more in the way of prime portable power assets and far less pumping capacity. It has been standard practice in Florida since the inception of the Typing Packages around 2000 to fine tune them and has worked with very great efficiency. The initial packages were built upon the experiences of a responding group to a particular type disaster scenario (worst case or most probable case) used as a base, and then refined as after action reports were compiled as to effectiveness and lessons learned. This refinement is an on-going process.

The current NIMS typing used for portable power (generators) is far too wide and has no bearing on real field applications. The very broad generator typing fields (I-V) run the gamut from generators far too small to facilitate prime power, to those which would be oversized but functional, and arguably not the best use of a limited resource.

It should also be understood that in designating the use of a particular type and size of generator for a priority facility, a responding agency or group is not absolutely bound to that particular size. A larger generator can be used (to a certain point) and still be functional. The questions that should be asked and answered are:

- What is the facility’s need?
- Where does the facility rank in the prioritization of needs?
- Are assets available to the jurisdiction to meet that need? Numerous examples of incorrect or greatly delayed portable power requests from a variety of stakeholders exists in the 2004-2005 and 2008 hurricane seasons, coupled with generally poor to non-existent backup prime power for much of what would be considered critical infrastructure. These critical infrastructure sites have either not maintained backup power sources or have not assessed their true need, source availability and readiness to accept and use it.
Pre-Event Response Planning (continued)

Coordination between the state and all power impacted jurisdictions at the highest levels is imperative as far as information flow regarding the recovery of the power grid and the reports issued by ESF 12 (or similar reporting group). Power grid and area recovery reports, as well as information consolidated from area energy providers regarding power being returned to grid sections, is crucial in providing critical guidelines for the prioritization of portable power placement. Unless there is a recognizable life-threatening situation, portable power should generally not be placed in an area or at a facility which is within 24-48 hours of being returned to the active grid.

Pre-Event Contracts
After Hurricane Isabel in 2003, several cities in Virginia sent out RFPs for pre-event disaster response contracts. Typing packages were designed for each municipality, and while almost certainly seeming reasonable from within the jurisdiction, they were excessive and unrealistic in their calculations. One municipality alone estimated they needed more than 450 generator units of varying sizes (all greater than 25kW units) to handle, among other priority needs, the extreme number of sewage lift stations. With other regional municipal jurisdictions involved, it was imperative to consider alternative functional solutions, in particular in regard to limited power resources in the region. What was proposed and accepted was the solution of using rolling power stock (generators on wheeled trailers) that would be used to pump lift stations down and then be moved to the next station. This strategy has been used in other jurisdictions on other responses successfully as well. It can be labor intensive, but allows the responding jurisdiction to rely upon fewer dedicated assets and still perform at an acceptable level. Pre-wired or pre-plumbed lift stations enhance the ability to rapidly respond and recover until such time as the power grid comes back on line.

Practitioners in pre-planning for portable power use as prime power source must be mindful that as a public entity utilizing private contracting energy sources, they are in keen competition with the private sector business entities accessing the same sources of prime power. The main difference is that the private sector has learned to regard the use of portable power as the necessary cost of doing business in those storm or hurricane zones in which they operate. As a result they are not shy about mobilizing or accessing limited power assets, even to the point of locking up their option for use by paying retainer fees.

The practice is trending now toward earlier and earlier commitment to these portable energy assets, thus removing them from the pool of readily available prime power assets available to address response and recovery in the public sector. Public sector entities are at a distinct disadvantage as they (with extreme few exceptions) do not pay retainers and generally do not commit early to bringing to bear regional prime power assets on a potential event. They typically await definitive information identifying them as a target (or post event) before committing limited public funds to a potentially declared/undeclared disaster.

There are, however, excellent strategies to help curtail the disadvantage at which the public sector often finds itself and will allow for the timely gathering and use of portable prime power sources in a calamitous event.
Pre-Event Response Planning (continued)

Our staff experts have spent many years doing precisely this type of work based upon review of plans and potential and historical hazards; and planning, training, exercising and responding in concert with all response stakeholders and with the guardians of the public finances. It is a welcome challenge.

SEMPER PARATUS (Always Prepared)
SEMPER GUMBY (Always Flexible)
Alternative Power Source – Different Grid / Power Source

What happens when a major power grid fails? Are users, especially critical facilities, willing or able to be without power for one second? One minute? One hour? One day? Do the critical facilities have business continuity power plans (i.e. Continuity of Operations Plan or COOP) in the event of a power outage, long or short?

Every critical facility must have electricity, and guaranteeing a reliable, steady source of power is crucial. This includes hospitals, sewage treatment plants, EOCs, police/fire stations, and water plants, to name a few. When the power is out, the cost to the community for loss of function at its critical facilities can be enormous, and sometimes deadly. The community may lose the ability to respond to the hazard, and recovery may be delayed. When the grid is down, the local economy may suffer, even to the point it may never recover, even after restoration of power. This makes access to a power source essential.

Two alternatives usually available: 1- alternative power grid sources or 2- on site backup generation.

Most critical facilities are connected to only one power grid. However, many major power suppliers have multiple grids spread over an area. Operators of critical facilities have long recognized the weakness that attachment to a single power grid offers, and some have made arrangements to overcome this weakness. For example, airline reservation systems receive their power from a minimum of two different power grids. When one grid is lost, the facility can quickly transfer to the other source. While alternative grids may get their power from the same generation plants, it is the delivery system that is vulnerable, not the generators.

Another alternative is back up power. They maybe sized to power only essential circuits, or entire facilities, depending on funding and need. Fuel is also part of the strategy. Many facilities tap into natural gas lines, which usually do not fail during major events. Others use storage tanks for LPG or other fuels, making the user reliant on an outside provider, whose supply and distribution may be out of the user’s control. (It is critical, of course, that above ground storage tanks be securely strapped against high wind, or otherwise protected.) Fuel, such as diesel or gasoline, needs to on a rotation schedule to maintain freshness. Backup generator should be connected to automatic transfer switches (ATS). The installation of an ATS can make power transfers seamless, if it senses partial failure, such as brown out condition. The installation of an uninterruptible power supply (UPS) will prevent any loss and will allow backup generators to start up and get online with no interruption to critical facilities (which maybe an issue of life or death.).
Effectiveness

- Little or no down time
- Reduction in loss of life for patients reliant on support

Limitation:

- Not all locations can afford user with another power grid source
- Initial connection to alternative power grid can be expensive
- Backup generators require some maintenance, and sufficient fuel supply
Critical Facilities - Data Base for Critical Facilities Power Tie-Ins

During a major outage or event, first responders are faced with the daunting task of determining which critical facilities need help, and what resources are available to meet the needs.

Local electrical co-ops should establish a database of all critical facilities, to include the following information:

- the facility's location on a map of the power grid (based on lat/long coordinates, rather than street addresses),
- the facility's power requirement under emergency conditions,
- the facility's backup power generation capability on site (this includes horsepower rating, amperage, voltage and phase specifications, fuel type and source / reserve capacity, and maintenance requirement during emergency usage),
- the facility's tie-in capability for external backup generators (i.e. type of NEMA style/model number of plug/receptacle, phase type, voltage specification), any already installed transfer switch, etc.

This database should also include emergency contact information (remember, cell phones may not be functional), and external resources that are available (such as backup generators and power cables).

This information should then be incorporated into local, regional and state Continuity of Operations (COOP) Plans. (For more information on COOP planning, please visit: http://www.fema.gov/doc/government/co-op/co-op_plan_template_instructions.doc.)

Effectiveness:
- Allows local critical facilities to quickly re-establish operations after an event.
- Greatly improves the likelihood that local community will survive and recover.
- Helps with emergency disaster drills and practices.

Limitation:
- Database for Critical Facilities Power Tie-Ins must be reviewed annually, and more frequently if the community experiences significant development changes.
- Just as the local community changes over time, so do the preparedness needs.
- When major critical facilities are added or changes in how they function occur, database and COOP plan should be updated and information disseminated to key responders and players.
Conductor - Aluminum Conductor Steel Reinforced (ACSR)

ACSR is commonly used for uninsulated overhead transmission cable, and as both primary and secondary distribution cable. It is now considered the industry standard.

ACSR is a concentrically stranded conductor composed of one or more layers of hard-drawn, 1350H19 aluminum wire stranded, which carries all the electrical current, with a high-strength coated steel core. The core may be single wire or stranded (up to 7) depending on the size, which handles 70% of weight load of wire.

The proportions of aluminum and steel can be varied to obtain the relation between current-carrying capacity and mechanical strength best suited to each application. ACSR can also be used to upgrade older copper conductor corridors.

Traditional copper is a great conductor. Unlike ACSR, it has a great many disadvantages. For example, when it stretches, it becomes brittle and fails. During wildland fires, utilities have reported that conductors were annealed and over stretched from overheating, and that insulators supporting conductor were also destroyed. When exposed to salt (anywhere within 30 miles of the sea coast, the air is considered contaminated by salt), copper corrodes and becomes brittle. Further, it then transmits less, due to attenuation of the skin effect. As all currents are carried on the outside skin, this leads to failure. When it oscillates (galloping) over time, again it gets brittle. When it gets cold, it becomes brittle (more than steel or aluminum). When it ages, it becomes brittle. By comparison, ACSR does not suffer most of the problems of copper.

Effectiveness:
- Meets ASTM standards
- ACSR offers optimal strength for line design
- Significantly less weight than copper
- Variable steel core stranding enables desired strength to be achieved without sacrificing current rating
- The principal advantages of these conductors are high-tensile strength and lightweight with longer spans as well as with lesser supports
- Due to the greater diameter of ACSR, a much higher corona limit can be obtained, plus higher voltage
- Lower inventory - a few select size can cover broad range of loads/voltage, reduce overall cost, warehousing, and increase flexibility
- Substantially fewer ACSR power lines were downed, compared to copper during the 2004 Florida hurricanes
- Able to perform, even under current overload, during wild land fires and ice storms
- Resistance to snow and ice accretion (ice accumulation on conductor)
- There are more advance styles, like ACCC, etc., that are more effective
- ACRS are not stolen for salvage value, unlike copper conductors
Conductor - Aluminum Conductor Steel Reinforced (ACSR) (continued)

- In high-voltage overhead transmission lines, due to the skin effect, it is mostly a moot point that conductivity of the steel cord is much lower than the aluminum outer covering. Skin effect is a phenomenon of physics where an alternating current will distribute itself on the skin of the conductor rather than the core.

- Aluminum has far greater corrosion resistance than copper. Therefore, there is less loss over long period, compared to copper. If a copper conductor has very corroded skin, much of the current would be loss to conductive heating of the conductor.

Limitation:

- Loss of steel caused by corrosion, which limits life span ultimately. However, some manufacturers have applied improved corrosion protection, including galvanizing steel core
Conductor - Breakaway Conductor
(For local service drop to an electrical customer)

Electric power to most customers on-line is usually supplied by an overhead service drop. The service drop usually consists of multiple conductors from the closest power pole, attached to a point at the customer’s building. Today, this is typical a triplex drop made of a bare ground conductor with a pair of insulated conductors twisted around the neutral conductor. The ground wire is mechanically tied to the power pole on one end, and to wedge clamps at the building. The pair of insulated conductors are made of a hot/load wire and a neutral conductor messenger.

Frequently, this type of arrangement is victim to falling trees, limbs, hangars or other debris during a storm event. Most often, the customer’s end will pull lose from the attachment to the building. This allows an energized (i.e. “hot”) conductor to become loose, threatening public health and safety. Damage may not be limited to the attachment point on the building. The drop may also break loose from the power pole, causing potential problems to power pole transformer, and to the feeder or distribution lines as well.

A solution is the use of a preferential breakaway overhead service drop. With the option the connection is made to self supporting connectors. A shear pin is used to join two connector portions adjacent the utility pole for the self-supporting, power conductors. The shear pin is sized to sever and release the self-supporting overhead service conductors adjacent the utility pole.

Male connector portions are coupled to the conductors of the service drop, and then mated with the female connector portions at the power pole.

Effectiveness:
- In the event of a fallen tree, for example, this would allow the power pole end to disconnect/separate. This results in only a short section that may be energized on the power pole end only, reducing potential exposure to the general public. This can also greatly reduce damages to the building and the power pole
- This type of device allows quick and easy repair of downed lines. Linemen can re-connect lines, using replacement shear pins
- Linemen will not have to repair power pole, attachment point on building, service drop line, etc
- Building owner will not have damages to repair. (This is important if building is a critical facility)
- Repair costs to the utility will be significantly less
- Lessened response and repair time allows timelier reaction to other events

Limitation:
- Very few utilities are aware of this type of device, especially REAs
- This type of arrangement maybe relatively complex and expensive, if requirement by utility is for multiple connections from single buss on a power pole
Conductor - Breakaway Conductor for Distribution, Feeders and Transmission Power Lines

When debris or other loading is placed on a power line, this will often result in a cascade failure of supporting power poles that may reach several miles (i.e., a domino effect). A solution to this is to setup a breakaway conductor. In effect, the solution is a “design-failure” mode for power lines.

Power lines would be dead-ended at certain intervals. Attachment bolts to the power line would usually be sized at 70% of the tensile strength of the power line. When a particular section is overloaded, the attachment bolts at the dead end will break, which will limit failure to only the immediate area between dead endings.

Effectiveness:
- Failure occurs at predetermined locations, permitting easier and safer repairs while minimizing the affected areas by reducing down time
- Reduction in overall cost by limiting damages to power lines and support system
- Reduction in threats to public health and safety by reducing area affected

Limitation:
- At present, industry does not have commonly available breakaway conductor for power lines

*This Handbook section was developed in the event that after this is published, a breakaway conductor might be developed.*
Conductor - Conversion from Bare Conductors to Insulated Conductors

Insulated conductors are conductors usually covered by an insulating shell, such as vinyl or rubber. They were developed to reduce failure rates compared to bare conductors and also improve performance and security, to be cost effective (spacing is reduce in supporting insulator conductors, thus reducing cost and material, plus lower maintenance). Often, in today’s environment, insulated conductors are used in distribution and feeder circuit (lower heights), and house drops.

Some electric co-ops are still using bare conductors for feeder and distribution circuits.

During a hazard event, insulated conductors typically have lower failure rates. This increases “up” time of the power lines (i.e. greatly increases mean time between failures).

**Effectiveness**
- Conductors can be positioned closer, thus reducing/eliminating need for large cross arms and large, elongated, external insulators. In fact, they can be installed with just line pole polymeric insulators, thus eliminating the need for cross arms
- Can be installed within tree canopy, allowing for direct contact with vegetation without short circuiting or inducing a fire
- Often, insulated conductors can be installed between tree limbs, branches, trunks...this is called “tree wire”. During a wind event, a conductor can be knocked to ground by falling limbs. Due to the insulating quality of the wire, a short circuit will not result

**Limitation:**
- Fallen insulated conductors can only be detected by power utility if a short circuit occurs, which often does not happen (short circuit would cause fuses/relays to fail). (See section on fallen conductor detection)
- By visual inspection by what is called “drive the lines” windshield survey/inspection. Visual inspection is ineffective (prone to human errors) and expensive operation (i.e. misses major problems).
- Accidental contact by people can still cause injury by the induced current into a person's body, or even death
Conductors - Dead End Bracing

Usually, power poles are positioned at the end of a straight run or section of power lines, at a point where it then ends, or continue at an angle in another direction. These are called dead-end poles. The poles, at this point, carry the horizontal load of these long sections of power lines. Dead-end poles are supported by guy wires running parallel to these lines. By regulation/stalking plans, these guy wires are connected by strain insulators somewhere along their length, to prevent flashover that may occur as a result of faults or lightning, to prevent it from reaching the lower portion that can be reached by people on the ground.

Because of the increased use of brittle, weak southern yellow pine power poles, when an excessive load is placed on the line, cascade failures often occur. In some cases, miles of power lines/poles are taken down.

In troublesome corridors, for every one to two miles, it is suggested, that these lines are dead ended at select points along the way. For a pole to be used for dead ending, the conductor is cut and both ends stop at this pole, and are connected together with a jumper wire. This pole is then heavily reinforced with guy wires, especially parallel to the direction of power line. If a load is excessive, only that section will go down.

Effectiveness:
- In event of an overload (such excessive icing, fallen tree, galloping), only poles between dead ending will be affected or downed (when one power pole falls, others are pulled down until heavy dead-end structures stop the cascading collapse)
- This will result in the co-operative/utility providing better and more reliable service to customers

Limitation:
- Increased costs, due to jumper wire connection, and extra guy wire bracing
- Increased time requirement to build a power line corridor.
Conductor – Aeolian Dampeners

Because of continuous low-velocity wind flow perpendicular to the phase or ground wires, those wires can start vibrating (i.e. Aeolian vibration). In a gentle wind, a power line will sing. That vibration can, eventually, cause the conductors to fatigue and break. In a severe wind, or when ice forms an airfoil shape around the wire, it can gallop (oscillate) wildy and cause severe damage, either from metal fatigue (where the conductor have gone beyond “endurance limit” of the metal) or from abrasion (e.g. at spacers). Regardless of cause, it can result in tremendous impact to the reliability or serviceability of a power corridor. Lines damaged by vibration may have their rating greatly reduced, as less power is transmitted to the customer, or maybe taken out of service completely until it can be repaired. An impact on one corridor may impact the power distribution in the entire power network.

Vast human ingenuity has been devoted to the problem of damping or eliminating this vibration, to protect the wire. This vibration can damage wires, insulators, poles and other connected parts. They have been known to cause a pole to be pulled out of the ground and back into it.

Economically, the transmission industry developed simple vibration (harmonic) dampers, which the major power companies typically use on their major lines. Mostly, the tuned version of the so-called Stockbridge type dampers are used (sometimes referred to as “dog bones”), in conjunction with sagging based on design tension. The dog bones attenuate the vibration to an acceptable level that is non-destructive to the conductor. Industry specification for Aeolian vibration dampers is IEC 61897:1998, “Overhead Lines – Requirements and Tests for Stockbridge Type Aeolian Vibration Dampers”.

Dog bones should be added at time of new construction. However, they can be added later, even if the lines are energized. This makes for a relatively inexpensive retrofit and mitigation, and the utility company/REAs can install them while the lines are active.

The area of the conductor most prone to failure is where it is attached to the end of an insulator. Typically, the dog bones are installed at the nearest anti-nodal point, i.e. points of maximum oscillator of the conductor, on either side of the clamp. Nominally, two dog bones are attached per conductor span. However, more can be install if the situation warrants this, especially for long conductor span.

For smaller lines, such as overhead static/shield lines, or optical ground wires (OPGW), a different dampener is used, which is more effective than the Stockbridge style for this application. The spiral Vibration Damper has been successful for over three decades to control vibration induced by the wind for smaller sizes of conductors and wire.

Effectiveness:

- Very effective and economical
- De facto standard of major utility, especially for transmission and feeder line
- Easy to install
Conductor – Aeolian Dampeners (continued)

- Can be retrofitted with line “hot”, using “hot stick” tools
- Can be installed well after a line has been installed or repaired

Limitation:
- Many small cooperative/utilities are not aware of this technology
- Demands for reliability by rural customers have not been high enough to force small coops to install in problematic corridors
Conductor - Fallen Conductor Warning System

A telemetry system for notifying and/or warning of fallen or down insulated conductor would provide the owner/operator will earlier notice of failure in the system. This generally would include a distribution system for distributing a utility, such as power, and a sensor system for sensing whether the distribution system is properly operating. The warning system could include a support structure; an arm carried by the support structure and extending outwardly there from; a distribution system providing a utility via at least one wire, the wire held aloft from a below surface via the arm; a communication cable transmitting a signal; a disruption assembly carrying the communication cable and in communication with the support structure. The disruption assembly is loaded with the potential of disrupting the signal transmitted by the communication cable; and a sensor system is adapted to monitor the distribution system based on the signal transmitted by the communication cable.

Read more: http://www.faqs.org/patents/app/20090103224#ixzz0iLZ24yCE

This is important for feeds to critical facilities and essential services, such as lift stations, water treatment plants, waste water treatment plants, potable water wells, etc.

Effectiveness:
- Reduces mean time between failure and repair, as normally, fallen/downed insulated conductors can only be detected by power utility if a short circuit occurs, which often does not happen (short circuit would cause fuses/relays to fail)
- Reduction in notification time would be essential for medical facilities and those reliant on power for life support
- More effective than visual inspections, which can be ineffective, prone to human errors, and expensive

Limitation:
- Can be expensive
- May not be cost effective for non-critical networks
Conductor - Static Line Protection

Overhead power lines, often utilized by larger utilities and cooperatives, are often equipped with what is called, a top static line. Some utilities call this a ground conductor (shield wire or overhead earth wire). Regardless of the terminology, it is usually a bare conductor that is grounded at the highest point of the supporting structure for a power line, to greatly reduce the probability of a direct lightning strike to the phase conductors. It also provides a parallel path to earth for fault current in an “earthen” neutral circuits.

This type of protection was derived, empirically, from “Faraday’s cage”. A grounded rod will provide a 45° cone of protection for objects below it. Anything within this 45° cone will not be struck by lightning. The static line provides this cone of protection for the phase line below it.

At present, the use of overhead ground wires is still the most effective method of shielding power lines from direct lightning strike, and the resulting economic losses to society. In the illustration, we simplify it by using only one static line and one power conductor. The static line placed above the power conductors is oriented such that nearly all lightning bolt will be intercepted by the static line. The static lines are grounded at each tower or pole through a low resistance ground as possible. The degree of protection is also depended on the ground resistance of the tower themselves.

Many rural or smaller electric co-ops may omit this vital element in their power line design to save money. Ironically, this omission often costs them significantly more in the long term, by way of the cost of increased maintenance, shorter lifespan of power lines and supporting structures, and the increased threat to public health and safety.

Effectiveness:
- For areas that typically experience frequent thunderstorms, this method can be very cost-effective

Limitation:
- Increased costs for installation of line, plus grounding, which may be burdensome for smaller utilities
Conductor - T-2™ Style Ice Resistant Conductors

T-2™ style conductors can be a low cost alternative to burial for lines subject to long-term Aeolian vibration, or galloping and sub-conductor oscillation damages due to wind and ice. T-2™ style conductors consist of a pair of identical bare standard conductors twisted about each other with a long lay (9 foot interval), instead of just one high-voltage bare transmission line conductor. Sizing is based on impedance and load capacity of wire. Since the two lines move in different direction, T-2™ easily resists ice acervation/accretion (ice forming). This allows the line to more easily break any ice forming and to resist galloping with changing wind-attack profile. This also dampens low Aeolian vibration (low frequency [5 - 50 Hz] vibration caused by high wind).

(Note: see oval conductor as alternative. In addition, T-2™ is trademarked name. There may be problem identifying what another manufacturer calls their version. Some naming conventions include duplex, vibration resistant, etc.).

Effectiveness:

- It is becoming better known and more popular
- Resists sub-conductor oscillation
- Low cost, long lasting, and reliable
- Lower maintenance than conventional lines
- Lower operating temperature for same current load as conventional line, which means lower impedance means, which results in more efficient transmission of power. This is due to increased surface area to dissipate heat. This results in less sag, less strength loss, and reduced creep.
- Constantly varying diameter drastically inhibits resonant vibration in the line
- Low-torsional stiffness of the twist absorbs and dissipates motion-causing wind forces to ineffective energy levels
- Installed in same method and with the same equipment as single conductor
- Installation costs about same as conventional
- Can be strung as replacement, to maximum tension, without the need for additional vibration dampeners
- Uses same splices as single conductors
- Has been used in FEMA-funded mitigation projects
Conductor - T-2™ Style Ice Resistant Conductors (continued)

Limitation:

- More education is needed to make it more widely known and accepted
- T-2™ conductors should not be allowed to sit for long period in stringing blocks during installation; damage may occur. Stands may be damaged by aggressive movement in stringing blocks, which defeats the reason for having T-2™
- Reels of T-2™ conductors should never be rewound to another reel, or damage may occur (T-2™ advantage would be lost due to damage to stands and twisting)
- Reels of T-2™ should be stored upright resting on rim, and never lay flat on side. Again, damage may occur that would negate the T-2™ advantage
- Special repair procedures are required for broken strands that must be adhere to maintain T-2™ style advantage
- Special instructions are required:
  - must follow manufacturer’s guide/instruction;
  - suggested installer follow manufacturer installation guide and IEEE (Institute of Electrical and Electronics Engineers) Guide to Installation of Overhead Transmission Line Conductor (IEEE Standard 524); and
  - Special procedures are required to maintain equal tension between strands.
Conductor - Underground Conductors

Electrical power is traditionally transmitted by overhead power lines. However, underground power lines have been used by major utilities to cross highly populated metropolitan areas, in areas where rights-of-way are not available, where permitting is a major hurdle, in areas with natural barriers such as rivers, environmental sensitive areas, in areas already congested with urban infrastructure, and across land set aside to future growth.

However, many power corridors have been troubled by high winds, wildfires, hurricanes, ice storms, etc. In many cases, the power utilities have performed their own benefit-cost analysis (BCA), and determined that it was more profitable, from a business standpoint, to bury lines than to continue to repair overhead lines.

Effectiveness:
- Buried power lines are less prone to damages caused by hazard events, such as winds, lightning, and ice storms.
- Great reduction in the amount of electromagnetic fields (EMF) into surrounding neighborhoods.
- Footprint for buried lines is much smaller, generally about 3 to 30 feet, as opposed to overhead transmission lines which may need 60 to 600 feet that must be maintained to allow for safety, access for repair, and ease of maintenance.
- Buried lines offer no hazard to wildlife passage, aircraft pathway, and are safer due to lack of exposed hazard.
- Buried lines are less likely to be subject to theft of metal conductors, sabotage, or damages from shooting conflict, vandalism.

- Since most buried power lines are insulated with XLPE (cross linked polyethylene), this allows fiber optic cable to be incorporated with power lines.

Limitation:
- Burying is two to five times more expensive, as compared to overhead lines.
- Life cycle cost is two to four times more than an overhead power line.
- Typically, overhead lines cost about $10 per running foot, compared to $20 to $40 per foot for buried lines.
- Fault finding and repairs are more difficult and more expensive than overhead.
- Often, for critical circuits, redundant lines are also buried.
Conductor - Underground Conductors (continued)

- Since the nearby earth is extremely close to live buried line, repairs cannot be performed while buried lines are energized
- Reactive power of buried lines can cause large charging currents, making voltage control more demanding
- Buried line should not be in areas with high water table, such as southern Louisiana or Florida
Historically, electrical controls for sewage lift stations, levee pumps, etc., have been near the motors or pumps. This increases the likelihood of flooding. Reduction in the flood risk to electrical controls can be achieved through a variety of methods. Regardless of means, this usually means elevation of the controls.

Protection can be achieved through building code enforcement. Most areas in the US have building codes implemented that meet one of the national standards. Provisions in the IBC, IRC and IEBC do require that electrical systems be protected to NFIP minimum standards. This means that electrical components are elevated above the base flood elevation.

Protection can also be achieved through application for FEMA Hazard Mitigation Funding under Section 406 (Stafford Act). Following a presidential disaster declaration, Section 406 provides discretionary authority to fund mitigation measures in conjunction with the repair of the disaster-damaged facilities. These opportunities usually present themselves during the repair efforts. The mitigation measures must be related to eligible disaster-related damages and must directly reduce the potential of future, similar disaster damages to the eligible facility. Normally, this work is performed on the parts of the facility that were actually damaged by the disaster. In some instances, an eligible mitigation measure may not be an integral part of the damaged facility. FEMA will consider these exceptions on a case-by-case basis. Elevation of electrical control is a commonly funded 406 measure.

Finally, protection can be achieve through FEMA’s Hazard Mitigation Grant Program (HMGP) which provides grants to States, local governments, and eligible PNPs to implement long-term hazard mitigation measures after a major disaster declaration. The purpose of the HMGP is to reduce the loss of life and property due to natural disasters, and to enable mitigation measures to be implemented during the immediate recovery from a disaster. The HMGP is authorized under Section 404 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act.

Effectiveness:

- Elevated control means the facility will remain operational, as long as fuel or electricity is available during major event
- Availability of facilities protected by elevation means significantly less damage to structures served by these facilities
- Reduces time for community to respond and recovery, when facilities are not in need of critical repair

Limitation:

- Other eligibility requirements apply for FEMA-funding
- State may not make elevation of electrical control a top priority for HMGP funding
- HMGP projects may take one to two years to process, from start to funding
Fireproofing

Structural fires or wildfires can disrupt or destroy a power distribution system. Fire resistance intumescent water-based coatings can withstand extreme temperatures for an extended time are readily available. These coatings provide barrier protection to a variety of materials, including drywall, lumber, plaster and lath, concrete, sheet metal, tin, foam, and composite panels, as well as fiberglass and space age carbon graphite. These coatings are approved by the California State Fire Marshal, and meet or exceed the industry’s most stringent requirements, showing the ability to prevent both fire penetration (ASTM E-119) and vertical flame spread/flashover (UBC 26-3/UBC 8-2 room corner tests) for a variety of materials.

These coatings can contain a fire by preventing the fire from penetrating walls and ceilings and the occurrence of flashovers, thus saving lives and preserving the structural integrity of the equipment. It can stop flashover and it may reduce the cost of rebuilding structures to meet applicable fire codes and/or reduce the cost of possible litigation. It is essential in wildland/urban interface areas.

The intumescent coating is non-toxic, environmentally friendly and applies as easily as paint. Depending on application, they are generally applied at a rate of 100 to 200 feet² per gallon, and usually cost less than $100 per gallon. Additives are also available that can be mixed with any standard latex paint, for interior or exterior. They represent a substantial savings over other means of fire proofing.

Intumescent coatings expand to 30 times their thickness, and maintain protection for up to two hours against 2000ºF flames. The following are some examples of the types of structures and equipment that can be fireproofed:

- **Transmission towers.** Brush fires can easily reach 2000º, well beyond the 1500º melting temperature of the steel that makes up tower frame.
- **Power poles.** In grass or brush fires, power poles temperature can reach kindling temperature and ignite.
- **Transformers.** Transformers can only function below a certain temperature. When that threshold is exceeded, they will fail and explode or catch fire.
- **Substations or transformer housing.** The same protection can be applied to the protective structure as to the equipment.
- **Conduit.** External conduit can be easily damaged both wildland and structure fires. Intumescent coatings can allow the conduit to survive long enough the fire’s fuel sources to be exhausted.

Fireproofing (continued)
- **Cable / cable tray.** Intumescent coatings are available specifically for these items. It can prevent flame propagation along vertical and horizontal cables and cable trays.

- **Critical Signage.**

**Effectiveness:**
- Inexpensive, easy to implement
- Can be used, in some jurisdictions, in lieu of sprinklers, especially for historic preservation concerns.
- May substantially lower fire insurance rate
- Transparent coating can fireproof equipment without look of paint, per se.

**Limitation:**
- Lack of knowledge of and experience with intumescent coatings has prevented their wide use.
Insulator - Polymeric Insulator

Ceramic Insulator
Many of the commonly used supporting insulators for power lines are the older ceramic style (i.e., porcelain) insulators, which can be problematic. This type of insulator is frequently damaged by natural hazard events, such as high winds, lightning, flashover, and, wild fire, as well as vandalism. They were designed for vertical tension loading, rather than horizontal loading. This means that if portion of line is elongated and sagged by an extreme event this can would cause the insulator to skew and fail under horizontal tension. This makes them subject to fracturing, which is a major cause of failure. Fracturing is aggravated by acid produced by atmospheric pollution, especially near a contaminated atmosphere (e.g. within 30 miles of the ocean, where the air has high concentration of salt), and lighting flashover. Further, these brittle insulators are subject to failures from seismic events. Finally, ceramic requires periodic wash downs to halt flashover; in contaminated atmospheres, these cleansings must occur more frequently.

Polymeric Insulator
Newer, high-voltage polymeric insulators can greatly reduce the long list of problems that accompany ceramic insulators. Silicon rubber is a common polymeric insulating material. Polymeric are much lighter (100 pounds versus 500-600 pounds) and resistant to contamination (unlike ceramic, which requires annual maintenance, to prevent chronic flashover problem and failure). Their smaller size also makes them a less attractive target for vandals. These polymeric insulators resist damages from bullets and have very small profiles (less half diameter of ceramic), which reduces changes of being hit by debris. In addition, they have a significantly higher safety factor than ceramic. They have superior performance from high flexural property and much higher shock absorption. Annual maintenance is not required for external polymeric insulators, which accommodate contamination under standard and non-standard conditions. Polymeric insulators are virtually unaffected by years of contaminant exposure and keep their high insulating value. Even if flashover occurs under extreme electrical stress, insulators will recover their hydrophobicity (i.e. repelling, tending not to combine with, or incapable of dissolving in water.) Operators can implement replacement of out-dated ceramic style with polymeric when re-staking, or as a preventive measure (even when not replacing conductors).

Effectiveness:
- The most reliable insulator in service
- Much lighter (100 pounds versus 500-600 pounds for ceramic)
- Resistant to atmospheric contamination (unlike ceramic which requires annual or more frequent washing down maintenance, to prevent chronic flashover problem and failure). Annual maintenance is not required for external polymeric insulators, which accommodate contamination under standard and non-standard conditions
- Even if flashover occurs under extreme electrical stress, insulators will recover their hydrophobicity
- High-corona resistance
- Vandal proof: resist damages from rifle bullets and high-velocity airborne missiles/debris and have very small profiles
Insulator - Polymeric Insulator (continued)

- Superior performance from high-flexural property and much higher-shock absorption, including horizontal loading
- Have significantly higher engineered safety factor than ceramic
- Polymeric insulators are virtually unaffected by years of atmospheric contaminant exposure and keep their high insulating value
- Flameproof
- Many direct replacement products to preclude the need to re-tension lines after replacement of traditional insulators
- Lower installation cost
- Improve power frequency insulation

Limitation:
- Can cost twice as much as equally sized ceramic
- Material is made from organic compounds, and eventually age, though long term data on aging process is inconclusive
Protection of Electrical Substations

An electrical substation is part of the delivery of a power system: generation, transmission, distribution. Power is transformed from low to high, or vice versa, using electrical transformer. There may be several substations between the generating source and the ultimate customer or user. Power may change voltage in many different steps.

Electrical substations maybe located on open land, underground, or located at customer. In large buildings, there may be multiple substations indoors. Indoor stations can provide a considerable amount of protection from weather, lightning, vandalism.

Methods for protecting substations:

- **Use of Faraday's Cage for both transformer and power lines.** This can be in the form of lightning rods for the transformer, static/ground line above the power lines coming in and out, or a tall well-grounded tower provide protection for electrical devices/liness in the substation. The most common method is the use of tower to attract lightning strikes by placing near transformer and shield wire. Any device, such as a tower, rod or static ground line will provide a 60° cone of protection for objects below it. Anything within this 60° cone will not be struck by lightning. It must be adequately grounded, and it must be tested and maintained on periodic basis. Recommend conservative calculation of 30°for single mast or shield/static line and 45°for two mast or shield wire. (See Lightning section.)

- **Surge Suppressor/lightning arrestors.**

- **Chain link fencing to act as barrier to debris/missiles.** Standard chain link fencing, using 1.5’ post and 11 gage fabric, is not strong enough to stop high-velocity wind. Recommend upgrading to 2 to 3’ diameter post, 9 gage fabric, bracing for fence, deeper footer (at least 3” or more), stainless steel ties, 1 5/8’ rails or larger. If the fencing is robust enough, it will act as a surrogate debris barrier, preventing debris and missiles from impacting the substation, while also providing security to installation. Fencing must also be properly grounded, to prevent high voltages that result from a fault in the network. Any fault, regardless of source, may cause the ground potential to rise. Current flowing through the ground/earth during a fault can cause any metal structure to have a far different voltage than the ground surface under an individual’s feet. This may result in electrocution of the person in contact.

- **Use of polymeric insulators to prevent damages from vandalism.** See Polymeric Insulators section.

- **Lighting of area, and maintenance of vegetation to prevent hiding places.**
Protection of Electrical Substations (continued)

At minimum, substation should meet the latest *Design Guide for Rural Substations* issued by the US Department of Agriculture, Rural Utilities Services (RUS), RUS Bulletin 1724E-300. This publication is up to date with latest industry standards, current RUS format and technical requirement.


**Effectiveness:**
- Very effective, prevents damage to substation and possibly life threatening outages
- Highly cost-effective

**Limitation:**
- Many rural co-operatives are not aware of this type of protection
- Towers must be brace for high velocity wind and size sufficiently for wind load
Flexible Power Tower

Metal poles/towers that carry high-voltage transmission lines across the country are built to take whatever blows at them. To accomplish this, they tend to be big and round and sturdy—as much as 12” in diameter and 100” tall. However, they can still fail under extreme wind loads and weight of ice accumulation.

A new way to mitigate cascading transmission tower failure is a hinged power pole (currently in development). This newer design isn’t simply a hinge; rather, it uses the same principle as a willow tree. A willow tree bends and is more likely to survive than a rigid oak tree, which has no ability to give, and often fails in a wind storm.

The hinged type of pole has a rectangular cross section with hinge at the base. This is the power pole version of the US DOT roadside post safety breakaway system for highway sign panel (see picture). The integral hinge plate is generally rectangular. The hinge plates are fixedly mounted on opposite sides of each of the posts supporting the sign panel. The selection of material and configuration is such that a portion of the hinge is engineered to weaken and break under extreme loads. This allows the hinges mounted opposite side to the impact direct to bend. This prevents the post from acting as a barrier to on coming vehicles, and causing harm or death.

The power pole version is similar. It is also rectangular in form, with a hinge near the base. There are structural fuses on either side of the hinge. However, with this design, there are also tendon cables running inside of the pole that act as resistance to stretching and aid in maintaining the pole in an upright position. When there is a failure/extreme load, a variety of things occur: the fuses bend, the hinge pivots, the interior cables tighten, and nearby poles immediately absorb some of the load from this pole. If there is sufficient deformation, the entire system’s reserved strength in other poles will pick up the load. This can happen with wind overload, ice accumulation loading or other failure. No single pole is forced to pick up the full load.

At this point, this design is being tested and work is in progress to secure a patent. The utility industry has a strong interest in this design.

Hinged power poles can be easier to install, as there is no need for a crane, especially in remote sections of the countryside.

Effectiveness:

- Allow for quicker repairs with little need for new poles or lines, or cranes
- No need for dead ending for long stretches of power lines
- Can be easily re-erected after falling, with power lines still attached

Limitation:

- Product is not available yet at publication time, but should be available soon
Pole - Larger Diameter Power Pole

Wooden power poles are a traditional, economic way of supporting and insulating electrical equipment. They provide insulation from the ground, overhead power lines, and related electrical equipment, such as transformers and overhead lighting. The vast majority of all distribution lines and a significant portion of lower voltage transmission lines are built with wooden poles. Available supply, cost, and ease of handling and installation are all factors in this. A study by the utility industry concluded: "The bottom line is that treated wood offers the most energy-efficient, functional, cost-effective and practical material for use by electric utilities in providing electrical service to the public." It should be noted, however, that these and other studies do not consider the effects of high wind events, wildfires and other disasters on these industry standards.

Standard wooded power/utility poles are usually 40” long, and are buried 6” into the ground. Formerly made from cedar, today’s poles are often pressure treated southern yellow pine. Following is a chart of uniform sizes for power poles, based on American National Standard ANSI 05.1 for wood poles.

### Class Chart/Sizing Dimension for Douglas Fir and Yellow Southern Pine Poles

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<th>Class</th>
<th>H-6</th>
<th>H-5</th>
<th>H-4</th>
<th>H-3</th>
<th>H-2</th>
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<td>min circumference at six feet from butt in inches</td>
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Pole - Larger Diameter Power Pole (continued)

Most power poles used for distribution feeder lines are class 1 to 5. Decade ago, the common practice was to use a number 3 cedar. Practice in today’s economy is the less costly southern yellow pine using a class 5 sizing. Southern yellow pine has only half the tensile strength of cedar. This, combined with the reduction in size, can compromise the strength of the electrical distribution system, i.e. reduction in load sharing.

Load sharing is a term in the utility industry that describes the mechanics by which elements in an electrical distribution system gain support from stronger, or less heavily loaded, adjacent elements. For power lines, the theory behind load sharing is that when one pole is deflected more than its adjoining neighbor, the cable that connects them all will automatically re-distribute the forces/loading to the adjacent poles and away from the heavily deflected pole. How well this works is depended on the design used (anticipated loading, whether this includes wind, fire, ice or not). Modern wooden power poles provide significantly less margin for error in these calculations.

Pole strength varies from pole to pole, with the weakest being the first to break. Designers estimate load sharing to the maximum rate, generally allowing a 10% increase for any additional line added. Often, the effects of natural disasters and hazards are not considered in these calculations.

The return to a larger class size would help to offset the effects of natural disasters, e.g. stalking plan modified to use class 3 instead of a class 5.

It should be noted that wooden poles should also be replaced periodically. The National Electrical Safety Code (NESC) requires that a wooden pole be replaced when strength deteriorates to 2/3 of its initial required strength for installations controlled by the district load provisions of NESC Rule 250B, or 3/4 of its initial required strength for installations controlled by the extreme wind load provisions of NESC Rule 250C.

Effectiveness:
- Meets all current design standards
- More reserve strength: Increased class size would require larger wind/ice loading before breaking
- Reduces number of down power line during a wind event
- Reduces lost of power to critical facilities and customers
Limitation:
- Cost for a class 3 southern yellow pine power pole is approximately 37% more than for a class 5
- Wooden utility power pole has limited life of 35 years, slightly longer with aggressive maintenance (40-50 years)
- Wooden poles are still vulnerable to high wind events and ice storm, more so than spun concrete, or other alternatives
Pole - Random Alignment of Power Poles

A simple method to stop wind from causing harmonic waves (galloping) in power line corridors is to do a slight rearrangement of how the poles are aligned. This is done by having new/replacement poles installed with random spacing and alignment.

Random span spacing would stop standing harmonic wave. The first span could be set at 300 feet apart. The next span maybe set at 294 feet again. The next one maybe set at 310 feet apart. These random span spacing would stop standing harmonic wave that may destroy line from galloping. To make it more resistance to stop harmonic wave is to have the poles not line up in a straight line either. For example, if a corridor run from east to west. Have an imaginary line from beginning of the corridor to the end of it. The second pole is installed 3 feet north of this line. The next pole is one feet south. The next one is 2 feet north. If the distribution system looks like it was done by a drunk, then it is less likely to have standing waves (galloping). This mitigative solution is very much, counter intuited.

**Effectiveness:**
- Stop propagating standing waves, galloping
- Prevents damages to lines and poles/towers

**Limitation:**
- May require larger Right-of-Way (ROW)
- More difficult to string power lines, as straight line is easiest to pull against
Spun concrete poles, with natural gravel or crushed stone with steel reinforcement and high-strength, low-permeability concrete, are made by spinning at 3000 rpm. This makes for a drier, denser concrete (up to 7,000 pound tested tensile strength), stronger than just cast concrete poles. No spun concrete poles failed during Hurricanes Charley, Frances, Ivan, Jeanne, Katrina, or Wilma. None failed during Hurricane Andrew, a Category 5 hurricane.

Wooden poles, in spite of the pressure treatment, will eventually decay. They also have a fairly limited life - 25 to 50 years, depending on weather and ground condition. In areas prone to high-velocity wind events, the useful life is generally much lower, as they are more prone to break under high-wind load.

Major power companies have made the move to upgrade to spun concrete whenever possible in major corridors. However, rural electric co-ops have not done so for a variety of reasons, many of them economic.

Mitigation is cost-effective. After the 2004 hurricane season in Florida, FEMA studies the effects of the hurricane season on the electrical distribution system in the state. Their findings were published in an economic study titled *An Estimate of Lost Earnings Due to Electric Supply Disruption: The Case of Florida’s 2004 Hurricane Season.* Recommendations from that report included:

- “Replacing wood utility poles with spun concrete poles is another way to potentially reduce future damages.”
- “Another potential mitigation measure is the replacement of wooden electric poles with spun concrete poles. Concrete poles are three to four times stronger than wood poles….”
- “Major utilities, such as Florida Power & Light, and all the municipal utilities have gone to concrete.”

Much like the Coliseum in Rome, concrete simply withstands the tests of time and nature better than wood. While wooden poles have historically been the material of choice, and while the applicable codes may specifically address wooden poles, the evidence is clear that spun concrete is a better, more economic, more durable material that will lead to fewer long-term replacement costs.

Note: It is expected that future wind load requirement for power poles under 60 feet may automatically preclude the use of wooden powers.
Pole - Spun Concrete Poles (continued)

Effectiveness:
- Meets all current design standards
- Environmental friendly
- Does not spall or rust
- Lighter than wood, steel, reinforced concrete poles
- Durable, strong, best strength to weight ratio
- 3-4 times stronger than wood poles
- With virtually no degradation from even the most severe environments or storm event
- Increase longevity of the power delivery line
- Support same loads as steel poles
- Easier, one step direct burial installation, significantly reducing installation costs
- Simpler to install and handle than wood, steel, pre-cast concrete poles.
- Economical to maintain: virtually no post-installation maintenance result in low lifetime costs. No need for internal inspections or use of toxic chemical to control insects or rot
- Higher return-on-investment (ROI) over long term
- Splice joints allow the manufacture spun concrete poles over 200 feet in length.
- The use of the splice joint provides a far more easily assembled and economical connection between pole sections than traditional flange splices
- For applications with special requirements, traditional flange splices can be used
- 80-100 year life expectancy. Project cost savings can be counted on through extended asset life
- Maybe eligible for FEMA 406 Mitigation, which allows for mitigation up to 100% of the cost of repair, for use of disaster-resistant materials for power poles
- Survives better in abusive conditions, such as acid-sulphate soils and marine environments
- Economic to install; concrete footing not required or needed. In bedrock condition, can be directly bolted to bedrock
- Provide increase support for pole mounted transformer. In many cases, a large transformer may require two or more wooden poles to provided needed support and strength to survive high wind loading
- The much stronger spun concrete pole are significantly more effective for “underbuild”, a practice where, to save space in narrow right-of-ways, a distribution line is often carried on the same pole as a subtransmission line, but mounted under the higher voltage lines. Telecommunication lines are also mounted, at a lower point
- Will not support combustion during wildfire or other sources of fire

Limitation:
- Initial cost is 2 to 3 times more than equivalent size standard southern yellow pine poles
- Many rural coop are not aware of performance advantage
Power Plant Fuel Strategy

After recent disasters, such as Hurricane Charley, Frances, Katrina or Rita, it became apparent that without fuel, most power plants would be forced to shut down. It is vital to have a readily available supply of fuel to feed power plants.

Local electric co-ops that own their power plants should develop a strategic plan to insure that there is sufficient stock of the fuel they require for operation, such as coal, fuel oil, natural gas, reservoir water, etc. If an active hurricane season is anticipated, then it might be advisable to have sufficient stockpile, to last one to two months, to allow for transportation interruption, such as lack of rail/river delivery or damage to gas pipelines.

Having fuel in remote location may not work after an event. An example is after Hurricane Charley in Florida in 2004. The Governor ordered fuel trucks to make delivery to gas stations and critical facilities (e.g. lift stations, waste water treatment plants, hospitals, etc.). However, due to the lack of signage, the drivers could not make their deliveries. (In Charlotte, Lee, and Sarasota counties alone, out of 132,000 traffic signs, 119,000 were destroyed or lost). Since the truck drivers did not have GPS, they could not navigate the sign-less road to their destination.

To make a point, one particular county in Florida, had sufficient fuel reserve that are rotated on regular basis, that they were able to supply all their critical facilities for over a month. In one county nearby, there was no fuel strategy. The sheriff had to arrest his friend (who was a willing participant and happened to own a fuel supply business), so he can legally confiscated all his fuel, because his county accountant refused to allow emergency purchase.

Power plant operators must plan for fuel shortage.

Alternative fuels can also be devised in strategic plan. For example, coal fire generators could be modified to burn biomass fuel, which can be readily made from disaster debris. For natural gas generators, or for coal fired plants that have been modified, methane gas can be generated from decomposing rubbish. If co-op has set some of its plant to run on methane gas during normal operations, during an emergency, this can be easily ramped up to take up the slack for generators running on other fuel not available.

Effectiveness:
- Minimizes downtime and impact to their customer base. This could be a matter of life or death, including economic, to their customers
- Reduces cost from buying off the national power grid, if this was an option

Limitation:
- Cost of extra reserve maybe economically difficult for smaller co-ops
- Some co-ops may not have in-house experts to set up fuel strategy plan that involves other sources
- Filling up reservoir may not leave capacity to prevent flooding downstream during an event
Rights-of-Way (ROW) Clearance

Trees and other vegetation should be kept clear and trimmed around high-voltage transmission lines. This enables reliable and safe power service to critical facilities and customers. Trees that are allowed to grow too close to high voltage power lines ROWs often result in hazardous conditions that may create or fuel wildfires and forest fires, threaten residential structures, disrupt power services, and may lead to total shutdown of the power grid. Trees can topple onto power lines by high-wind event, wild fires, or by ice acervation.

Depending on conditions, this can be maintained with manual labor or by power machinery. Regardless, when vegetation is removed, useable logs can be left to landowner’s use. Resulting brush and limbs can be trimmed to within 18 inches of the bare ground.

It should be noted, generally, that trees are removed that pose a serious threat to safety and electric service. Not only does this work help maintain electric safety and service reliability, it is required by state and federal regulations. Failure to perform maintenance may make any federal disaster reimbursement during a presidential declaration ineligible for public electric utilities.

Local utilities should design and implement an aggressive vegetation management plan for pruning trees along power line rights-of-way (ROW). This should address:

- Adjustments that may be made in light of potential ice accretion and other problems
- Reviewing existing easement requirements and laws
- Enforcing existing easements
- Expanding inferior easements through cooperative efforts and eminent domain
- Recommending in critical areas and new developments, on a case by case basis, that tall trees or potentially hazardous trees should be avoided or removed and replaced with low-growing trees

Adjustments can often include more aggressive widening of ROW to allow for larger disaster events.
Rights-of-Way (ROW) Clearance (continued)

Effectiveness:
- Greatly increase reliability of power system during major event
- Low tech method of mitigating problem

Limitation:
- Many co-ops feel they do not have sufficient funding to perform ROW maintenance
Stalking Plans

Staking (or re-staking) is a complete engineering evaluation of all the conditions surrounding the choice of each structure and its location (usually all the components of an overhead electrical distribution system), prior to repairs or installation. It is a complex process that combines both science and art to produce a set of plans that a construction crew uses to build an electrical distribution power line. A properly staked line will result in adequate construction/re-construction at minimum costs. A poorly staked line will result in substantially larger construction, unnecessary delays and possible re-staking, invariably higher costs, and most importantly, critical threats to services to the public, especially threats to public health and safety. Stalking plans should incorporate local standards, as well as national and state standards. Stalking planners should use this opportunity to mitigate by leverage new technology, as they become available. This section will look at re-stalking, especially for installation using older technology such as wooden poles and copper conductors.

One major aspect re-stalking should address is the required replacement of damaged conductors with updated design and material. The exact sags and conductor stretching caused by damaging events, such as extreme wildland fire, ice storms or hurricanes, are very difficult to calculate. This is made even more difficult by the old wire that has undoubtedly stretched since it was installed, but probably not beyond its allowable/design tolerance before the event. Further, conductors made of copper wire are annealed by aging (e.g. oxidation).

Stalking plans often do not address emergency/outage, after the planned corridor is staked or re-staked. They should address inventory levels afterwards for emergency response and recovery. They should also include testing emergency equipment, steps to put line crews, support staff and customer service personnel for emergency story duty assignments, fueling/loading up of co-op service and repair vehicles with equipment and supplies ahead of announced storms like hurricanes.

**Wildfires**

Annealing, during manufacturing of copper conductors, involves heating then cooling slowly to make the metal less brittle, and thus to provide greater flex life and reliability. When a copper conductor is heated during a fire, the heating and cooling cycle is rapid, causing the wire to be annealed, i.e., the copper conductor becomes more brittle and less flexible. If the wire reaches 1,000°F, embrittlement will take place, which can lead to catastrophic failure during high load event, such wind.

Complicating matters, there appears to be no documentation with original specifications for copper conductors. However, in an AIEE Transaction, comparing various copper conductors, the study shows that Hard Drawn copper conductor will have a 5% loss of strength at a relatively cool 302°F for 2.3 hours. The actual temperature of a wild fire maybe unknown, but a reasonable, educated approximation could be made of at least 1200 to 1500°F range. This would cause wire to anneal quickly and have an even greater loss of strength; this is in addition to the embrittlement already noted above.
Stalking Plans (continued)

It is not unusual for electric utilities to do metallurgical analysis on sample of in-service lines to determine duty cycle and on failed lines, so as to prevent future reoccurrence. However, with no sample of new manufactured newer style copper conductor, this is a moot point. As a result, utilities (often as a long-term policy) will declare conductor to have been annealed when:

- Suspension insulators out of plumb. Insulator swing in the direction of higher tension. Annealed conductor will elongate and increase the overall conductor length in a ruling span which reduces the horizontal tension in that particular span
- Blacken or discolored conductor as a result of smoke fouling or burnt off green discoloration (normal copper corrosion patina)
- All three “horizontal” phase conductors no longer level.
- Reduced or insufficient ground clearance.

Once a copper conductor has been stretched beyond design tension (a percentage of breaking tension), the conductor is permanently stretched and will not return to design sag. Design sag is required to prevent power line problems: wind induced destructive “galloping” which can lead to destruction of both the line and the towers, insufficient clearance with objects below such as automotive and rail traffic and the ground itself, stress on towers to due improper, destructive tensioning, vibration induced failure of conductors and towers due to metal fatigue, etc.

If a section of lines are visibly over sagged, NESC (National Electrical Safety Code) and the local utility's minimum clearances are usually violated under these conditions. The conductor is then deemed to be damaged beyond design condition. Further, the conductor thus stretched, is diminished in area and current carrying capability and that it is more likely to break and/or pull out of splices (e.g. under frequent Santa Ana wind which often are at gale force velocity.).

Further, re-tensioning the conductor to its initial stringing tensions would create safety and system reliability concerns to LADWP and the general public due to the loss of strength as a result of a fire. Loss of strength means that the wire is no longer able to reach its “original” ultimate rated strength without permanent deformation. This ultimate rated strength is used in initial stringing calculations with a safety factor of 2 to 1 for maximum loading conditions on the conductor. Since there is a reduction in strength, the safety factor is reduced and ultimately the line no longer adheres to local standards. A reduced tension would require to re-sag the wire, would result in low clearance issues along the entire ruling span.

For single dead-end to dead-end (where a run of conductors would end and a new run would start, and which are connected by jumpers), spans that were 2 to 3 feet lower than adjoining spans, most local utilities will determine that conductor is serviceable if there were no clearance issues or they are able re-tension the conductor to within a foot of the adjoining spans. However, if the stretched conductor sags lower than 3 feet, the conductor needs to be replaced as engineering necessity and by most policies.
For multiple suspension spans, where there is a single damaged span, slipping of the suspension shoe to balance out the tension is feasible. However, for multiple suspensions span where there were multiple damaged spans, re-tensioning or re-sagging of the conductor is not possible due to the inability to determine where the actual damage may have occurred. The area of stretch within any given span is extremely difficult to pinpoint. If the region of stretch can be located, the work involved to splice in new conductor would be very difficult and labor intensive. The alternative (to install a new conductor) is a much more efficient and cost-effective method of repair to the local utility.

(For more ideas, please see the following sections: Fireproofing, Towers, Conductors, Transmission System, Wildland Conflagration Prevention.)

**Ice Accumulation**
Damages during ice storm/glaze storm mostly are the results of overloading and galloping. Overloading of conductors are the results of accumulation of ice from winter storms, the type that characterized by freezing rain. Galloping, or oscillation, is the result of wind loading.

The US National Weather Service defines an ice storm as one in which more than ¼’ of ice on exposed surfaces accumulates. On a power line, this is 500 pounds of weight per span, which is usually 300 feet apart. Lines have been known to have 4’ of ice accumulation.

When the ice loading exceed design specification, the line will break/fail. In addition, severe damage/breakage to power poles, insulators, and guide wires can also occur. Nationally, the rate of occurrence is over 16 times per year.

(For more ideas, please see the following sections: Towers, Pole, Insulators, Conductors, Transformer Support, and Transmission System.)

**Wind Storm**
Wind storm includes hurricanes, tornado, straight line winds, etc. Wind storms can cause damages due to wind gusts, high-wind velocity, wind-generated debris, galloping (wind driven waves/harmonics), and wind loading of conductors and poles. For mitigation suggestions and ideas, please see the sections on: Conductors, Towers, Poles, Transformer Support, and Insulators.

**Parallel Replacement of Other Phase Conductors**
Replacement of a damaged conductor also requires replacement of parallel/other phase line conductors. This is based codes and standards, as well as good engineering practices. Replacement with newer conductors, especially aluminum conductor with steel core (ACRS), would cause impedance imbalance/mismatched with older copper conductors. This would cause loss of power and increased loading of step-up and step-down transformer, possibly exceeding load design. Further factor is creep (i.e., to slip out of place; shift gradually). New conductor will have a different rate than existing conductor, which would soon require re-sagging of all lines.

Operators should make it their standard practice to replace out-dated ceramic style conductors with polymeric when re-staking, or as a preventive measure (even when they are not replacing conductors).
**Stalking Plans (continued)**

**Effectiveness:**
- Exponentially increases the reliability of an overhead electrical distribution system.
- Provides economy By reducing the overall, long term cost of providing service
- Mitigates against damages from known hazards, such as lightning, flooding, etc

**Limitation:**
- Requires careful planning
Tower - Increase Performance in High Wind or Seismic Condition

Large, elevated power line towers are commonly damaged by high-wind loads, ice-storm loading, or by ground movement. Friction harmonic dampers can be retrofitted to allow for energy absorption of tower movement and for increase wind/seismic resistance. The harmonic dampeners are designed to slip at a predetermined loading to attenuate the energy loading on the tower and retrofitted as part of the cross bracing support of the tower. This takes into account previous high velocity wind events and/or seismic event loading.

A friction damper consists of a series of plates that are clamped together with high-strength bolts. During an earthquake, the dampers absorb energy and generate heat through the rubbing of the plates much like a person rubbing their hands together generates energy in the form of heat.

Effectiveness:
- More cost effective than conventional reinforcement, which generally consist of upgrading to larger steel braces and expensive modification to foundation.
- When a tower is conventionally strengthened, one of the things done is to replace cross members and X bracing with stronger pieces at key points of higher stress. Use of friction dampeners eliminates this extensive modification.
- Very effective in reducing tower damage.
- Effectiveness is dependent on analysis of existing tower behavior and location of dampeners.

Limitations:
- Costly, but less costly than replacing tower with conventional high wind/seismic design.
- Approximately 35% less than conventional method.

For more information, we suggest visiting: [http://www.djc.com/news/ae/11151100.html](http://www.djc.com/news/ae/11151100.html)
Transformers – Separation of Outdoor Oil Insulated Transformers from Buildings/Other Equipment

Transformers may contain very large quantities of combustible materials at a substation, especially the oil-filled type. High temperatures will damage transformer insulation of winding. If not cooled, this usually results in a fire.

Smaller transformers can be cooled by natural convection of air. For larger transformers, part of their design involves the proper dissipation of generated heat. Often this is performed by immersion of the winding in oil. Oil is mechanically circulated through a radiator or water-cooled heat exchanger.

Increased worries about fire at or near structures have raised questions regarding how to properly locate transformers to minimize potential problems, especially oil-filled transformers. We suggest that local co-ops consult with the National Electrical Code (NEC) and the National Electrical Safety Code (NESC), plus their insurance carrier, for installation requirements for varying types of transformers. This should guide the decision making, such as whether to use an oil-filled transformer and how it should be located and installed. It is important to locate them away from control buildings, other transformers, and other highly combustible equipment. If a fire should occur, the distance of separation will help mitigate the possibility of nearby equipment catching fire or destroyed by the heat of the fire. This would also reduce down time, as only the transformer would require replacement, and not an entire electrical infrastructure. Consideration could also be given to using less flammable or non flammable type of transformers (non-flammable coolant is used).

A few standards to consider:

- Most local units of government enforce the NEC (either 1993 or 1996 editions). Note: the 1993 edition specifies transformer installation.
- Listing requirement, performed by independent third party, for a specific transformer model
- Insurance carrier requirements, since a fire will result in damage to life and property which they are covering
- Local ordinance requirements are often more stringent than national codes

We suggest that local electrical co-op review article, Knowing Liquid-Filled Transformer Installation Requirements, at http://ecmweb.com/mag/electric_knowing_liquidfilled_transformer/. This article can provide valuable decision-making information.

It is suggested that co-ops also review the Fireproofing section of this handbook.
Transformers – Separation of Outdoor Oil Insulated Transformers from Buildings/Other Equipment (continued)

Effectiveness:
- Limits fire/damage to transformer, and not immediate nearby structure and equipment
- May reduce insurance premium
- Greatly reduce downtime/impact to transformer replacement only, and not to nearby structure and infrastructure

Limitation:
- Existing location and lack of space may prevent relocation of transformer
Transformer Support

Electrical transformers are very heavy equipment. By necessity, many are pole mounted, especially for local feeder power lines. Often only one power pole is used for support. This can be insufficient when there is a high-wind load from a storm event.

Often, transformers located on the ground need to be elevated to prevent flooding, or vandalism. Again, proper support is necessary to allow for survival in a large event.

Some suggested methods to improve transformer support:

- Doubling of wooden power poles. If poles/transformer were damaged in a presidential declaration, FEMA may provide funding for increase support of transformer. (See FEMA Disaster Declaration section)
- Replacement of wooden power poles with larger size poles, or replacement of wooden poles with spun concrete poles. (See Spun Concrete Poles and FEMA Disaster Declaration sections.)
- Use of hurricane-rated supports to elevate transformer in flood-prone locations. If transformer was damaged by flooding in a presidentially declared disaster, local co-ops may be eligible for funding to elevate transformers. (See FEMA Disaster Declaration.)

Effectiveness:
- Very cost effective, especially when coupled with FEMA funding
- Minimized downtime/impact from high-wind event or flooding, to local community

Limitation:
- Habit and custom can lead to foreseeable damages
- If repairs were performed before contacting FEMA, opportunity for FEMA disaster reimbursement is usually lost
Transmission System – Increase Design Loading for Wind/Ice for Transmission System as Whole

In any power distribution system, damages and power outages are caused by a number of factors. Often, it is caused by broken or weakened, sagging tree limbs. Under the heavy weight of accumulated ice, this can the weight of a limb can increase by 30 times or more. Small tree branches and weak tree limbs will break with ice accumulation between ¼ and ½" (6-12 mm), while a ½ to 1” (12-25 mm) accumulation can cause larger branches to break off. If the high-storm winds are in concert with ice loading, then the damage to trees and power lines would increase. Without trees in the immediate vicinity, power outage during ice storm usually only result from high-ice loading on lines.

In many areas, (and in almost all areas with a history of destructive ice storms), the standard design limit for overhead power lines is roughly 25 mm (about 1") of radial ice accumulation (note that this is different from the precipitation total accumulation). In general, damage to the transmission system occurs in the more severe ice storms. However, this does not mean that damages may not occur during lesser events as a result of galloping. Galloping is a direct, un-dampened harmonic oscillation and uncontrollable stretching under moderate but also steady wind conditions. Galloping can be so severe that a pole in the middle maybe pulled out of the ground, and then pushed back into the ground by the wave action of the wire. This may be repeated hundreds of times during a storm event.

Power distribution towers are generally designed to withstand higher ice and wind loading, but can fail or collapse under heavy ice accretion.

Recommendations include switching from copper to ACSR, polymeric insulators, spun concrete power poles, larger diameter power poles, increase sizing of conductors, use of Aeolian dampers, the increase use of dead ending, increase use of guy wire bracing, increasing number of poles to support transformers, random spacing of poles and towers.

Effectiveness:
- Very cost effective in long run
- Reduced/minimized power outage during storm events. This reduces property and economic losses and human suffering to electric co-op customer, which can be a matter of life or death

Limitation:
- Usually higher cost in short run
- Higher costs for rights-of-way (ROWs) maintenance
Wildland Conflagration Prevention

Electric Power Distribution
Overhead transmission and distribution of electric power is a major source of ignition for the conflagrations (major intense wildfires) that have destroyed many hundreds of homes in California, Florida and elsewhere in recent years.

Contrary to popular belief, the large high-voltage transmission lines (130kv to 785kv) are not the worst offenders. In one study they accounted for less than 8% of the fires over 5,000 acres in size. They are commonly built of sturdy materials, maintained with adequate vegetative clearances, and inspected frequently and thoroughly.

Distribution circuits (usually less than 50Kv) accounted for nearly 17% of the conflagrations studied (Task Force on California’s Wildland Fire Problem, 1972). This proportion was exceeded only by arson and was equaled by machine use. All other fire causes were smaller in number. Distribution circuits are of two types: primary and secondary. Primary circuits bring the power from the substation to the user's transformer. Primary electric power distribution circuits are a serious cause of wildland conflagrations.

The thousands of miles of these lines present a tremendous exposure and an almost insurmountable problem of inspection and maintenance. Secondary circuits, which convey power from the transformer to the point of use (e.g., home, pump), often cause fires because of inadequate vegetative clearance which is currently unregulated by state or local law. Secondary circuits cause nearly one fire for every two caused by primary distribution lines (California Division of Forestry, 1972; Moore, 1977).

In the lower half of their voltage range (i.e., 2.4 to 17 kilovolts), primary distribution circuits often can be successfully installed underground rather than overhead. In the foreseeable future, even higher voltage lines can be installed underground. The subdivision codes of many cities now require such installation in new subdivisions, although usually for visual esthetic reasons. The same requirement could be imposed in rural and wildland areas for fire protection reasons. Such a requirement would eliminate both primary and secondary circuits as sources of vegetation fires since the transformers would be at ground level or below.

If the cost of underground installation cannot be justified in relation to fire safety benefits, the developer can arrange for and the permitting agencies can require higher standards of construction, vegetative clearance, inspection and maintenance of overhead power lines.
Wildland Conflagration Prevention (continued)

Mitigation Measures - Suggested Standards:

1. Install all new distribution circuits and extensions of existing circuits underground in fire wildland areas, if technologically feasible.
2. Bury all distribution circuits (new or existing) carrying less than 20,000 volts in areas of "extreme" fire hazard severity class.
3. Maintain the following clearances between vegetation and conductors (wires) for all overhead power lines:

<table>
<thead>
<tr>
<th>Fire Hazard severity Class:</th>
<th>Secondary Distribution</th>
<th>Primary Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0-750V</td>
<td>2.4-17kV</td>
</tr>
<tr>
<td>Clearance in Feet:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>High</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Extreme</td>
<td>6</td>
<td>8</td>
</tr>
</tbody>
</table>

Additional Mitigation Measures

The following measures can also be implemented:

- Use of intumescent coating to coat transmission tower and poles. (See Fireproofing section.)
- Upgrade copper conductor to ACRS. (See Conductor - Aluminum Steel Reinforced Conductors (ACRS) section.)
- Upgrade insulators, by replacing ceramic with polymeric. (See Insulator - Polymeric Insulator section.)
- Increase tower height to allow power line clearance, well away from the heat, for occasional brush wildfire
- Program to reduce fuel, e.g. controlled/prescribed burn of underlying brush on regular basis
- Access to firefighter. Many areas where a substation, transmission towers, etc, are located in remote area. A road access, that would allow two vehicles to pass each other, will allow firefighter access
- Establish of clear area. 130 feet in radius; keep area brush-free and grass cut low

Effectiveness:
- For areas with history of repetitive loss, this is very cost effective.

Limitation:
- Certain activity must performance as a required maintenance, such as fuel reduction, clearing rights-of-way (ROWs),
FEMA Disaster Declarations and the Reimbursement Process

After a major ice storm, it is not unusual that many power lines are knocked down, probably having a reach of a few states where power is lost. Local electric co-ops work to restore power. After the proverbial dust is settled, some public co-ops will receive disaster reimbursement from FEMA. Most will not.

The Federal Emergency Management Agency (FEMA) was created by a Presidential Executive Order in 1978. FEMA’s role is to coordinate response and recovery operations for major disasters, both natural and manmade. Assistance is generally provided by financial reimbursement for the costs incurred by eligible applicants in their disaster efforts.

While FEMA is mandated to help in the recovery, they are still financially responsible to Congress, in addition to the victims. As a matter of accountability, they are constantly on guard for ineligible applicants and damages, policy and regulatory violations, and outrageous costs and estimates. The majority of reimbursements are issued in the form of federal grant, subject to full federal audit.

It is in the local co-ops interest to fully understand and follow rules set by FEMA. The following is an example of what might happen:

A co-op has suffered damages to many of its substations. The surrounding area for each substation is covered with flood debris, preventing response teams from working on the transformers. A local contractor is put to work clearing the debris using front end loaders with operators. When the co-op has a FEMA Project Worksheet (PW) prepared for reimbursement, it is declared ineligible. FEMA stated that there were no competitive bids for the work. It does not matter that the situation was urgent, or, that vendor was well known to applicant. While the co-op likely did not have sufficient time to formally bid the work, the co-op could have conducted a quick telephone/e-mail survey to demonstrate that the contractor’s prices were competitive. Another solution would have been to have a pre-positioned contract for debris removal and clearance, prior to the event.
So what should a co-op do to ensure their eligibility for reimbursement?

- **Preliminary Damage Assessments.** FEMA and the state will likely conduct what is called a preliminary damage assessment (PDA) immediately following a major disaster event. This is performed rapidly over the course of a few days. This PDA is exactly that – a preliminary damage assessment, and is not a detailed estimate. Because of this, damages are often missed and unaccounted for. This may be due to many factors:
  
  i. Event damages may have occurred over a large area, making it difficult to cover every corner. Affected co-ops need to make the State aware of the damages in their system.
  
  ii. Co-ops may have decided to complete repair before FEMA/State inspects area. Any work completed prior to inspection is often declared ineligible. Co-ops need to immediately contact the State prior to any work.
  
  iii. Total estimated damage amount for county or parish where co-op is located may not reach normal threshold for declaration. If FEMA declares a state, each county that is declared must have at least $2 in damage, per capita. In some cases, the threshold is set at $2.66 per capita. The co-op may have suffered tremendous damage, but overall, the county/parish did not meet the FEMA threshold. If damages were in nearby county/parish that was not declared, the co-op should make the effort to document damages to total co-op system and to make sure that it is included in PDA. When damages do not reach the threshold amount, then the co-op can reason with the State and FEMA that a declaration should be issued due to “extraordinary concentration of damage” to “critical facilities”.

- **Meeting eligibility requirement.** FEMA normally provides disaster reimbursement to local, regional, or state units of government, and to eligible Private Non-Profit (PNP) organizations. These are not-for-profit organizations that provide critical functions – often governmental in nature - to the population. Generally, electric co-ops meet this litmus test. However, documentation verifying the co-op’s eligibility is usually required. Please be prepared to provide tax exempt status documents, and have them readily available, along with copies of state law that regulate non-profit status of co-op.

- **Bid issues.** Problems can arise if the co-op’s bid contracts do not meet FEMA regulations, policies or rules. This can result in FEMA declaring the contract amount ineligible for reimbursement. A frequent problem is the appearance of a lack of competitive bidding. Having an emergency does not preclude or exempt these requirements. The use of the sole source argument may not be valid by FEMA standards. The safest bet is to allow some form of competition among possible vendors. Better would be the use of a pre-positioned contract for disaster services prior to event, when there is time to follow the co-op’s normal bid procedures for procurement.

- **Justification for disaster related response and recovery cost.** FEMA will vigilant indications of costs that may not be the result of the disaster. For example, FEMA generally accepts only the overtime from co-op staff, because, whether or not a disaster occurs, the regular salary of the staff will still be paid. This means that the base salary of the staff is not a disaster-related cost, and is not eligible for reimbursement. However, if the co-op chooses to have outside help, both regular pay and overtime (i.e. lump sum) for such temporary services may be eligible.
However, it is another matter when it comes to the issue of mutual aid. (In emergency management, mutual aid is an agreement among emergency responders to lend assistance across jurisdictional boundaries. This may occur due to an emergency response that exceeds local resources, such as a disaster or a multiple-alarm fire.) Nearby communities may provide people and resources. It is here where FEMA determines if the resource costs are eligible item for the co-op to recover from FEMA. If FEMA determines that is a charitable donation, then the co-op will not be reimbursed.

However, the importance of recording keeping cannot be over stressed. Applicants should carefully track the donated resources. It can often be used to fund the non-federal cost share required for most FEMA assistance grants. Applicants should generate a list of volunteers, their address, the hours they put in, the area are they working in.

It should be noted that FEMA does not reimburse for lost revenue during response and recovery, nor does it reimburse the cost of buying power off the major national grid, if a generator failed.

- **Code and Standards and FEMA Mitigation.** What about old, worn out equipment that does not meet newer codes and standards? This can be covered in a few different ways:

  Any equipment damaged by the declared event can be upgrade to the latest code and standard in effect before the event. It is to the applicant’s advantage to adopt the local building code and to be aware of the latest advancements in codes and standards. FEMA is obligated to replace or repair damaged equipment to pre-disaster condition. If upgrades are required due to advancements in codes and standards, this is something that FEMA is required to consider, so long as certain conditions are met.

  If it can be demonstrated that any upgrade will mitigate the effects of future events, then it may qualify in one of three ways under the PA 406 Hazard Mitigation program.

  1. If the cost of the mitigation is equal to or less than 15% of the total eligible project cost, it is deemed administratively cost effective.

  2. If the mitigation measure is listed on a list of eligible items in the FEMA PA guidebook, then up to 100% of the costs are eligible. For co-op, this can include upgrading from weak wooden power pole to stronger spun concrete poles. It can include double poles to support transformer. It can include elevation of equipment, control panels, and electrical services to prevent flood damages. It can include bracing of overhead power lines and anchoring non-structural elements such as parapets and veneers on buildings, bracing interior walls and partitions against seismic event. It can include relocation of utilities from hazardous locations.

  3. If the co-op wants to perform upgrades/mitigation that are not normally eligible for federal reimbursement, FEMA will allow the cost of restoring facility to pre-existing condition (which include the aforementioned codes and standards), the co-op can use these funds to offset the cost of their ineligible improvement.
FEMA Disaster Declarations and the Reimbursement Process (continued)

- **Duplication of Benefits.** Federal regulations prohibit the duplication of benefits, regardless of the source. The most common duplication for utilities and co-ops is the availability of insurance proceeds, whether claimed or not. It is to the co-op’s advantage to inform FEMA of any insurance policies and any settlement received, as well as any claims paid. The co-op should also list any other sources, so that FEMA can easily determine eligibility. In the absence of provided information, FEMA will likely make assumptions as to other reasonably available benefits.

- **Debris Management.** It is important that the applicant becomes familiar with and well-versed in FEMA’s debris policy, particularly any special policy that maybe particular to a disaster event. Most applicants will have trouble proving where the debris originated and how it is disposed, without detail documentation. Co-ops should consult with FEMA for any special debris record keeping requirement for a particular event.

**Document, Document, Document**

It is important that applicants follow FEMA rules and policies for disaster reimbursement, which includes maintaining records and documentation. Failure can mean ineligibility and lack of disaster reimbursement. Simple planning will insure success funding after a presidential declaration.

Remember to:
- Prepare in advance. It is not if a disaster will hit, but when will the next one will hit.
- Review mutual aid agreements.
- Risk managers should carefully review all insurance policies, ensuring that they are up to date and provide adequate coverage
- Be sure that any strategy for procurement is simple enough to be implemented during chaos after an event.
- Applicants should perform internal audit to identify area of vulnerability to disaster.
- Get to know players at local and state emergency management. These are the people you will likely be working with after the event.
FEMA-State Agreement

Immediately after a disaster declaration that heavily affects or impacts the State's public electrical distribution system, a representative from the State's electrical co-ops should request to be a voice in the preparation of the FEMA-State Agreement.

The FEMA-State Agreement is a legal agreement between the federal and state governments, and lays out the understandings, commitments, and conditions under which FEMA disaster assistance will be provided. The agreement imposes binding obligations on FEMA, States and their political subdivisions, in the form of conditions for assistance which are legally enforceable. The agreement also outlines:

- what types of the assistance will be available
- the incident period
- the areas designated by FEMA as eligible
- the percentage of non-federal cost share (by default it is 25%) that will be required
- easement and access as necessary for response and recovery work
- any hold harmless agreements
- the authorized state representative

However, such conditions may be modified by a properly executed amendment to the FEMA-State Agreement.

Co-ops can request 406 Hazard Mitigation be included, and that co-ops are allowed immediate access to recovery funding. Since the co-ops must restore the electrical distribution, FEMA can authorize mitigation of wooden power poles with spun concrete, or replacement of copper conductor with ACSR conductor, or use of additional poles to support transformer, etc. If the repairs have already taken place, it would be difficult to come back and replace poles once system is up and running.

Effectiveness:

- This avoids the usual loss opportunity in a majority of FEMA declarations, as the FEMA teams arrive well after the utilities have already repaired system
- This is cost effective, as elements are mitigated against future events

Limitation:

- It must be explicitly stated in FEMA-State Agreement that electrical co-ops are considered eligible entities
References

- Electrical Construction & Maintenance (EC&M) magazine article, “Knowing liquid-filled transformer installation requirements”,
  http://ecmweb.com/mag/electric_knowing_liquidfilled_transformer/.
- FEMA Continuity of Operations (CO-OP) Plan Templates instruction,
  http://www.fema.gov/doc/government/co-op/co-op_plan_template_instructions.doc
- FEMA economic study, “An Estimate of Lost Earnings Due to Electric Supply Disruption, The Case of Florida’s 2004 Hurricane Season”, by Keith Burbank, Todd Davison, Shabbar Saifee, Gina White, Charles Beck, Dennis Quan.
  http://www.fema.gov/library/viewRecord.do?id=3693&fromSearch=fromsearch
- FEMA publication 321, “Public Assistance Policy Digest - January 2008”,
- FEMA publication 322, Public Assistance Guide

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