EEI Workforce Issues
Arc Flash –

Hydro One Networks Experience

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Hydro One at a Glance

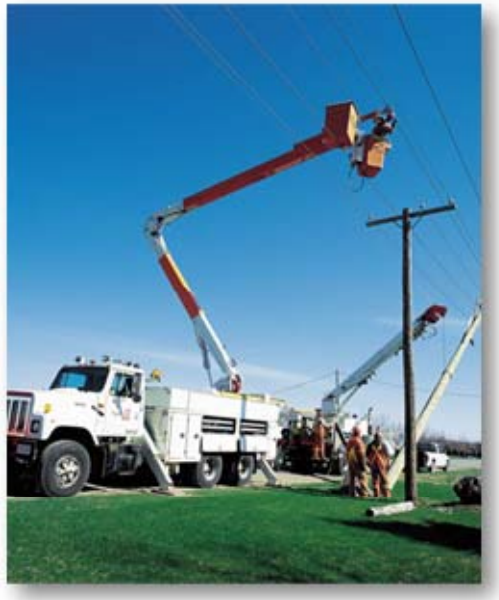
- 76,590 mi distribution system serving Ontario's rural communities, small municipal distribution and large industrial customers
- 18,043 mi transmission and interconnected system (169 mi underground transmission)
- Serve 247,123 sq mi
- 5,032 regular employees; 1,880 non-regular
- Fleet – 6,923 units driving 84,456,000 miles annually

Hydro One Networks

- Customer Operations
  - Lines
  - Forestry
  - Customer Care
- Grid Operations
  - Station Maintenance (transmission & distribution)
  - System operation
  - Fleet

Hydro One Networks

- Engineering & Construction
  - Lines & Stations construction
  - Engineering
  - Supply Chain
- Asset Management
  - System investment
  - Business integration
  - Strategy/Conservation
- Health Safety & Environment
  - Field safety support
  - Injured worker case management
  - Work methods & training
  - HSE Management System



Challenges

- Large, geographically dispersed, mobile workforce
- Workforce – regular and temporary staff
- Large number of “new/young workers”
- Trades staff
  - Work at heights
  - Work with heavy equipment
  - Work in the outdoor environment in all conditions
  - Work in an ever changing environment
  - Work in live electrical environment
  - Work 24x7
  - Work remote and often independently

Hydro One Networks “Timeline” on Arc/FR Issue

- Early 1980’s:
  - introduced the requirement for high visibility clothing.
  - Included requirement for clothing to be flame resistant (combined with high visibility since could not ‘sell’ FR on its own)
  - Implemented use of FR cotton clothing (Proban)
- Early 1990’s - Policy implemented to ‘encourage’ employees to wear FR and high visibility clothing when and where it enhances safety

Hydro One Networks "Timeline" on Arc/FR Issue, cont'd

- Provided initial issue of clothing (no charge to employee) and replacements at subsidized prices
- Provided to employees who
  - routinely work within the limits of approach to energized electrical equipment (750 V and above)
  - Routinely work in proximity to vehicular traffic
- Clothing consisted of: long jacket, coveralls with hood or bomber jacket and overalls, T-shirts or long sleeve shirts

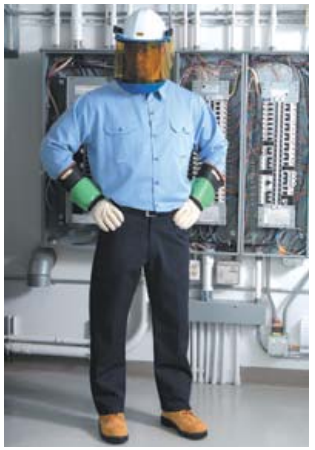
Hydro One Networks "Timeline" on Arc/FR Issue, cont'd

- 1999 - Questions raised regarding rainwear – is it FR? Simple answer … No
- Initiated work on development of FR clothing specification (including rainwear) – to meet ASTM 1506, 1891, and 1959
- 2000 final version of Specification for Arc and Flame Resistant Clothing

Hydro One Networks “Timeline” on Arc/FR Issue, cont’d

- 2002 established first contract for arc/FR rainwear (Ranpro Utiligard)
- 2003 established first contract for arc/FR clothing (AGO; based on Westex Indura Ultra Soft fabric)
  - Full range of clothing – T-shirt, work shirt, sweatshirt, pants, overall, coverall, jackets, parka, chainsaw pants, balaclava, hard hat liner (cold weather)
  - Included repair service and repair kits
  - High visibility and non-high visibility
- Clothing provided to trades staff based on collective agreement ($600 initial issue and ongoing replacement)

Arc/FR Clothing



Standards Development

- Preparation of harmonized rules for electrical utilities initiated (Hydro One and Electrical & Utilities Safety Association of Ontario)
- Rule – When working on or in proximity to exposed energized apparatus:
  - Only outer clothing that is either treated with fire-resistant chemicals or is inherently flame resistant shall be used
  - All garments shall have and be worn with full length sleeves extending to the wrists and full-length pants extending to the ankles
  - All foul-weather clothing shall comply with the above.

Standards Development, cont'd

- 2009 – Electrical Utility Safety Rules requirements for FR clothing adjusted.
  - When working on or in proximity to exposed energized apparatus:
    - The arc flash, flame resistant clothing and approved protective equipment selected must provide an adequate level of protection to protect the worker
    - The outer layer of clothing must be made of arc flash, flame resistant material
    - Clothing worn in conjunction with arc flash, flame resistant clothing must not contribute to increased worker injury
    - Clothing and protective equipment must be manufactured, tested and maintained to current recognized industry standards

Standards Development, cont'd

- 2006 – Hydro One provided $250,000 to the IEEE/NFPA Arc Flash Phenomena Study
- CSA and NFPA agreement to adopt 70E (adjusted for Canadian regulatory requirements)
  - Initially CSA technical committee proposed to eliminate all exclusions from Z462
  - How can we meet the requirements (i.e., need to carry out arc flash calculations)?
  - Utilities lobbied CSA and 70E was adopted in CSA Z462 with exclusions intact.

Standards Development, cont'd

- Canadian Utilities through the Canadian Electricity Association developed the *CEA Guide on Electrical Utility Workplace Electrical Safety for Generation, Transmission and Distribution* (based loosely on NESC)
- Document formed seed document to CAN/ULC S801 *Standard on Electric Utility Workplace Electrical Safety for Generation, Transmission, and Distribution*
  - Include direction on minimum approach distances, protective equipment, work on energized equipment arc/flash protection, work on isolated systems, working near utility systems
  - Balloting complete, to be finalized late 2009

Arc Energy Calculations

- 2004 – Concern for EPAC insulator failures and arc flash; Regulator required arc/flash study – tables prepared for field staff

- Required to wear arc face shield plus safety glasses, work shirt and leather gloves (shirt provides 8 cal/cm^2 protection)

26 kV & below

Phase to Phase Fault Current (amps)	Distance to Insulator with No Arc Flash Protection (inches)	Distance to Insulator with Arc Flash Protection (inches)	Phase to Phase Fault Current (amps)	Distance to Insulator with No Arc Flash Protection (inches)	Distance to Insulator with Arc Flash Protection (inches)	Phase to Phase Fault Current (amps)	Distance to Insulator with No Arc Flash Protection (inches)	Distance to Insulator with Arc Flash Protection (inches)	Phase to Phase Fault Current (amps)	Distance to Insulator with No Arc Flash Protection (inches)	Distance to Insulator with Arc Flash Protection (inches)
20000	97	33	14900	81	26	9800	62	18	4700	37	12
19900	97	33	14800	80	26	9700	61	18	4600	36	12
19800	96	33	14700	80	26	9600	61	18	4500	36	12
19700	96	33	14600	80	26	9500	61	18	4400	35	12
19600	96	33	14500	80	25	9400	60	18	4300	35	12
19500	95	32	14400	79	25	9300	60	18	4200	34	12

44 kV

Phase to Phase Fault Current (amps)	Distance to Insulator with No Arc Flash Protection (inches)	Distance to Insulator with Arc Flash Protection (inches)	Phase to Phase Fault Current (amps)	Distance to Insulator with No Arc Flash Protection (inches)	Distance to Insulator with Arc Flash Protection (inches)	Phase to Phase Fault Current (amps)	Distance to Insulator with No Arc Flash Protection (inches)	Distance to Insulator with Arc Flash Protection (inches)	Phase to Phase Fault Current (amps)	Distance to Insulator with No Arc Flash Protection (inches)	Distance to Insulator with Arc Flash Protection (inches)
20000	123	42	14900	103	34	9800	78	24	4700	48	24
19900	122	42	14800	102	34	9700	78	24	4600	47	24
19800	122	42	14700	102	34	9600	77	24	4500	46	24
19700	122	42	14600	101	34	9500	77	24	4400	45	24
19600	121	42	14500	101	33	9400	77	24	4300	44	24

Arc Energy Calculations, cont'd

- 2004 – initial arc/flash calculations in transformer stations

Preliminary Draft Hydro One Stations

Distance of Fault from Station	Voltage ph-ph/ ph-grd (kV)	Max Arcing Flt Current ph-grd (kA)	Assumed ph-grd Separation (mm)	Assumed Arc Length (mm)	Assumed Total Arcing Time (ms)	Incident Thermal Radiation (cal/cm2) Distance of Worker from Arc (meters) 1	2	3	4	5	6	7	8	9	10
At station	13.8/8	30	480	960	400	29.4	7.9	3.6	2.0	1.3	0.9				
At station	27.6/16	30	480	960	400	29.4	7.9	3.6	2.0	1.3	0.9				
At station	44/25	30	480	960	400	29.4	7.9	3.6	2.0	1.3	0.9				
At station	115/66	50	1100	1650	200	41.1	12.3	5.7	3.1	2.1	1.5	1.1	0.8		
At station	230/133	70	1800	2700	200	80.8	28.2	13.8	8.1	5.3	3.7	2.7	2.1	1.7	1.3
At station	500/289	70	4000	4000	200	90.1	35.6	18.6	11.3	7.5	5.3	3.9	3.1	2.4	2.0

Note that distances are distance from arc not distance from apparatus
1.2 cal/cm2 (for 1 sec based on Stoll Curve) is the NFPA assumed threshold for incident energy to cause second degree burn
Note assumptions made regarding arc length being longer than arc gap
Recommend consideration of worst case "reasonable" spacings and ph-ph available fault currents with corresponding ph-ph spacings

Arc Energy Calculations

- 2005 – carried out arc flash study of new 500 kV station; seven areas where arc energy was well over 40 cal/cm^2 (maximum 381 cal/cm^2)
- 2006/07 – initial work identified equipment of highest risk to be:
  - 600 V and 208/240 V panels in stations
  - Revenue metering – residential and commercial
- Initiated study to quantify arc energy using IEEE 1584 calculations and ArcPro software

Arc Energy Calculations

- Studies ongoing:
  - Residential revenue metering suggests 8 cal/cm^2 max
  - Commercial revenue metering – some over 40 cal/cm^2 (what approach should be used?)
  - 600 V station panels (some Category 3 & 4) (most work done de-energized)
  - 204/300 V station panels (many Category 3 & 4 for station service) (can work be done de-energized?)
  - Calculations for panels in buildings (governed by CSA Z462/NFPA 70E) (work on these systems often done by external contractors – how do we share the information?)

Challenges

- Funding priorities – not a blank cheque for analysis
- Reconfiguring existing stations (lower arc/flash energy) – now or end of life
- Complex issue for Utilities - working de-energized not always possible (customer demands, just in time delivery plants, supply through switching not always available)
- Regulatory requirements regarding reliability – system must meet specific guidelines or company penalized
- Communicating information to employees as it develops – making it readily accessible at worker level (how should this be done?)

Future Direction

- Design new stations so that arc hazard is close to zero (“safety by design”)
- Generic solution for stations – change fusing and/or breaker settings (determine station by station)
- Study arc/flash protection through:
  - Alternate fusing, relay settings
  - Interlock switch on switchgear to automatically change relay to a low setting
  - Dedicated arc/flash protection system using fibre optic light sensors to detect hazard and initiate fast tripping
  - IEC 61850 GOOSE used to transmit the arc/flash protection trip to the substation network (normal OC relay coordination bypassed to clear fault within 5 or 6 cycles)

Utility Approaches to Arc/Flash

- What approaches are used for arc/flash:
  - Category 2 - does it include face shield with chin cup and balaclava?
  - Lines and forestry work? (use face shields, level of protection?)
  - Stations work? (use of flash suits?)
  - Training of workers on the issue?
  - Provision of PPE (uniforms, clothing, face shields, flash suits)?
  - Labelling of equipment for arc flash hazard?
  - Availability of arc energy information to workers (specific to equipment/tasks)?