EPR Use at High Voltages – Cost Justification

Rachel I. Mosier, P.E.
Northeast Utilities

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Experience with HV EPR Cable

- 2.6 circuit miles installed to date at 115-kV
- Class I – Discharge Resistant
- Excellent reliability – no failures in the 6 years of high voltage experience
- Cable warranty – free from defects in material and workmanship for the life of the installation.

Installation Execution

- We install the duct bank
- Manufacturer fabricates, delivers, installs, terminates, and tests the cable
  - 96 Porcelain and 12 Polymer outdoor terminations
  - 24 Single-Conductor Splices
  - After Installation Test – 240 kVDC for 15 minutes

Typical Installation Scenario

EPR or Alternate Insulation?

- Depends upon the ampacity required
  - 2000 kcmil conductor is currently maximum size for EPR-insulated cable
  - 90°C/130°C EPR insulation
- Reel lengths (no sheath required with EPR, therefore lower weight, longer pulls, and fewer vaults/splices)
  - 16.3 lbs/ft (lead sheath) vs. 10.7 lbs/ft (no sheath)
- Cost justification

Steps to Cost Justify

- Number of cables per phase
- Cost of losses
  - 89 TD 370-8 PWRD, “Loss Evaluation for Underground Transmission and Distribution Cable Systems”, Insulated Conductors Committee Task Group 7-39, Cost of Losses

    Task Group Members: J.A. Williams, Chairman, M.D. Buckweitz, R.R. Burghart, A. Ernst, D.E. Koonce, D.W. Purnhagen, and F.A. Teti

Current-Dependent Losses

- Conductor Ohmic Losses
  - $I^2 R_{ac}$ [W/ft/phase]
- Shield/Sheath Losses
  - Negligible, since we use single-point bonding

$$\text{Peak Ohmic Losses} = 3 \cdot (I^2 R_{ac}) \cdot \text{length [W]}$$

$$\text{Average Annual Ohmic Losses} = \text{Annual Loss Factor} \cdot \text{Peak Ohmic Losses [W]}$$

Non-Current Dependent Losses

- Dielectric Loss
  - $W_D = 2 \pi f C E_o^2 \tan\delta$ [W/ft/phase] ~OR~
  - $W_D = I_c E_o \tan\delta$ [W/ft/phase]
- Charging Current Loss
  - $W_{Ic} = \frac{1}{3} I_c^2 \, length^3 \, R_{ac}$ [W/phase]
    where $I_c = 2 \pi f C E_o$ [A/ft]

Total Non-Current Dependent Losses = $3 \cdot W_D \cdot length + 3 \cdot W_{Ic}$ [W]

Cost of Demand and Energy Losses

- Cost of Demand Losses = Demand Cost x Peak Ohmic Losses [$]
  - E.g., $1000/kW x Peak Ohmic Losses
- Cost of Energy Losses = Energy Cost x Average Annual Ohmic Losses x 8760 hrs/yr [$/yr]
  - E.g., $0.04/kWh x Avg Annual Ohmic Losses x 8760 hrs/yr

Present Worth of Cost of Losses

Present Worth of Cost of Losses =
Cost of Demand Losses +
(PWF x Cost of Energy Losses) [$]

where, for example, the Present Worth Factor (PWF) for a 10% carrying charge, 40 years = 9.779.

Example of Evaluation

	2000 kcmil copper - 800 mils insulation	
	Lead Shield/Sheath	Copper Tape Shield - No Sheath - EPR
Permittivity	2.3	2.6
Conductor Operating Temperatures	90°C/105°C	90°C/130°C
Ampacity - 1 cables per phase, 100% loss factor, single point bonded	1132 amps (normal)/ 1340 amps (12-hr emergency)	1056 amps (normal)/ 1524 amps (12-hr emergency)
Moisture Barrier?	Yes	No
Overall Diameter (inches)	3.892	3.77
Approximate Weight (lbs/ft)	16.3	10.7
Bending Radius	22 x OD	12 x OD

Example of Evaluation (cont'd)

	2000 kcmil copper - 800 mils insulation	
	Lead Shield/Sheath	Copper Tape Shield - No Sheath - EPR
D/d	1.96	1.98
Permittivity	2.3	2.6
Capacitance (F/ft)	5.78E-11	6.47E-11
Charging Current per Phase (A/ft)	0.0014	0.0016
Rac (ohms/ft) (based on 1056 amps)	8.15E-06	8.19E-06
Charging Current Losses per Phase (A/ft)	**5.68E-12**	**7.15E-12**
Tan Delta at 90°C	0.0003	0.0125
Dielectric Losses per Phase (W/ft)	**0.0288**	**1.3433**
Conductor and Shield/Sheath Losses (W/ft)	**9.082**	**9.128**

Example of Evaluation (cont'd)

	Difference in losses between cable with lower permittivity and EPR cable (kW)	Typical Costs		
		Cost of Demand Losses at $1000/kW	Cost of Energy Losses at $0.04/kWh ($/yr)	Present Worth Cost of Δ Losses (10% Carrying Charge over 40 Years)
1,000-ft job:	4	$4,081	$1,430	**$18,066**
2,640-ft job (1/2 mile):	11	$10,775	$3,776	**$47,696**
5,280-ft job (1 mile):	22	$21,550	$7,551	**$95,393**
7,920-ft job (1.5 miles):	32	$32,326	$11,327	**$143,095**
10,560-ft job (2 miles):	43	$43,104	$15,104	**$190,804**
13,200-ft job (2.5 miles):	54	$53,884	$18,881	**$238,521**
15,840-ft job (3 miles):	65	$64,666	$22,659	**$286,248**
18,480-ft job (3.5 miles):	75	$75,451	$26,438	**$333,989**
21,120-ft job (4 miles):	86	$86,240	$30,218	**$381,745**
23,760-ft job (4.5 miles):	97	$97,032	$34,000	**$429,518**
26,400-ft job (5 miles):	108	$107,829	$37,783	**$477,310**

Cost Justification

- To cost justify the use of EPR, the following condition needs to be met:

  Total Cost of Project using EPR + Present Worth Cost of **Δ** Losses ≤ Total Cost of Project using a Lower Permittivity Cable

  assumes all else equal (including reliability, warranty, etc.)