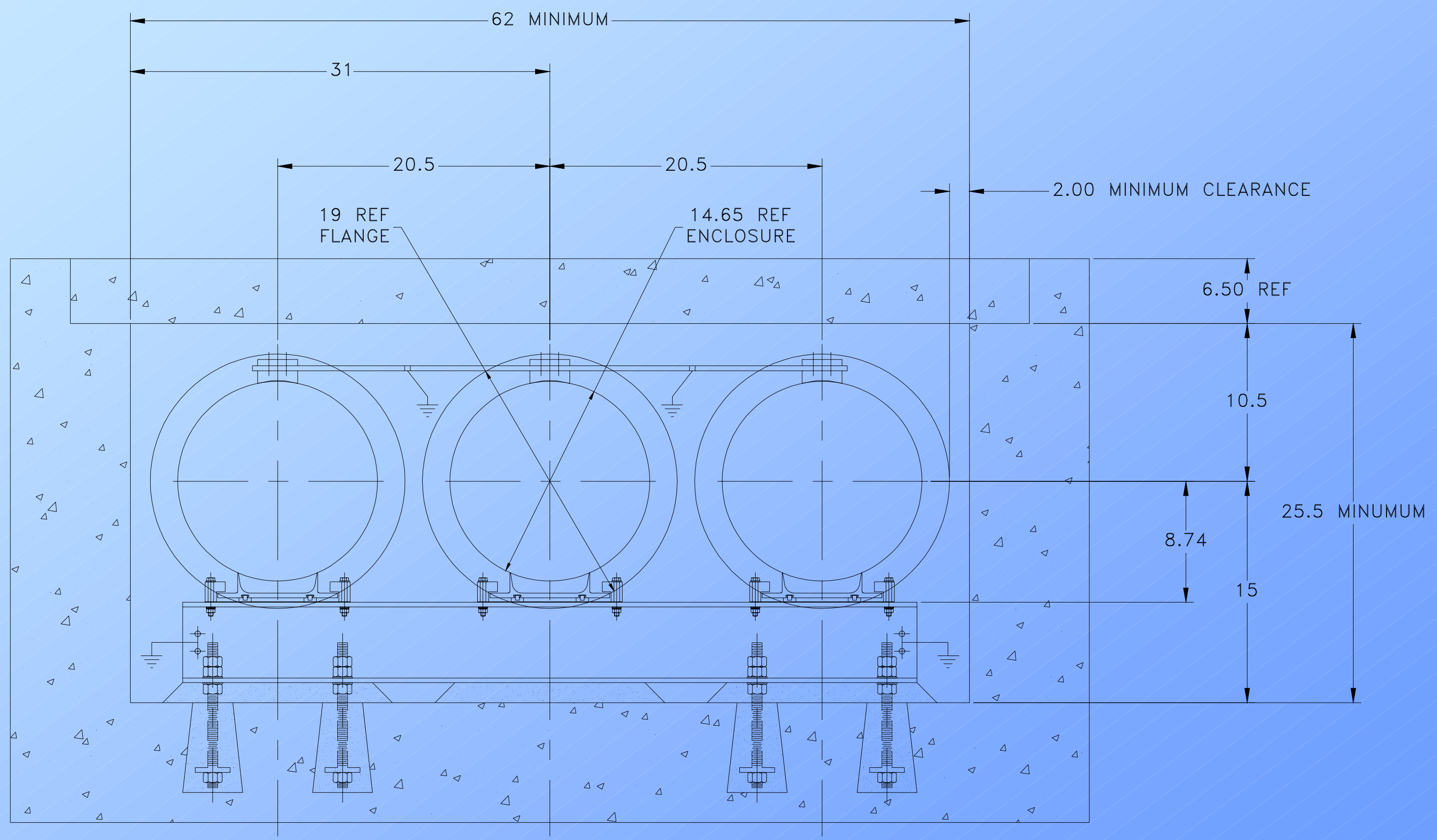
CGIT Bus Systems
Problem solving solutions

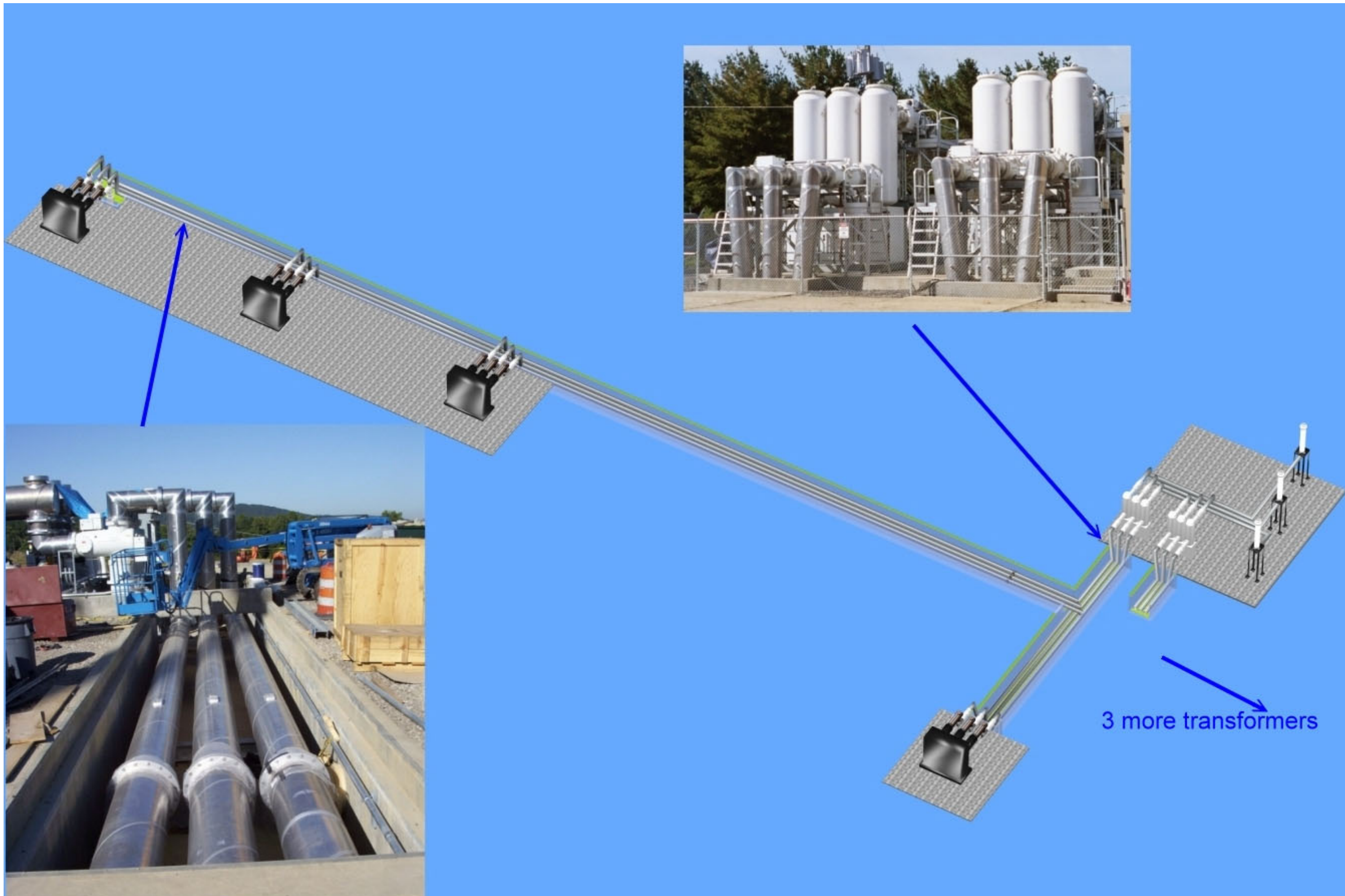
AZZ | CGIT™

362 kV Trench

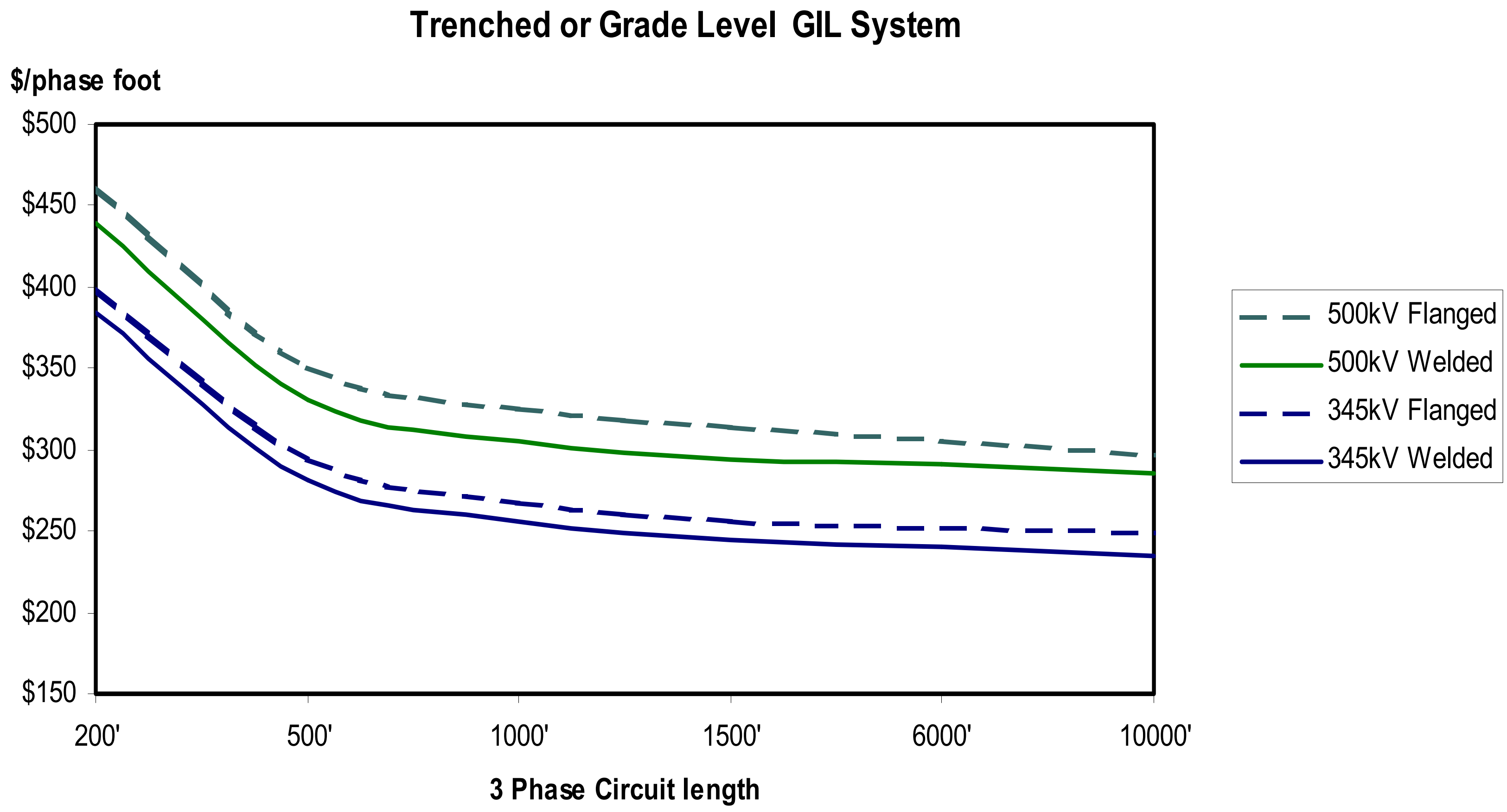


555 kV 8 unit IPP generation station. 7 of 8 xfmrs are 550 kV connected with GIL.
Very narrow area for running 550 kv so GIL is in a trench.

- o Picture shows ½ of the station there are 3 more transformers not shown.
- o very low profile. Surge arrestors are located in pits below ground to minimize height.
- o GIL in concrete covered trench
- o 550 kV 2000 amps



Equipment costs



Introduction to GIL
Cumulated Length of GIL World-wide

Ur ***kV***	***Cumulated length*** ***m***
1200	**420**
800	**1200**
550	**52.650**
420	**63.600**
362	**10.107**
242/300	**32.900**
72/145/172	**37.100**
73 to 1200	**198.000**

Excerpt from ROC report with CGIT Data Added

A summary of the major attributes of the HPFF and XLPF cable system types is provided in Table 1. The remaining sections of this document describe these items in more detail.

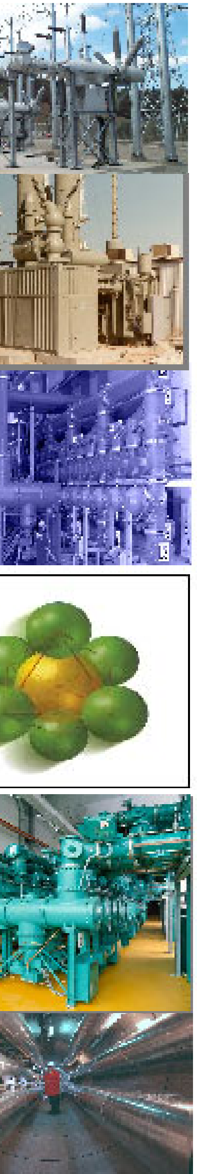
Table 1 – Summary Comparison, HPFF vs XLPE Cable System
15.5-mile Singer-Norwalk Line Used for Comparison*

Item	HPFF	XLPE	CGIT
SYSTEM CONSIDERATIONS			
Capacitance, microfarads/mile/phase	0.461 uf/mi/ph	0.269 uf/mi/ph	0.0854uf/mi/ph
Charging current, amperes/mile	34.6 A/mi	20.8 A/mi	6.41A/m
Reactive power, MVAR/mile	20.7 MVAR/mi	12.4 MVAR/mi	3.83MVAR/mi
MVA transfer, each line, typical conditions	633 MVA	825 MVA	2030MVA
MW transfer 15.5 mile line, all charging current flow from one end	546 MW	802 MW	
12-hr emergency rating, MVA each line, assuming preload current 70% of rating	1000 MVA	1140 MVA	2700MVA
12-hr emergency rating, MVA each line, assuming preload 70% of 633 MVA	1000 MVA	1190 MVA	
INSTALLATION CONSIDERATIONS			
Trench dimensions, width by Depth, inches (assuming 36 inches to top of envelope)	48"W x 64"D	46"W x 63"D	62"Wx32"D
Typical progression rate for pipe or duct, trench feet per day	200	200	>200
Ease of maneuvering around buried obstacles	Difficult	Difficult	Difficult
Typical vault spacings	2600 ft	1800 ft	
Number of vaults for a 15.5-mi line (XLPE can be reduced if 2 lines are in one vault)	32	96	
Typical time to make a 3-phase splice, working around the clock	7 days	7 days	1Hr
Splicing	Continuous	May be 15 10-hour shifts	
Number of manufacturers worldwide, meeting the Companies' prequalification requirements	3	4-6	
Substation Terminations	same	same	Simple Bushing
Pressurization plants required at termination	Yes	No	No
OPERATION AND MAINTENANCE			
Typical maintenance requirements, mandays/year (Rough estimate)	40	10	1
Time to locate an electrical fault	16-32 hours	16-32 hours	16-32
Expected cable damage in event of electrical fault	Large	Small	Small
Able to work on a failed circuit with companion in service?	Yes	Possibly	yes
Time to locate a fluid leak	2 hrs – 2 + weeks	N/A	1Hr or less
OPERATING EXPERIENCE			
Number of years operating history, 300 kV and higher	40 yrs	7 yrs	30 yrs
Approximate total number of circuit miles in service, 300 kV and higher	400 mi est	100 mi est	~40 mi
Expected forced outage rate, two 15.5-mile lines, outages in 40 years.	6	20	71 yearsMTTF/1km
Expected outage duration, repair failed cable	30 days	21 days	5-6 days
ENVIRONMENTAL CONSIDERATIONS			
Magnetic field for 15GW case MVA/line, 1m height, max level	3.3 mG	28 MG	~5 micro T
Magnetic field for 15 GW case, 1 m height, 25-ft from trench centerline	0.23 mG	7 mG	~0.7 microT
Dielectric fluid, 15.5-mile line, two cable pipes and two return pipes	440,000 gal	N/A	SF6

*The parameters listed in this table are for the same cable sizes as proposed in the M-N application, i.e., 2,500 kcmil copper HPFF cable and 3,000 kcmil copper XLPE cable.

Introduction to GIL
300 kV Tunnel Installation

Systemlength 1 km – Palexpo, Swiss
Undergound Part of a GIL / Overhead Line



Introduction to GIL
Cumulated Length of GIL World-wide

Ur *kV*	*Cumulated length* *m*
1200	**420**
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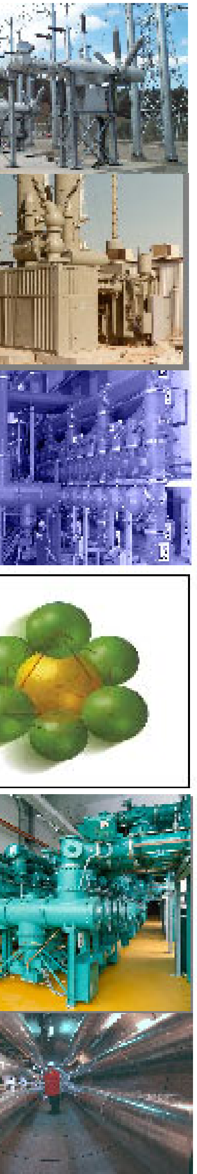


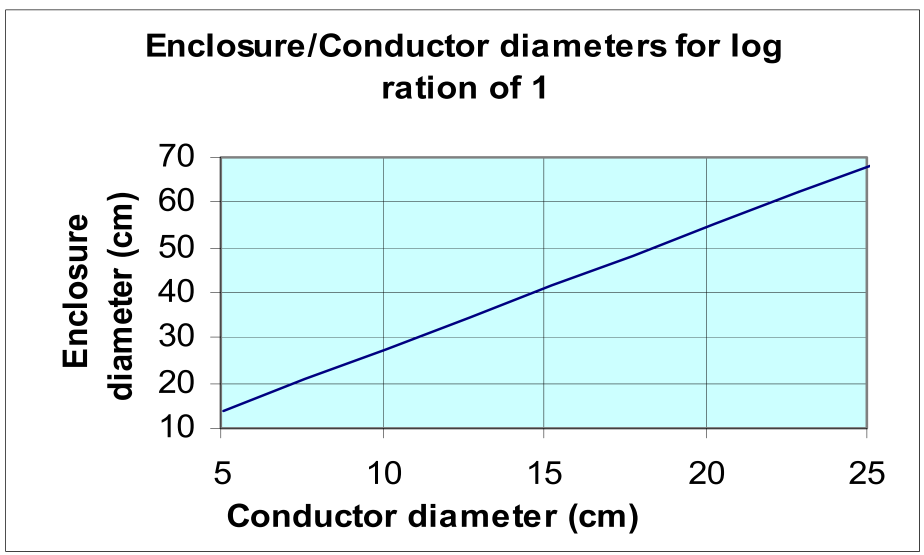
Design Features of GIL
Basics

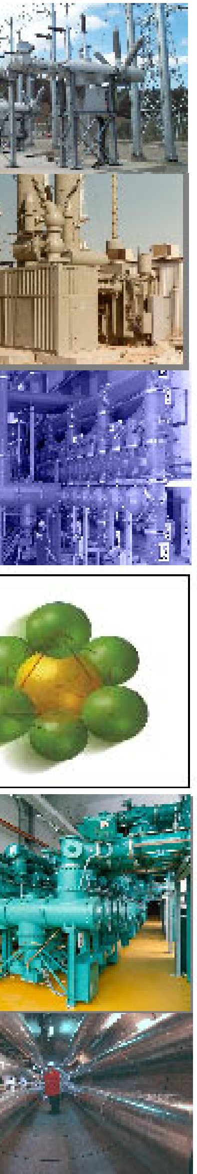
- The dielectric design of GIL is based on a simple formula. The electrical stress (E) at any given radial point (r) in the system is determined by:

$$E = \frac{U}{rIn(r_2 / r_1)}$$

Where U is the applied voltage, r2 and r1 are the enclosure and conductor radii respectively.

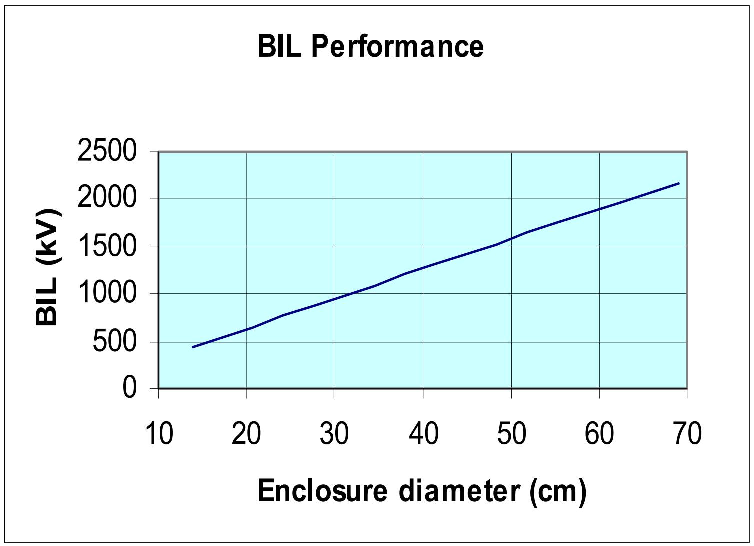
- The most economical use of materials occurs when $In(r_2/r_1) = 1$

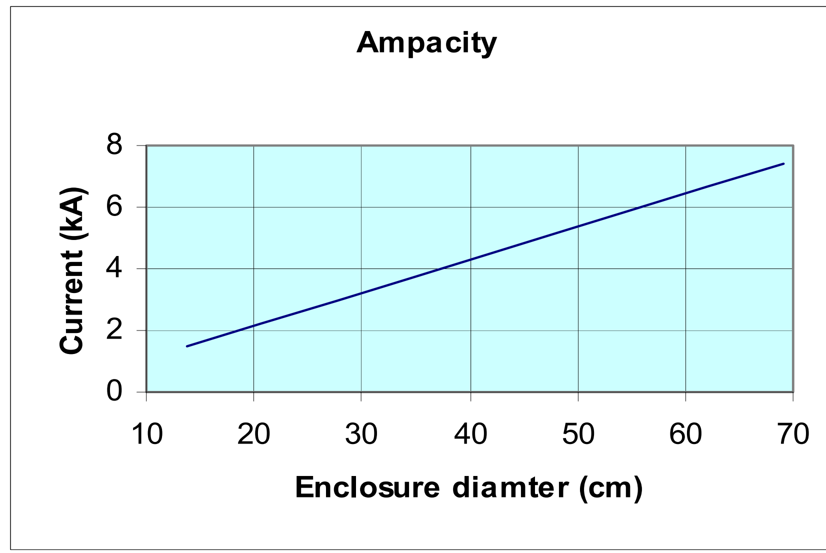




Design Features of GIL
Dimensions and Current Carrying Capacity

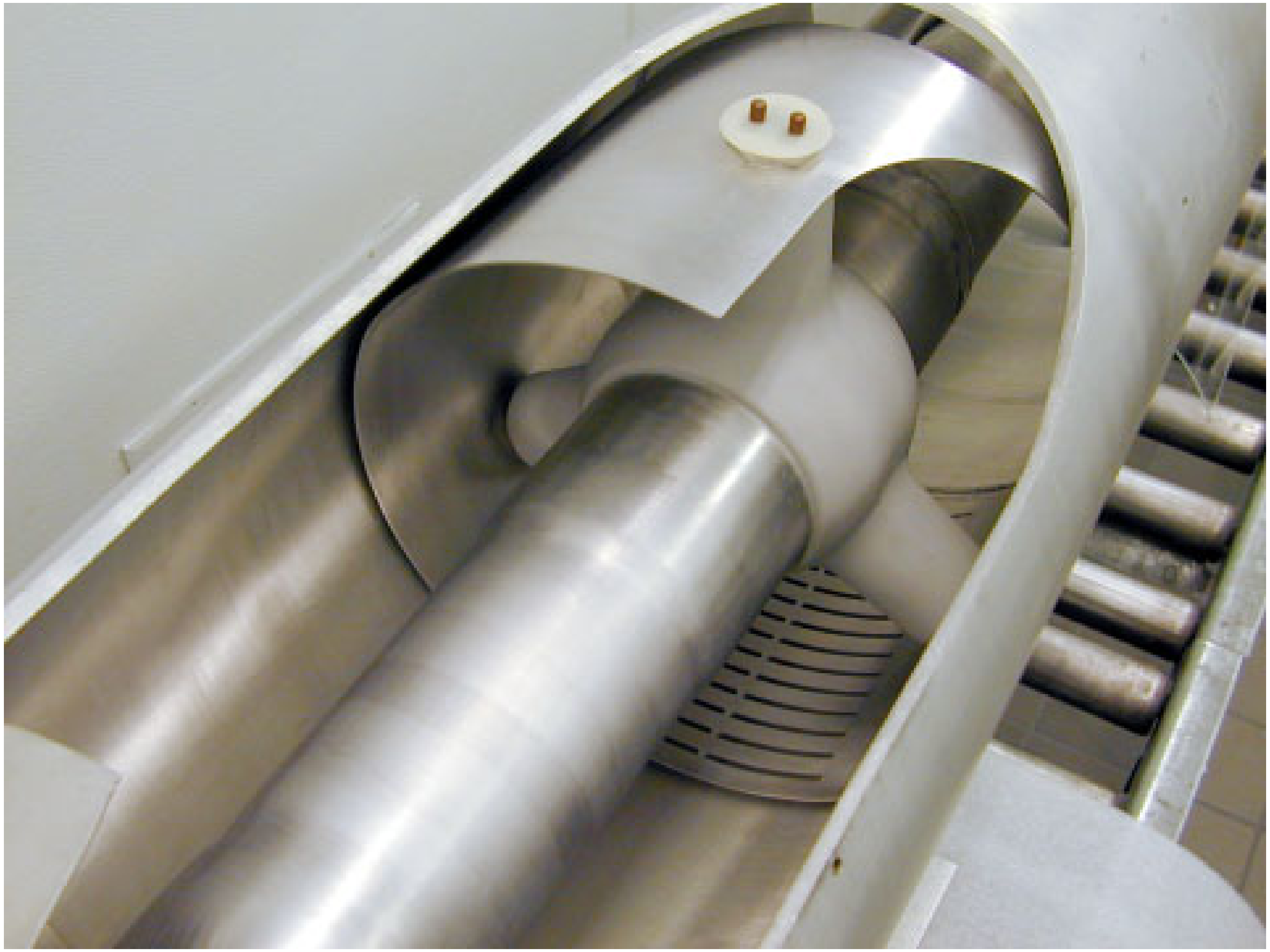
- Conductor stress is higher than the enclosure stress.
- Therefore negative impulse voltage (BIL) determines the system size.
- Properties of the materials used will determine ampacity.

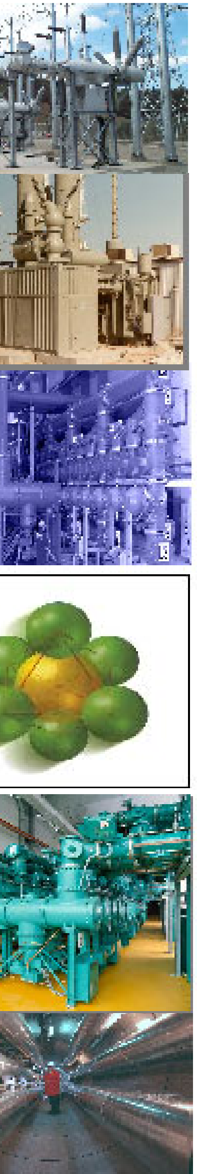




(Curves are shown for 4 atmospheres SF_6. Other gas densities or mixtures of SF_6/N_2 will give different results)

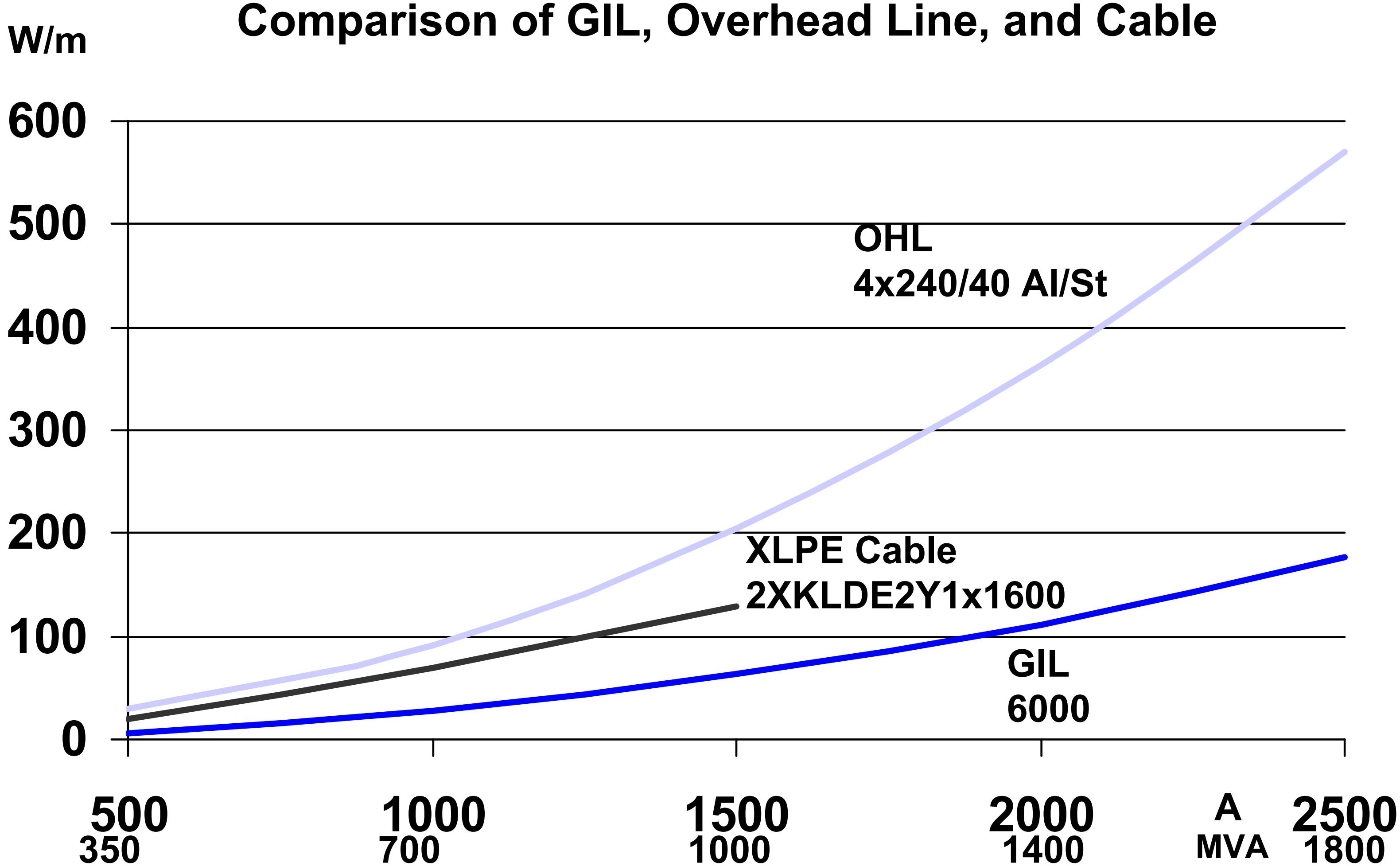
Design Features of GIL
GIS Tri-Post Support Insulator (Particle Trap)





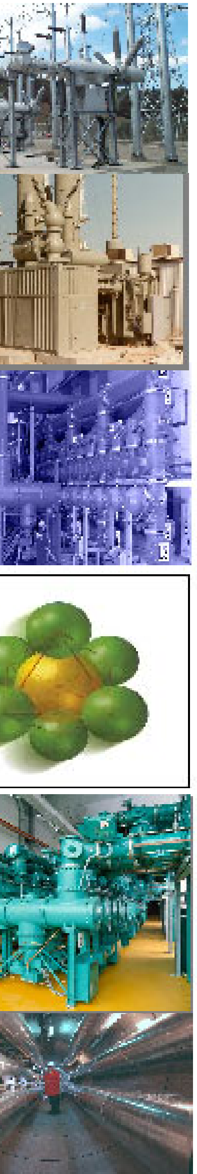
Design Features of GIL
Transmission Losses

Comparison of GIL, Overhead Line, and Cable



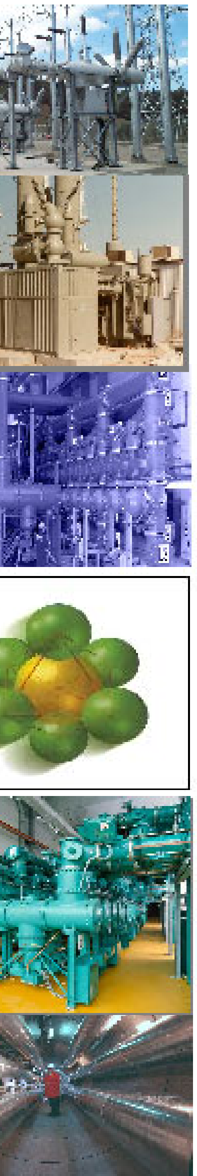
Design Features of GIL
Transmission Losses

Comparison of Overhead Line (OHL) with GIL
Cost of Losses



		OHL	GIL
Transmission power	**MW**	**1400**	**1400**
Losses per system meter	**W/m**	**580**	**180**
Losses per 32 system kilometer (20 miles)	**MW**	**18.56**	**5.76**
Difference between GIL and OHL	**MW**	**Δ 12.80**	
Additional Losses of the OHL per year	**USD**	**10,908,000.-**	

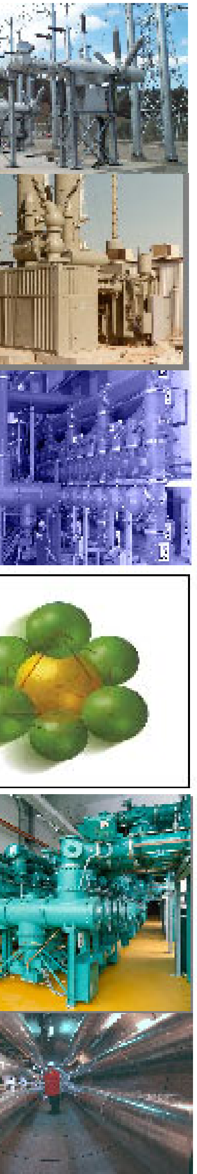
(Energy cost: $0.10/kWh x 8,600 h x 12,800 kW)



Design Features of GIL
Transmission Losses

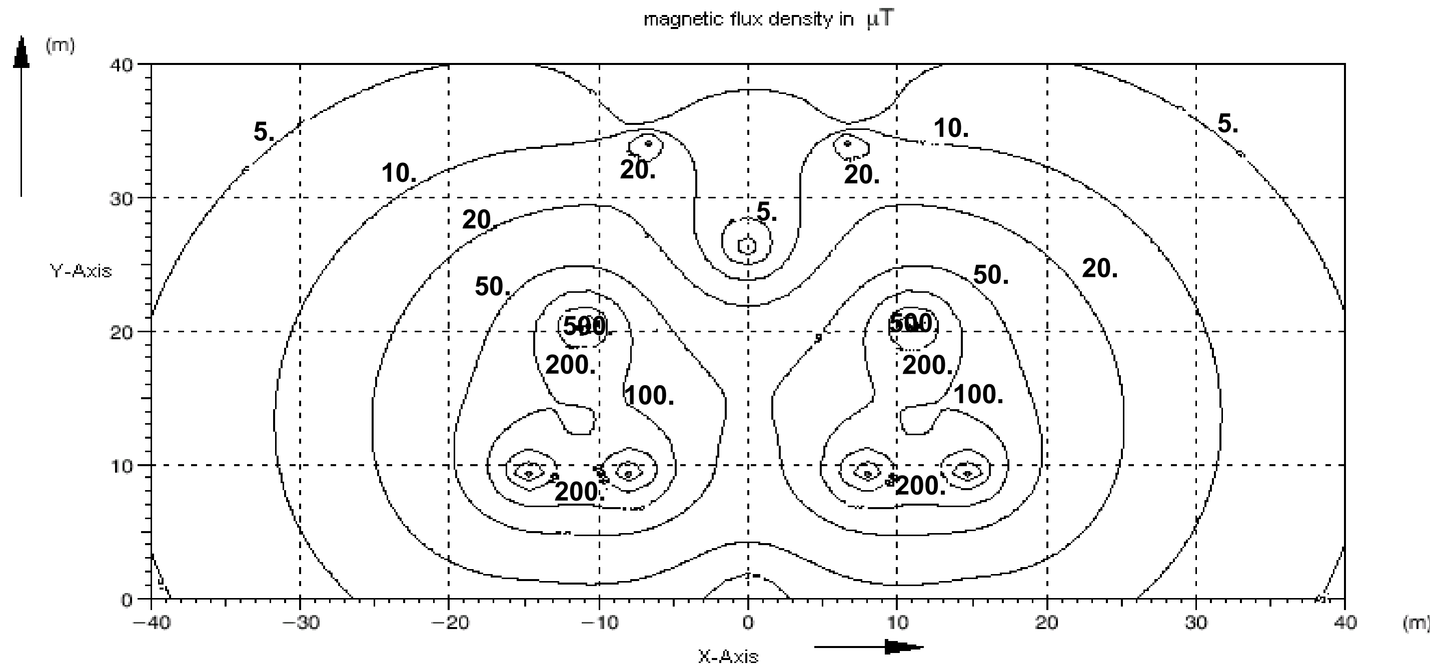
Technical Data of 420 kV Overhead Line (OHL) and GIL

		OHL	GIL
Cross section	mm^2	4x 240	2x 564
Conductor diameter	mm	4x21,9	2x32,9
Ohmic resistance R‘ at 20°C	W /km	0,031	0,027
Inductive resistance X_1‘ at 50 Hz	W /km	0,26	0,30
Capacity per unit length C_1‘	nF/km	14,4	12,1
Earth capacity C_O‘	nF/km	6,5	5,7
Capacitive load Q_C‘	kvar/km	650	550
Surge impedance Z_1	W	240	280
Natural power	MW	600	515
Thermal power limit	MVA	1700	1380

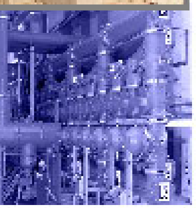


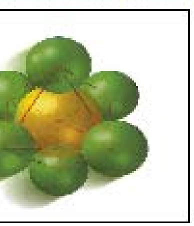
Design Features of GIL
Low electromagnetic fields

- Rated Current: 3150 A
  Magnetic Flux Density Calculated for OHL



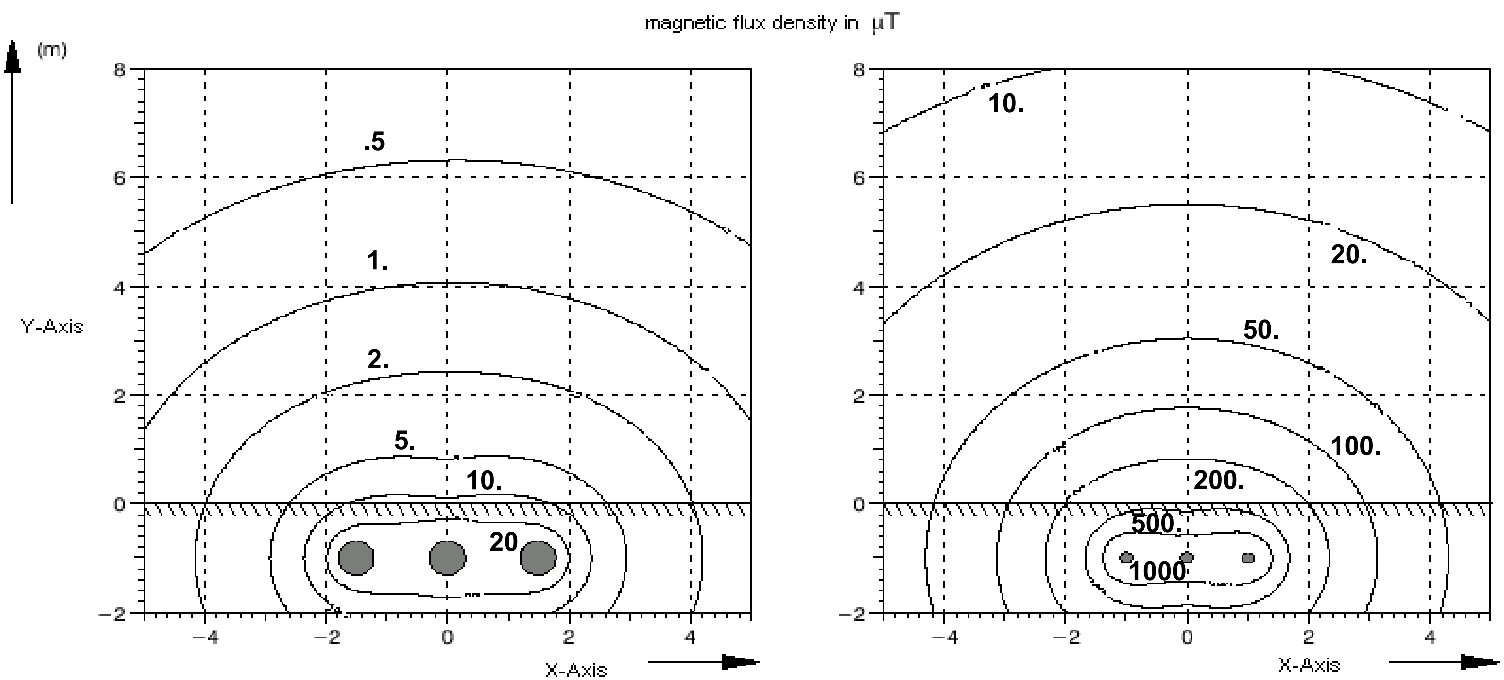
400 - kV - overheadline (Donau - tower with two earth wires)
magnetic flux density between two towers at a rated current of 3150 A (2 x 1575)



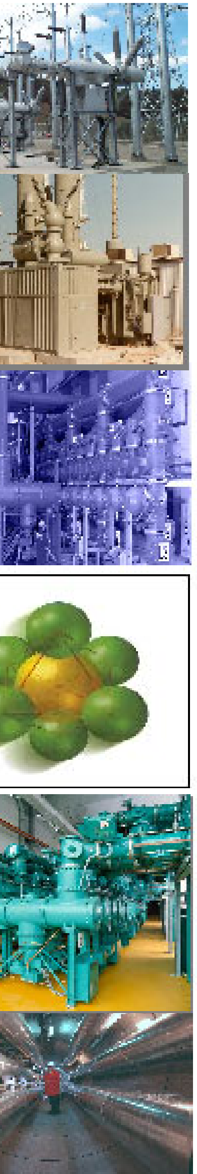


Design Features of GIL
Low electromagnetic fields

- Rated Current: 2500 A
  Magnetic Flux Density Calculated GIL and Cable

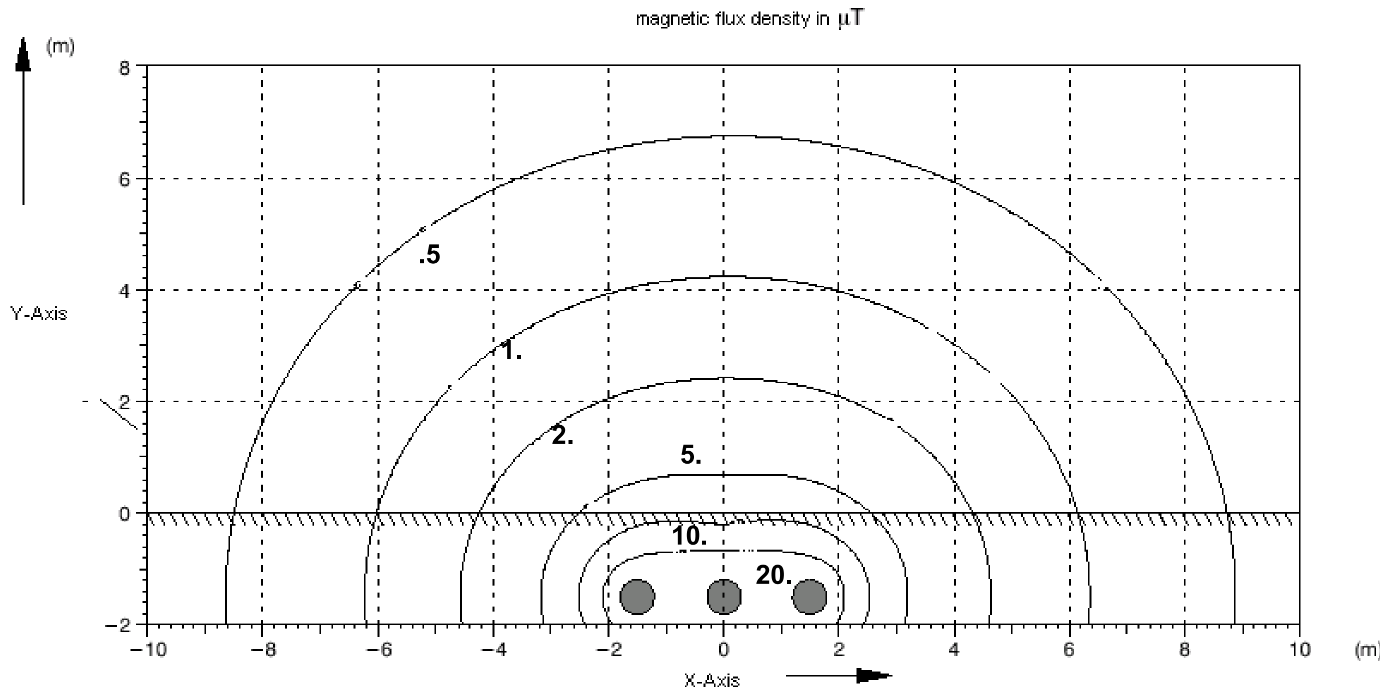


400 - kV - GIL compared to 400 kV - cable (cross-bonding)
magnetic flux density at a rated current of 2500 A



Design Features of GIL
Low electromagnetic fields

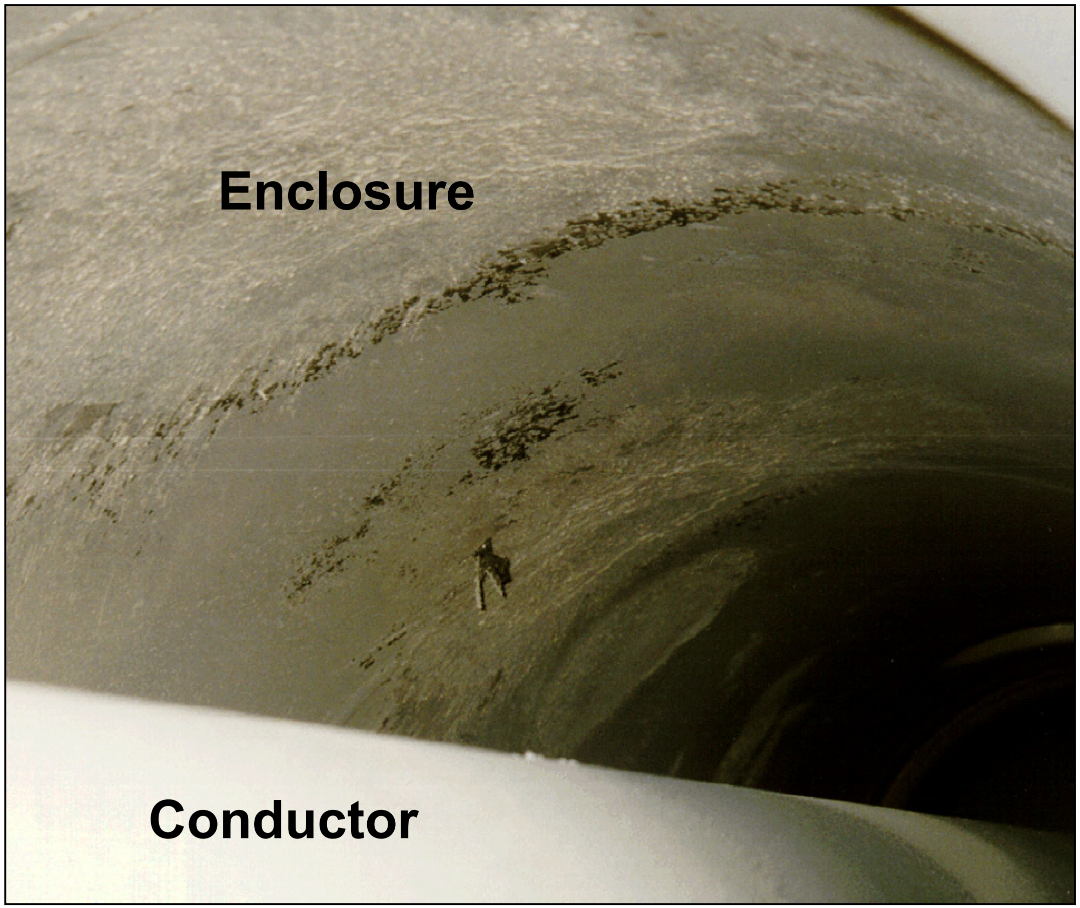
- Rated Current: 3150 A
  Magnetic Flux Density Calculated GIL



400 - kV - GIL
magnetic flux density at a rated current of 3150 A

Design Features of GIL
No external impact due to internal failure

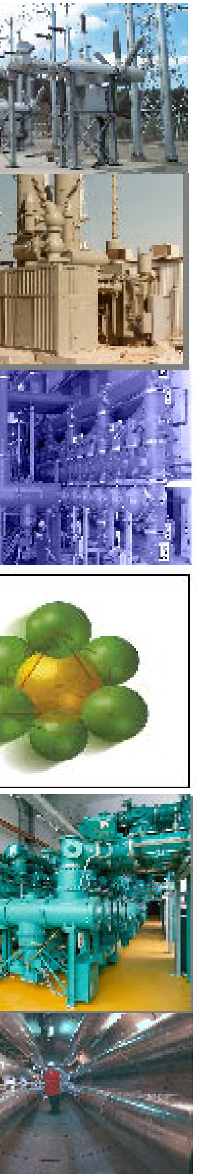
View inside the GIL. Test Conditions: 63 kA, 500 ms



No external impact

Low pressure increase

Operation as an overhea
line possible, because no
safety risk



Installation and Commissioning
Sequences of Erection

Contact System Connection

Corrosion protection on enclosure. Note no special protection from dirt trench or weather conditions during assembly.

Installation and Commissioning Sequences of Erection

Flange Connection

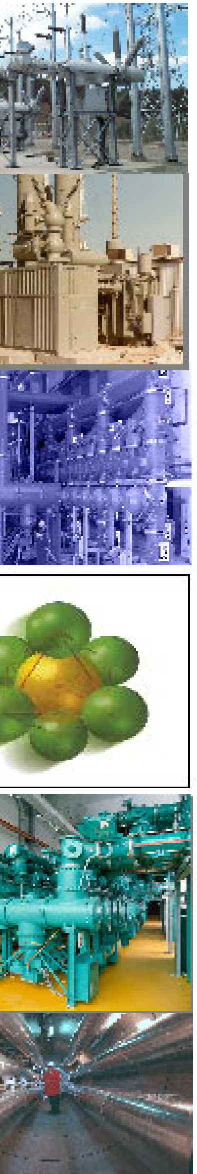
- No special tools required
- No extensive protection from weather or dirt required
- Assembly is complete in about 15 minutes

Installation and Commissioning
Civil Works

Flange Connection of 18 m Sections erected on Concrete Bases

Monitoring
Gas Monitor, Fill Valve and Cross Bonding

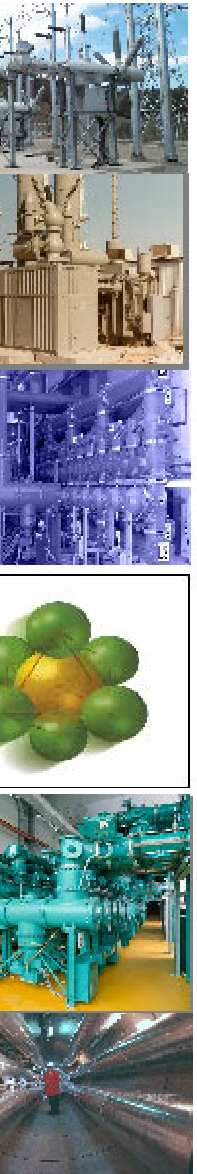
In Brief



- More than 25 years of GIL experience world wide, without any major failure and an easy to operate GIL system, the GIL combines technical advantages with low operation and life cycle costs and is also in service as transmission lines.

- The GIL brings the Power directly to the load centres of metropolitan areas, crosses mountains in tunnels and can be used in traffic tunnels, too.

GIL is reality !
It is the future of high power, long distance transmission systems directly buried or laid in energy or traffic tunnels.



Explosion of a XLPE Cable After Internal Failure

- 50 kA , 300ms
- After explosion, burning of insulation material with toxic gases
- Damage of adjacent phases and tunnel
- Life risk
-

Explosion of Oil Cable

14,1 kA, 1,2 s

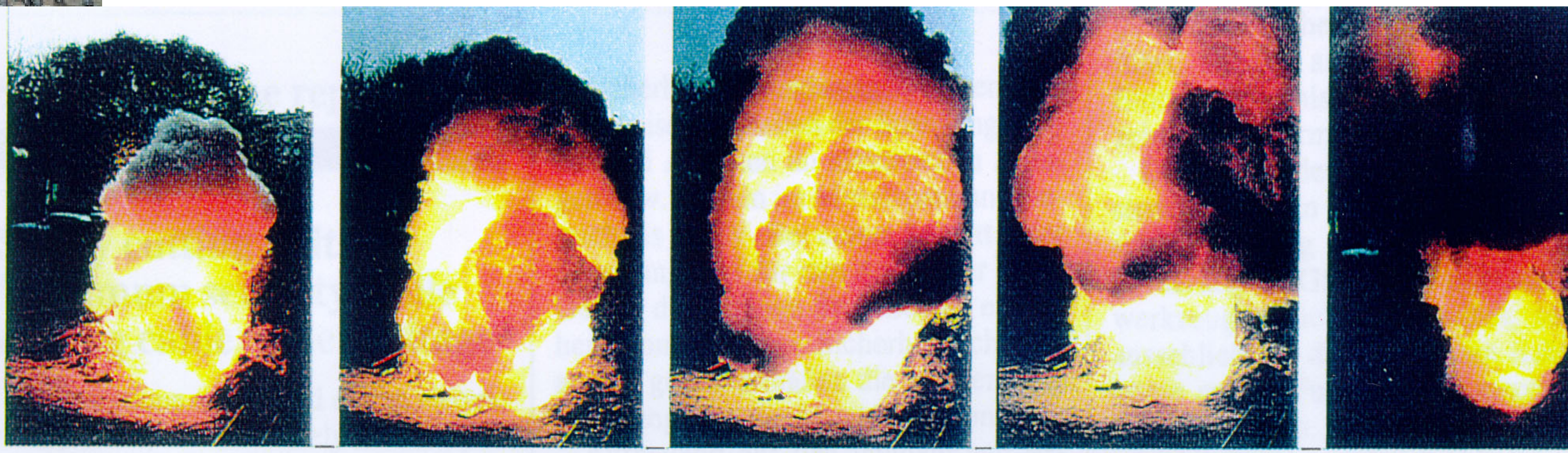


Bild 3. Entwicklung eines Lichtbogens, beginnend mit der Zündung (links) bis zum Erlöschen (rechts); Lichtbogenstrom 14,1 kA, Phasenspannung 5,2 kV, Lichtbogenzeit 1,2 s

- **(Published in "Elektrizitätswirtschaft" Jg. 97 (1998), Nr. 26)**

CGIT Westboro, Inc.

30 Oak Street
Westborough, MA 01581 USA
(508) 836-4000

TempCalc Version 1.0.6

Project: Trench GIL to match 2 cables at 825 MVA Each
Voltage Class: 362k V 2800 amps

Calculation Performed: Saturday, February, 12, 2005 02:56 PM

SF6 percentage = 100.00% at filling pressure of 480 kPa

```
In Air or Buried or Tunnel ................. Air
Grounding Style ............................ Cross Bonded

Current .................................... 2800 Amps (AC)
Frequency .................................. 60 Hz

Phase Spacing .............................. 22.00 inches

Conductor OD ............................... 5.000 inches
Conductor ID ............................... 4.000 inches
Conductor Wall ............................. .500 inches

Enclosure OD ............................... 14.642 inches
Enclosure ID ............................... 14.250 inches
Enclosure Wall ............................. .196 inches

Conductor Weight ........................... 8.23 lb/ft
Enclosure Weight ........................... 10.35 lb/ft
Total Weight ............................... 18.58 lb/ft

Surge Impedance ............................ 62.8 Ohms
Inductance ................................. .0638 mH/ft
Capacitance ................................ 16.168 pF/ft

Conductor Characteristics:
  R(DC) at 20°C ............................ 1.94 µOhm/ph-ft @ 20° C
  R(AC) .................................... 2.58 µOhm/ph-ft
  Losses ................................... 20.2 Watts/ph-ft
  Conductor Emissivity ..................... 0.29
  Conductor Conductivity ................... 59.5% IACS

Enclosure Characteristics:
  R(DC) at 20°C ............................ 2.62 µOhm/ph-ft @ 20° C
  R(AC) .................................... 2.87 µOhm/ph-ft
  Losses ................................... 22.5 Watts/ph-ft
  Enclosure Emissivity (Inside) ............ 0.29
  Enclosure Emissivity (Exterior) .......... 0.50
  Enclosure Conductivity ................... 35.0% IACS

Total R(DC) at 20°C ........................ 4.55 µOhm/ph-ft @ 20° C
Total R(AC) ................................ 5.45 µOhm/ph-ft
Total Losses ............................... 42.8 Watts/ph-ft

Actual Temperatures:
  Conductor ................................ 78.6 °C
  Enclosure ................................ 61.6 °C
  Ambient .................................. 40.0 °C
```

CGIT Westboro, Inc.
30 Oak Street
Westborough, MA 01581 USA
(508) 836-4000

TempCalc Version 1.0.6

Project: Trench bus 3400 amps`
Voltage Class: 362 kV

Calculation Performed: Saturday, February, 12, 2005   02:54 PM

SF6 percentage = 100.00% at filling pressure of 480 kPa

```
In Air or Buried or Tunnel ................. Air
Grounding Style ............................ Cross Bonded

Current .................................... 3400 Amps (AC)
Frequency .................................. 60 Hz

Phase Spacing .............................. 22.00 inches

Conductor OD ............................... 5.000 inches
Conductor ID ............................... 4.000 inches
Conductor Wall ............................. .500 inches

Enclosure OD ............................... 14.642 inches
Enclosure ID ............................... 14.250 inches
Enclosure Wall ............................. .196 inches

Conductor Weight ........................... 8.23 lb/ft
Enclosure Weight ........................... 10.35 lb/ft
Total Weight ............................... 18.58 lb/ft

Surge Impedance ............................ 62.8 Ohms
Inductance ................................. .0638 mH/ft
Capacitance ................................ 16.168 pF/ft

Conductor Characteristics:
  R(DC) at 20°C ............................ 1.94 µOhm/ph-ft @ 20° C
  R(AC) .................................... 2.69 µOhm/ph-ft
  Losses ................................... 31.1 Watts/ph-ft
  Conductor Emissivity ..................... 0.29
  Conductor Conductivity ................... 59.5% IACS

Enclosure Characteristics:
  R(DC) at 20°C ............................ 2.62 µOhm/ph-ft @ 20° C
  R(AC) .................................... 2.93 µOhm/ph-ft
  Losses ................................... 33.8 Watts/ph-ft
  Enclosure Emissivity (Inside) ............ 0.29
  Enclosure Emissivity (Exterior) .......... 0.50
  Enclosure Conductivity ................... 35.0% IACS

Total R(DC) at 20°C ........................ 4.55 µOhm/ph-ft @ 20° C
Total R(AC) ................................ 5.62 µOhm/ph-ft
Total Losses ............................... 65.0 Watts/ph-ft

Actual Temperatures:
  Conductor ................................ 94.5 °C
  Enclosure ................................ 70.7 °C
  Ambient .................................. 40.0 °C
```

CGIT Westboro, Inc.
30 Oak Street
Westborough, MA 01581 USA
(508) 836-4000

TempCalc Version 1.0.6

Project: 4000 amp 24 hour overload
Voltage Class: 362 kV

Calculation Performed: Saturday, February, 12, 2005   02:53 PM

SF6 percentage = 100.00% at filling pressure of 480 kPa

In Air or Buried or Tunnel .... Air
Grounding Style .... Cross Bonded

Current .... 4000 Amps (AC)
Frequency .... 60 Hz

Phase Spacing .... 22.00 inches

Conductor OD .... 5.000 inches
Conductor ID .... 4.000 inches
Conductor Wall .... .500 inches

Enclosure OD .... 14.642 inches
Enclosure ID .... 14.250 inches
Enclosure Wall .... .196 inches

Conductor Weight .... 8.23 lb/ft
Enclosure Weight .... 10.35 lb/ft
Total Weight .... 18.58 lb/ft

Surge Impedance .... 62.8 Ohms
Inductance .... .0638 mH/ft
Capacitance .... 16.168 pF/ft

Conductor Characteristics:
  R(DC) at 20°C .... 1.94 µOhm/ph-ft @ 20° C
  R(AC) .... 2.83 µOhm/ph-ft
  Losses .... 45.2 Watts/ph-ft
  Conductor Emissivity 0.29
  Conductor Conductivity .... 59.5% IACS

Enclosure Characteristics:
  R(DC) at 20°C .... 2.62 µOhm/ph-ft @ 20° C
  R(AC) .... 2.99 µOhm/ph-ft
  Losses .... 47.9 Watts/ph-ft
  Enclosure Emissivity (Inside) 0.29
  Enclosure Emissivity (Exterior) 0.50
  Enclosure Conductivity .... 35.0% IACS

Total R(DC) at 20°C .... 4.55 µOhm/ph-ft @ 20° C
Total R(AC) .... 5.82 µOhm/ph-ft
Total Losses .... 93.1 Watts/ph-ft

Actual Temperatures:
  Conductor .... 112.9 °C
  Enclosure .... 81.3 °C
  Ambient .... 40.0 °C