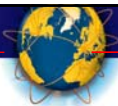

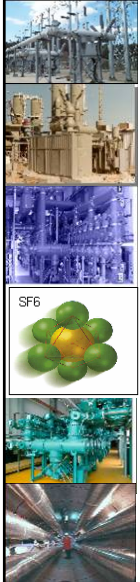



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IEEE

**Substations Committee
Subcommittee K0
Working Group K2
Module
Gas Insulated Transmission Line (GIL)
Basics**

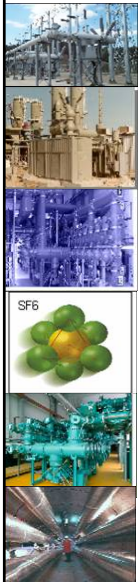
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**Contents
GIL Basics**

- A Introduction to GIL**
- B Design Features of GIL**
- C Development and Manufacturing**
- D Typical GIL Layout**
- E Testing**
- F Installation**









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Contents

GIL Basics

A Introduction to GIL

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Introduction to GIL

420 kV Above Ground Installation










Cumulated Length 17 km - PP9 Saudi Arabia
Longest 420 kV GIL Installed in the World

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Introduction to GIL 300 kV Tunnel Installation












System Length 1 km - Palexpo, Switzerland
Underground Part of a GIL/Overhead Line

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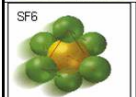


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Introduction to GIL GIL Units



Only 4 GIL units are needed to build a transmission line:

- Straight unit
- Angle unit
- Disconnecter unit
- Compensator unit




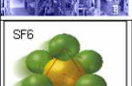









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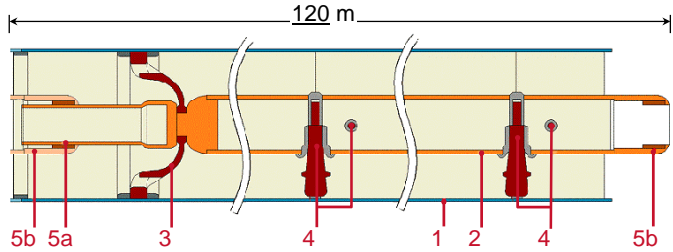



Introduction to GIL Straight Unit



- Typical length of 120 m
- Bending radius down to 400 m

- 1 enclosure
- 2 inner conductor
- 3 conical insulator
- 4 support insulator
- 5a male sliding contact
- 5b female sliding contact




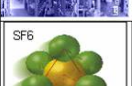




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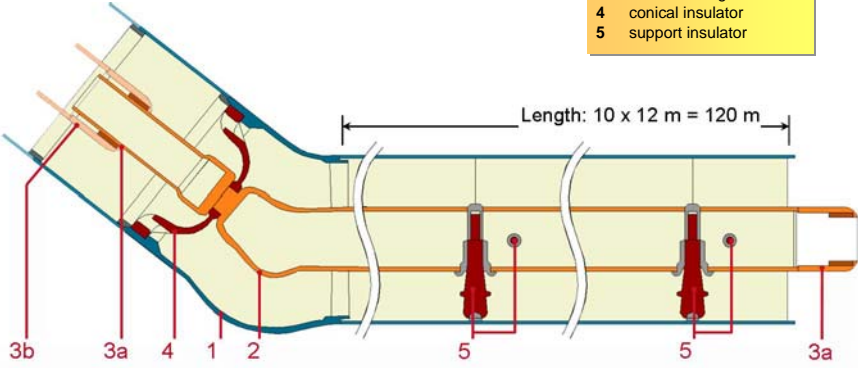



Introduction to GIL Angle Unit



- For directional changes
- Flexible angle from 4° to 90°

- 1 enclosure
- 2 inner conductor
- 3a male sliding contact
- 3b female sliding contact
- 4 conical insulator
- 5 support insulator

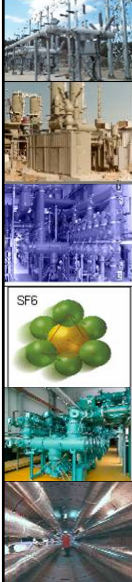


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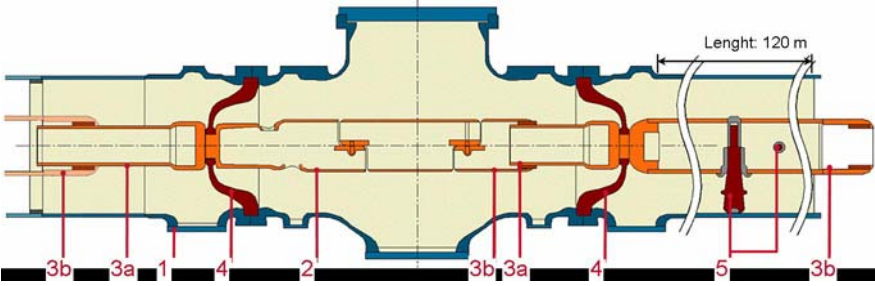
Introduction to GIL Disconnecter Unit



SF6



- Separation of gas compartments
- Connection point for sectional commissioning of the GIL
- Location of the decentralized monitoring units

- 1 enclosure
- 2 inner conductor
- 3a male sliding contact
- 3b female sliding contact
- 4 conical insulator
- 5 support insulator

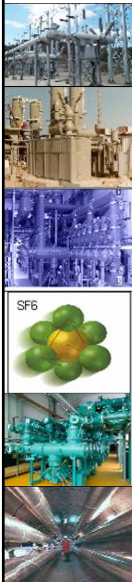


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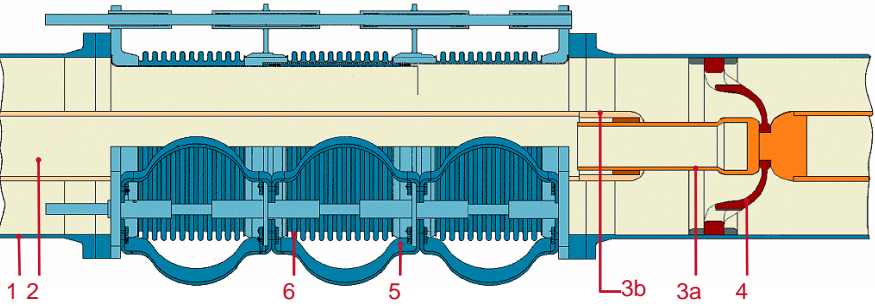
Introduction to GIL Compensation Unit




SF6

- Compensation for the thermal expansion of the enclosure
- Flexible connectors are leading the current


- 1 enclosure
- 2 inner conductor
- 3a male sliding contact
- 3b female sliding contact
- 4 conical insulator
- 5 flexible connector
- 6 compensator below









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Introduction to GIL

Advantages


- 30 years of experience with gas-insulated systems
- High reliability and high safety because of the metallic enclosure
- Low operating costs: resistive and capacitive
- Practically no ageing because of insulating gas
- Very low electromagnetic fields
- No external influence in the case of an internal failure (low fire risk)
- Operates like an overhead line, with autoreclosure







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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

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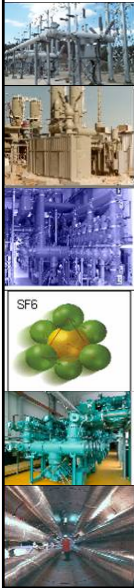
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Contents GIL Basics



B Design Features of GIL



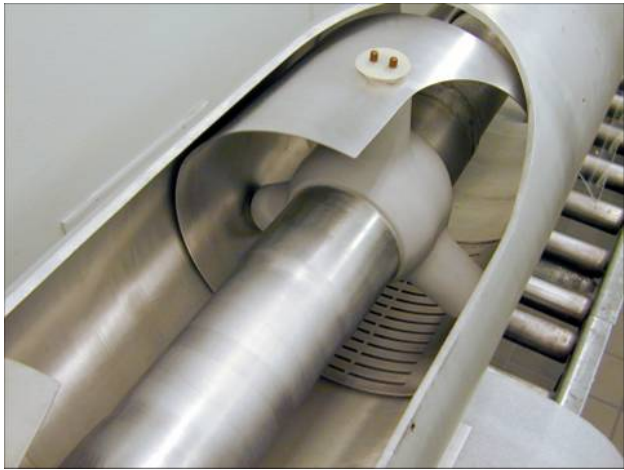
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Design Features of GIL GIS Tri-Post Support Insulator (Particle Trap)



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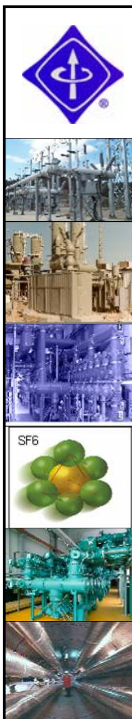


Design Features of GIL Four Examples

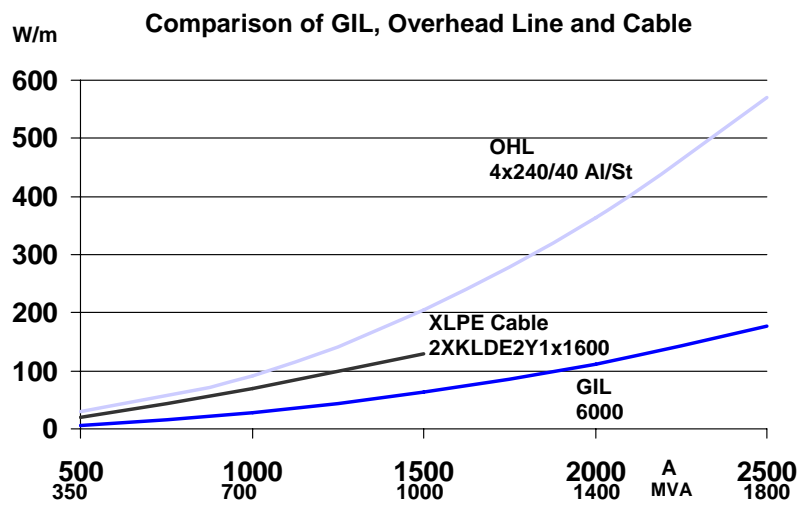
- **Low transmission losses and investment costs**
- Low electromagnetic fields
- High quality automated welding
- No external impact due to internal failure.

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Design Features of GIL Transmission Losses



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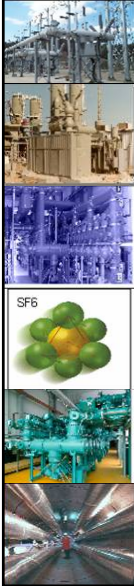
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Design Features of GIL Transmission Losses

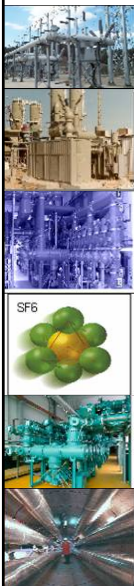
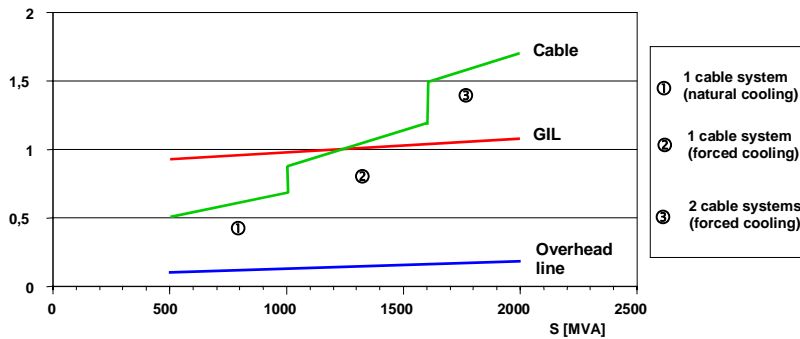
Comparison of Overhead Line (OHL) with GIL
Cost of Losses

		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)			



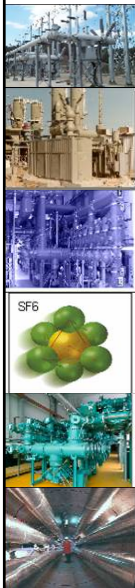
Design Features of GIL Cost Comparison of 420 kV Cable, OHL and GIL

Cost Factor





Design Features of GIL Example Two



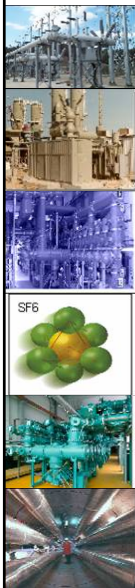
- Low transmission losses
- **Low electromagnetic fields**
- High quality automated welding
- No external impact due to internal failure

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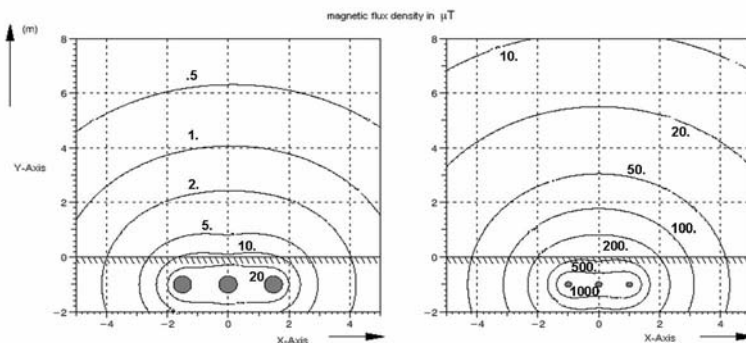
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Design Features of GIL Low Electromagnetic Fields



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



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Design Features of GIL Example Three



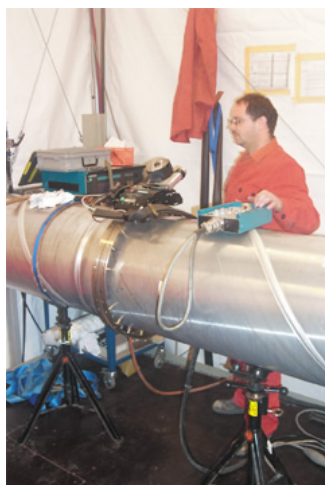
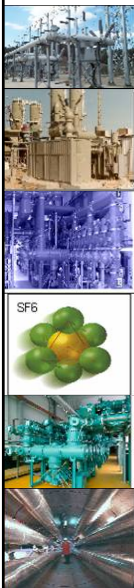
- Low transmission losses combined with low electromagnetic fields
- Low electromagnetic fields
- **High quality automated welding**
- No external impact due to internal failure

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Design Features of GIL High Quality Automated Welding

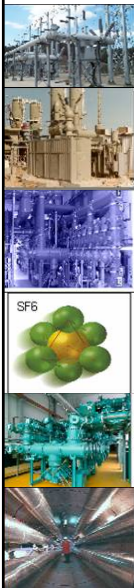


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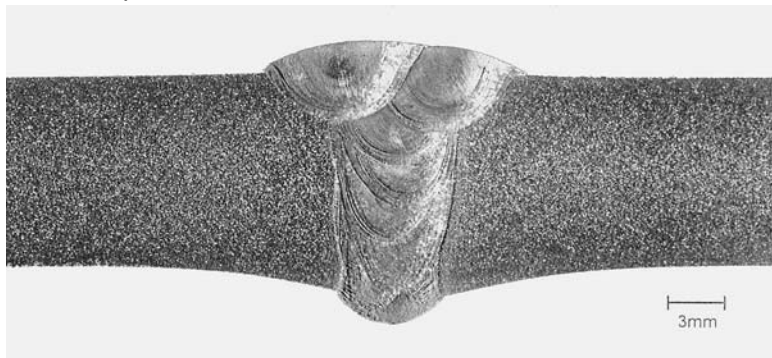
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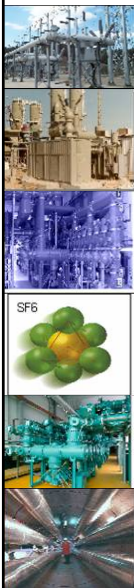
Design Features of GIL High Quality Automated Welding



Microscopic View of the Weld





Design Features of GIL Example Four

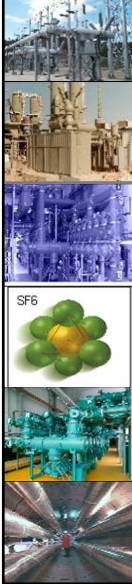


- Low transmission losses combined with low electromagnetic fields
- Low electromagnetic fields
- High quality automated welding
- **No external impact due to internal failure**

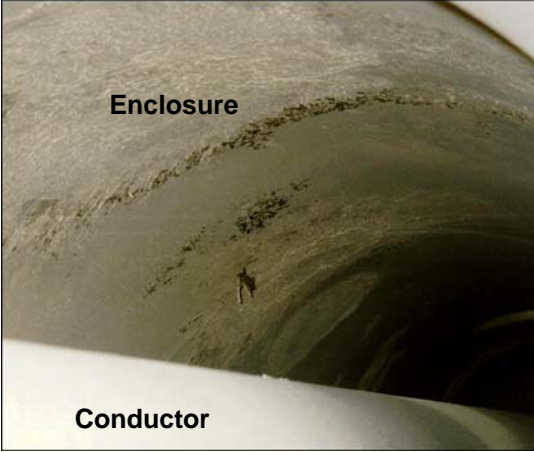
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Design Features of GIL No External Impact Due to Internal Failure





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



- No external impact
- Low pressure increase
- Operation similar to over head lines

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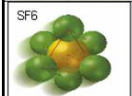


C Development and Manufacturing

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Development and Manufacturing Steps of Development

More than 40 years of experience in gas insulated technology



- 1960 : Start of fundamental studies in research and development of SF₆-technology
- 1968 : Delivery of first GIS
- 1974 : Delivery of first 420 kV GIL
- 1976 : Delivery of first Directly Buried GIL
- 1985 : Delivery of 550 KV and 8000 A High Power GIL
- 2001 : First Gasmixture GIL of 300 kV installed in Geneva, Switzerland
- 2007 : Delivery of first 800 kV, 4000 A GIL

more than 190 km in more than 100 projects installed world-wide




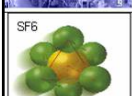


more than 5700 km-years of operation

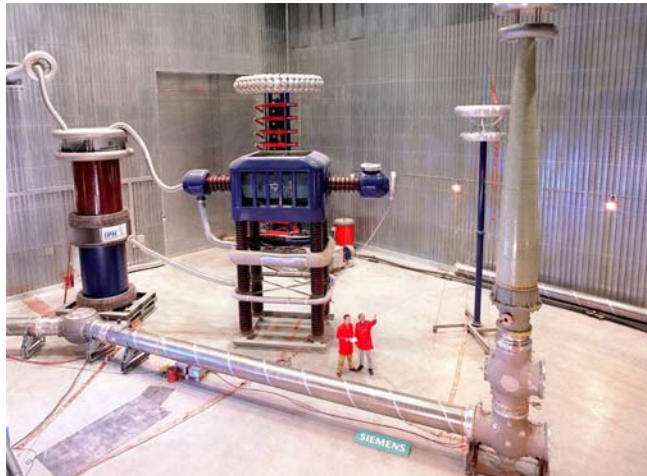
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Development and Manufacturing High Voltage Test – 420 kV/3150 A GIL




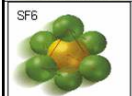





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Development and Manufacturing Short Circuit Current Test – 63 kA






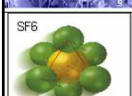


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Contents GIL Basics

D Typical GIL Layout

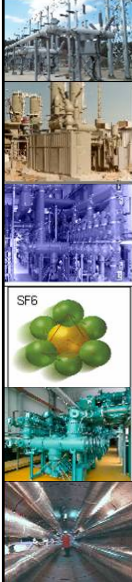







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Typical GIL Layout Arrangement in a Tunnel





SF₆



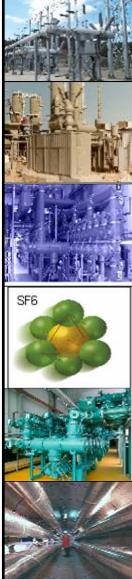
Two Three Phase Systems
 $U_N = 420/550 \text{ kV}$
 $I_N = 3150 \text{ A}$
Tunnel Diameter 3 m

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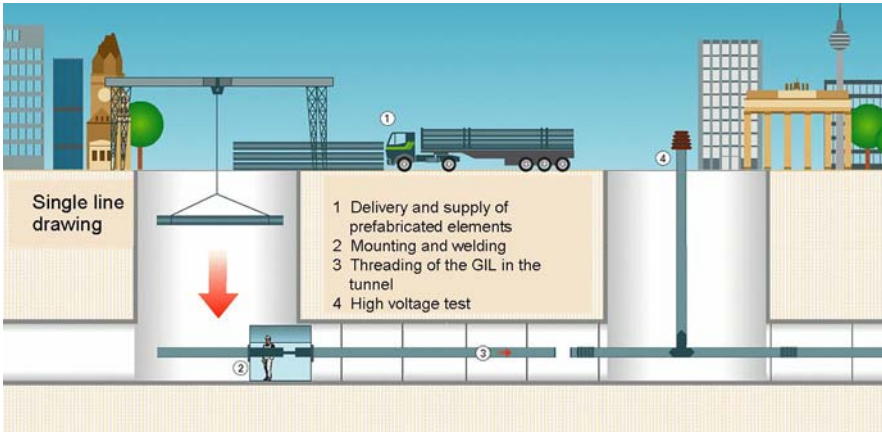
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Typical GIL Layout Principle Tunnel Laying Process





SF₆









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Typical Layout Directly Buried (3)










Orbital Welding and Backfill in the Trench

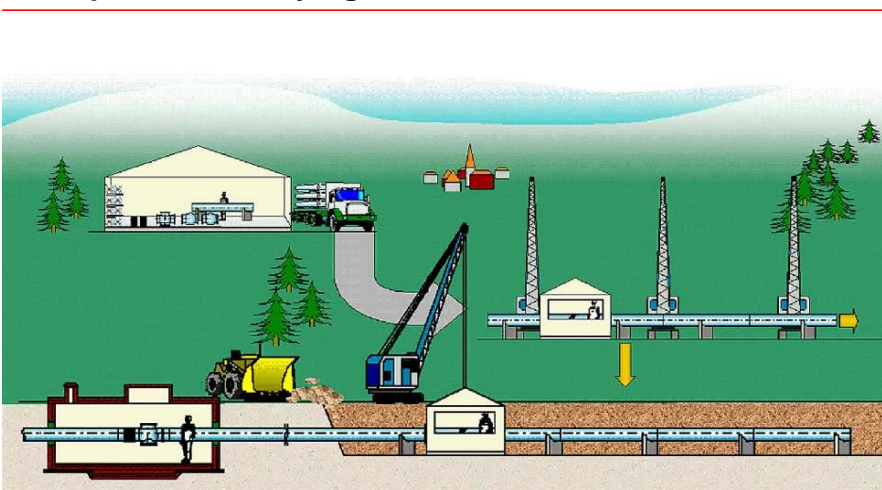



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Typical GIL Layout Principle Tunnel Laying Process



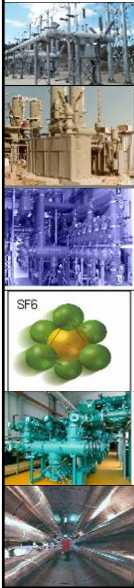
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E Testing



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Testing High Voltage Testing



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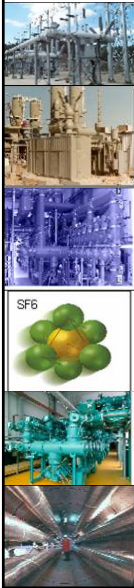
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Contents GIL Basics

F Installation



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Installation and Commissioning Shipping and Transportation

Delivery Transport Units



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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.

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Installation and Commissioning Sequences of Erection



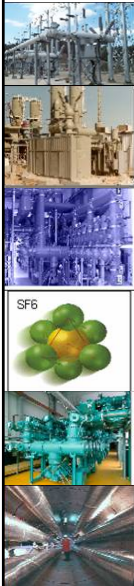

Shaft Welding Tent in the Tunnel



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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

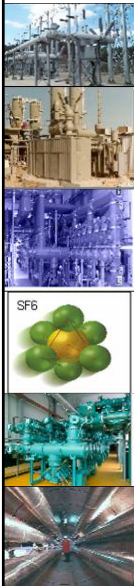


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Installation and Commissioning On-Site Testing



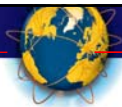
Variable Frequency High Voltage Test Set



Designed to test long lengths of GIL and short lengths of conventional cable.

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**Thank you for your attention
for
the GIL Basics Module.**