

Grid Connected

October 2018

# Gas-insulated transmission lines



# Our High Voltage Substations Solutions

SIEMENS

## Gas-Insulated Substations



## Air-Insulated Substations



## Gas-Insulated Switchgear GIS



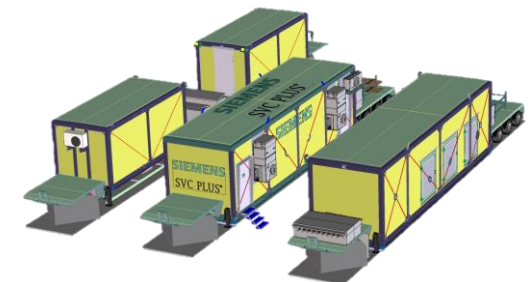
## Dead Tank Switchgear Bay



## FACTS Products STATCOM - SynCon



## FACTS Products STATCOM (Mobile)





# Siemens Gas-Insulated Switchgear Overview of Possible Applications

**GIS indoor**



**GIB (Gas-insulated busduct)**



**Subterranean GIS**



**GIS outdoor**



**GIL (Gas-insulated line)**



**GIS in special buildings**



**Extension / Retrofit / Refurbishment**



**E-House / Containerized GIS**



**Mobile GIS**







# Gas Insulated Transmission Lines (GIL) – A short overview

Cover Picture:  
Directly buried GIL installation  
420 kV AC  
Kelsterbach, Germany

# Reference Project

## Dominion Energy 245 kV GIB

### Project Details

Customer:	<i>Dominion Energy</i>
Location:	<i>Brambleton</i>
Installation type:	Tunnel and above ground Installation
Single phase length:	2.136ft
Date of operation:	2016
Max. power rating:	1273 MVA
Rated voltage:	245 kV
Rated current:	3000 A
Short time current:	63 kA, 3s
Rated impulse withstand voltage:	900 kV
Key buying factor:	Restricted space
Specific challenges:	Congested substation





# Reference Project

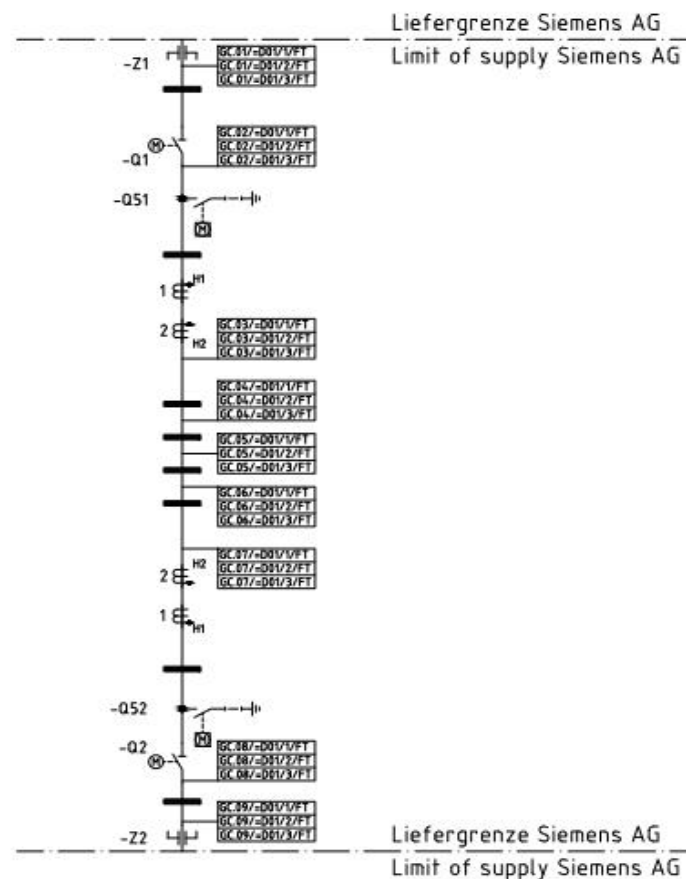
## Dominion Energy 245 kV GIB



# Reference Project

## Dominion Energy 245 kV GIB

Bay	Feld	=D01
Serial No.	Fabrik-Nr.	31 269 734

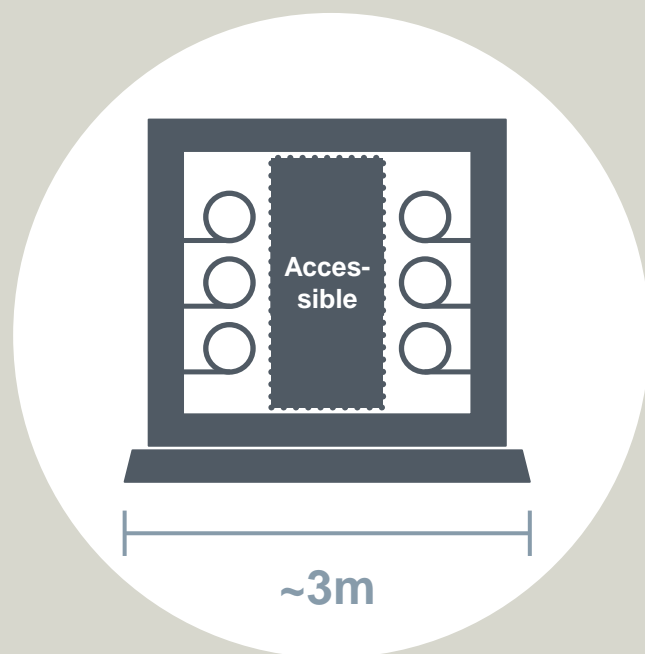


Rating	Bemessungsdaten	
Rated voltage	Bemessungs-Spannung	245 kV
Rated frequency	Bemessungs-Frequenz	60 Hz
Rated lightning impulse withstand voltage	Bemessungs-Stehblitzstoßspannung	900 kV
Rated short-duration power frequency withstand voltage	Bemessungs-Kurzzeit-Stehwechselspannung	460 kV
Rated switching impulse withstand voltage	Bemessungs-Stehschaltstoßspannung	--- kV
Rated normal current	Bemessungs-Betriebsstrom	3000 A
Rated shorttime withstand current	Bemessungs-Kurzzeitstrom	3 s 63 kA
Rated shortcircuit breaking current	Bemessungs-Kurzschlussausschaltstrom	63 kA
Rated supply voltage	Bemessungsversorgungsspannung	125 V DC
Rated supply voltage isolator/earthing switch	Bemessungsversorgungsspannung Trenner/Erder	125 V DC
Heater voltage	Heizspannung	240/120 V AC

Filling pressure (gauge pressure at 20°C)	Fülldruck (Überdruck bei 20°C)	kPa	psig
Disconnecter	Trennschalter	520	75.4
SF6-air bushing	SF6- Luft Durchführung	520	75.4
GIB / CT	GIB / CT	400	58.0

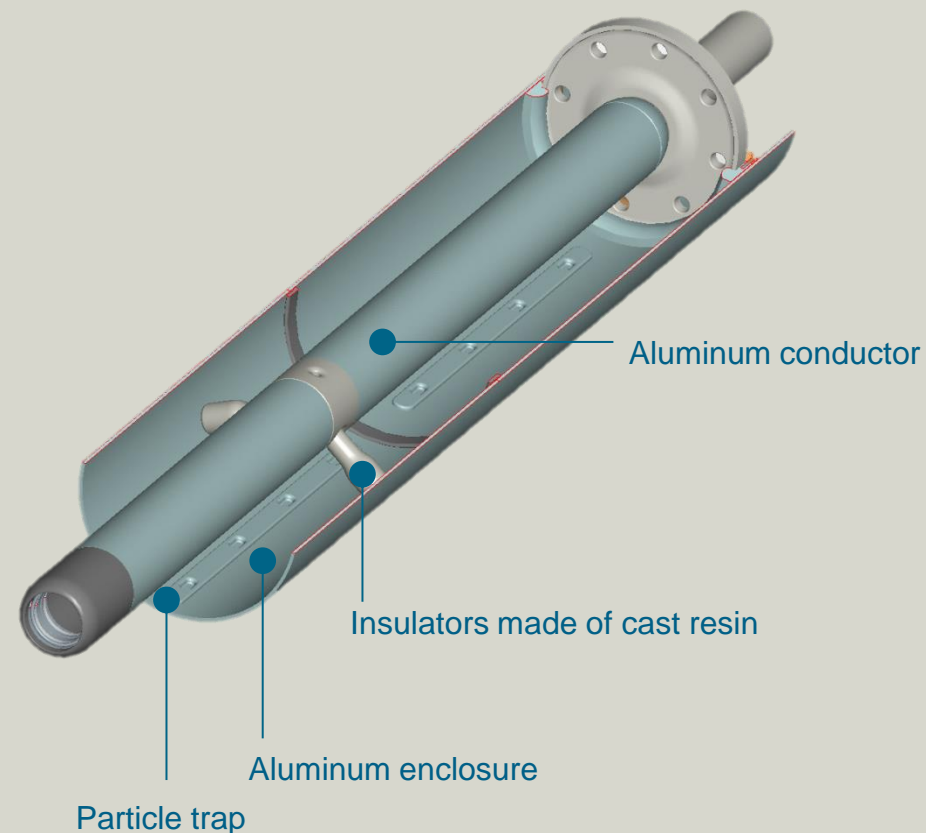
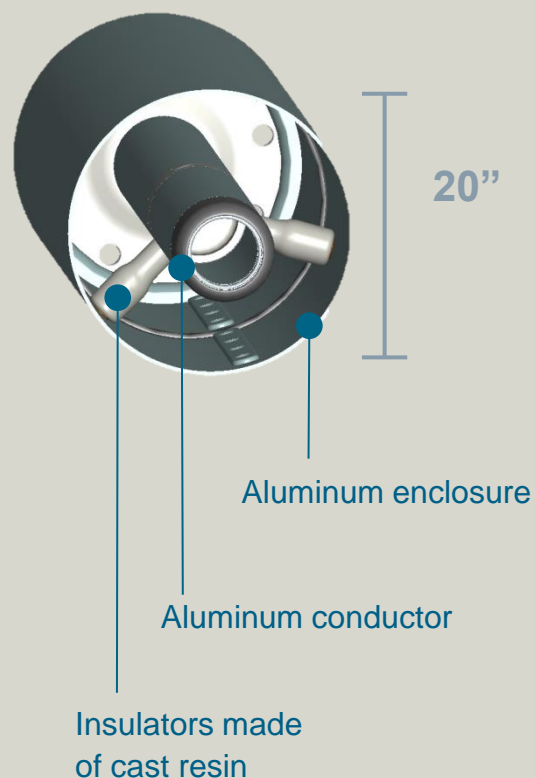
# Gas-insulated Transmission Lines as compact alternative for high power underground transmission

## Gas Insulated Lines (GIL)



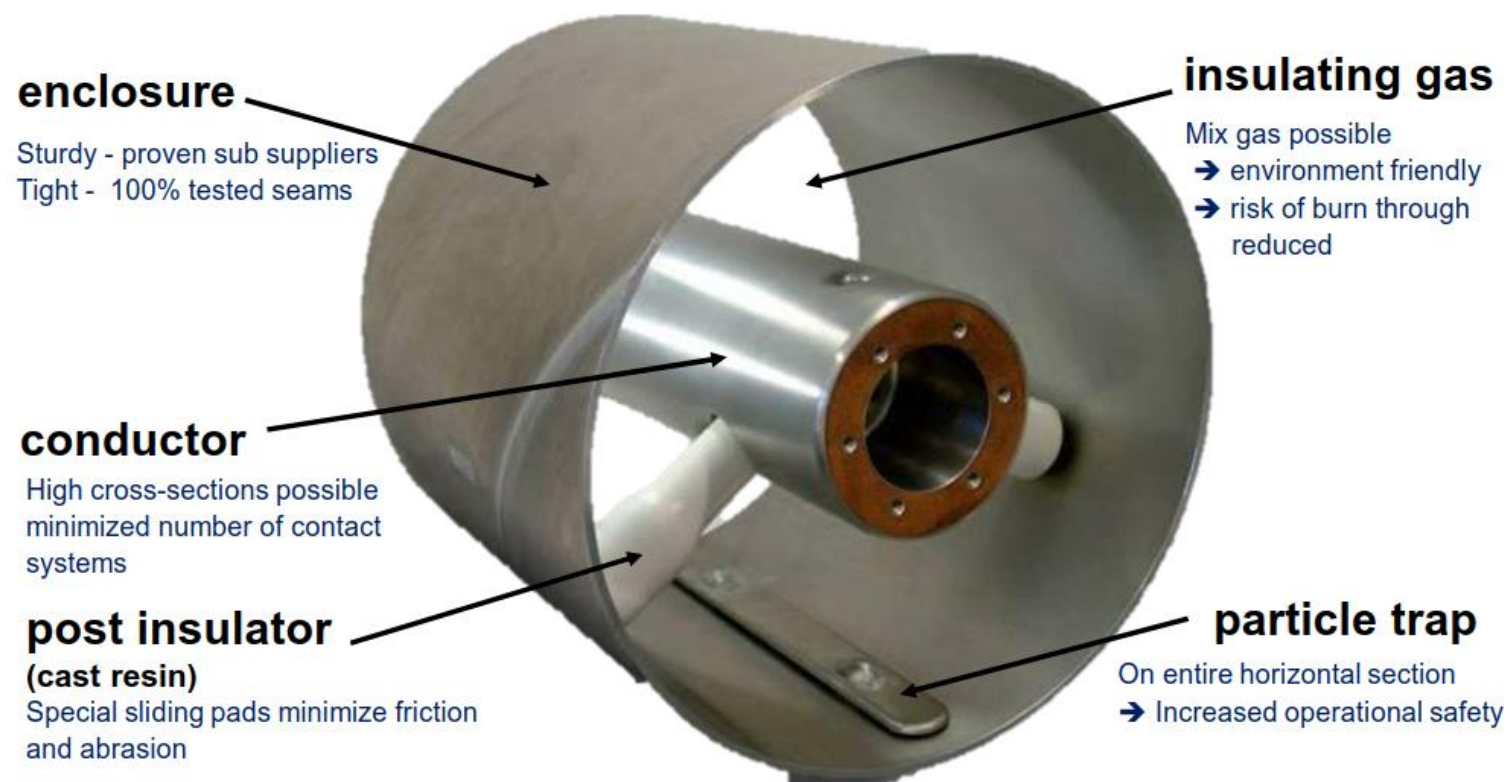
Tunnel

Also directly buried!





# Gas-insulated Transmission Lines as compact alternative for high power underground transmission Bus



# Gas-insulated Transmission Lines as compact alternative for high power underground transmission - Angle Modules



Connection of elbow module and expansion joint



Coupling of male and female sliding contact



## Gas-insulated Transmission Lines with possible load up to 4,700 MVA


Rated Voltage	245 kV ... 550 kV
Impulse Withstand Voltage	... 1,675 kV
Rated Current (typical)	2,000 ... 5,000 A
Rated Short Time Current	63 kA / 3s
Rated Transmission Load	up to 4,700 MVA
Capacitance	88 nF/mile
Overload capability (typical)	100%
Insulation gas mixture	0-80% N <sub>2</sub> / 100-20% SF <sub>6</sub>

Designed and tested in accordance with IEC 62271-204:

*High-voltage switchgear and controlgear –*

*Part 204: Rigid gas-insulated transmission lines for rated voltages above 52kV*

## Areas of use

Application fields for transmission lines	OHL 	GIL 	Cable 	Reference projects	Market Drivers
<b>Lines with special constraints, requiring underground solutions (e.g., close to airports, through cities or villages, in space-restricted areas, <u>right of way</u> etc.)</b>		✓	✓	Dominion, VA Brambleton  Palexpo, Geneva	<ul style="list-style-type: none"> <li>• Congested Substation</li> <li>• Restricted land usage</li> <li>• Increasing public opposition</li> <li>• Environmental awareness</li> </ul>
Underground lines with power < ~ 2000A		(✓)	✓		
Underground lines with power > ~ 2000A		✓	(✓)		
<b>Special requirements concerning EMC for AC</b>		✓		Paulaner, Munich	<ul style="list-style-type: none"> <li>• Increasing public opposition</li> </ul>
<b>Installations where fire protection and / or explosion protection is crucial</b>		✓		Limberg II, Austria	<ul style="list-style-type: none"> <li>• Infrastructure projects (tunnels, bridges)</li> </ul>
<b>Vertical transmission solutions</b>		✓		Jingping & Xiloudou, China	<ul style="list-style-type: none"> <li>• Hydro power market</li> </ul>
Standard lines in rural area	✓				



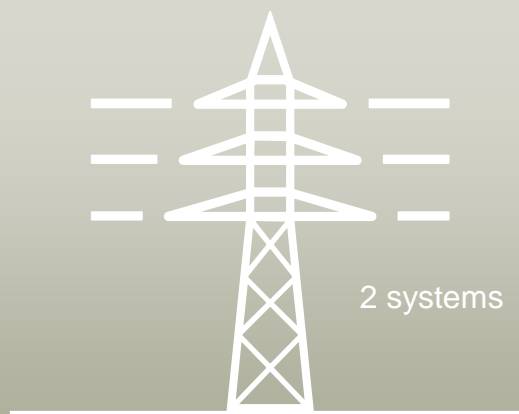
# Gas-insulated Transmission Lines (AC)

More power → Less capacitance → Less losses

	<b>GIL</b>	<b>XLPE Cable</b> 4934 kcmil - 2500mm <sup>2</sup> , Cu	<b>XLPE Cable</b> 3160 kcmil - 1600mm <sup>2</sup> , Cu
Rated Voltage	420kV	420 kV	420 kV
Impulse Withstand Voltage	1425kV	1425kV	1425kV
Rated Current (typical) depends on laying & soil condition	~ 2,000 ... 5,000 A	... ~2.500 A	... ~ 1.600 A
Rated Short Time Current	63 kA / 3s		
Rated Transmission Load	... ~ 3600 MVA	... ~ 1,800 MVA	... ~ 1,100 MVA
Capacitance	88 nF/mile	368 nF/mile (~737nF/mile @ 2 cores)	304 nF/mile (~608nF/mile @ 2 cores)
Overload capability (typical)	100%	defined	defined
losses	2 side bonding; X-boding (EMF~0) @ 2000A: 114 W/m; 59 W/m @ 3000A: 266 W/m; 139 W/m @ 4000A: 476 W/m; 255 W/m	X-boding 2 cores @ 2000A: 114 W/m @ 3000A: 214 W/m @ 4000A: 330 W/m	X-boding 2 cores @ 2000A: 130 W/m @ 3000A: 250 W/m @ 4000A: 442 W/m
Insulation	gas mixture 0-80% N <sub>2</sub> /100-20% SF <sub>6</sub>	XLPE	XLPE

# Benefits of Gas-insulated Transmission Lines - High transmission (Details)

Overhead Line



~200'

- Above ground
- Visual impact
- Devaluation of land area nearby

Cable

4 systems

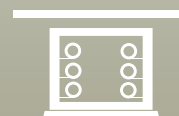


~83'

- Underground
- Restricted land utilization after installation
- Devaluation of land area nearby

GIL

2 systems Tunnel OR 2 systems directly buried



~10'

~28-33'

- Underground
- Nearly no restrictions to land usage after installation
- Accessible
- Highest electromagnetic compatibility

Value creation

through

**ENVIRONMENTAL  
SUSTAINABILITY**

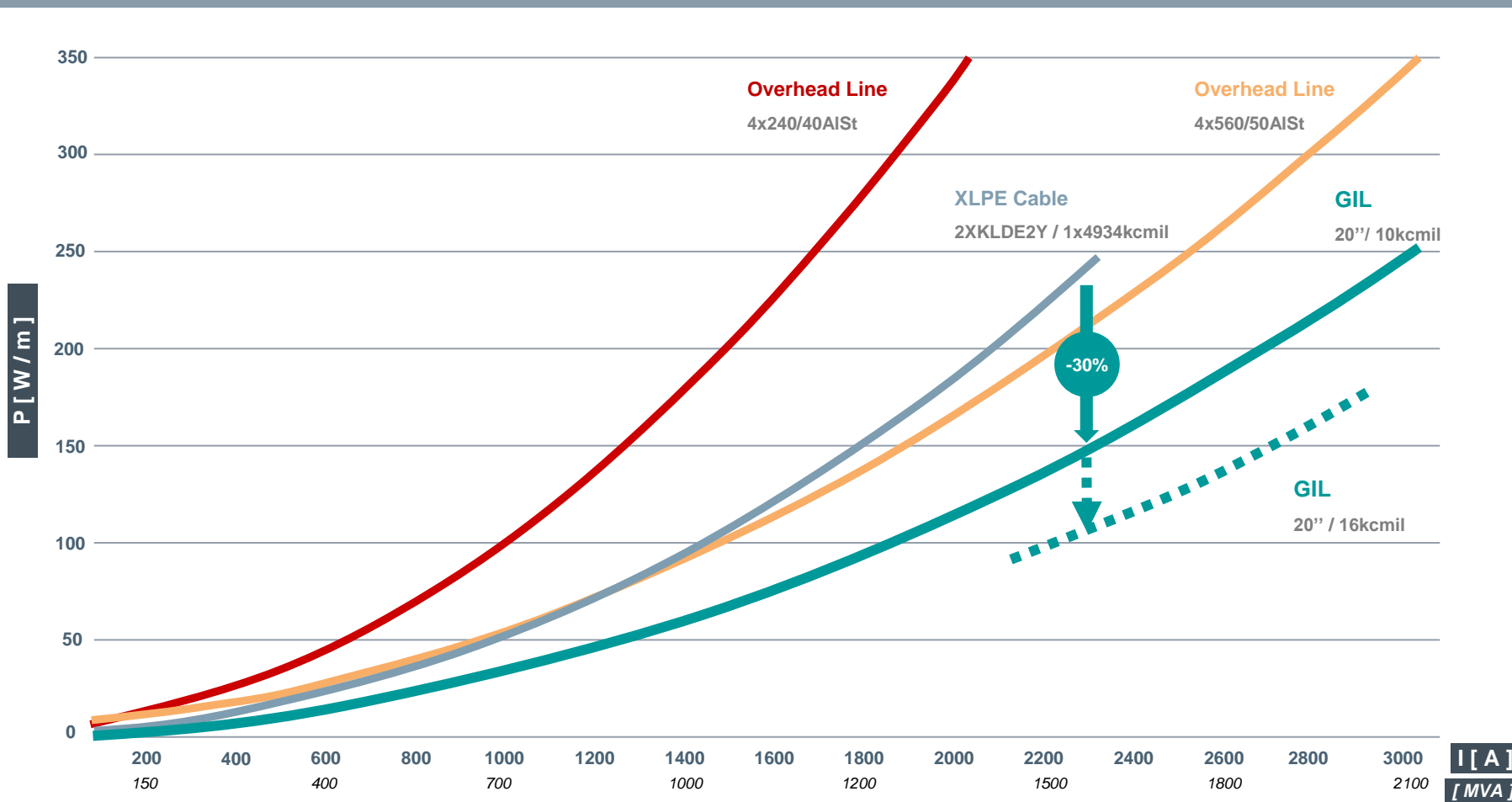
with

**Gas  
Insulated  
Lines**



# Benefits of Gas-insulated Transmission Lines - Low losses (Details)

Comparison of Losses (1 system)



Value creation

through

**EFFICIENCY**

with

**Gas  
Insulated  
Lines**

# Benefits of Gas-insulated Transmission Lines - Safety (Details)

400kV Power Cable – Arc Test



**Risk of injury to humans and damage of property**

400kV GIL – Arc Test



**No external impact, no fire risk**

Value creation

through

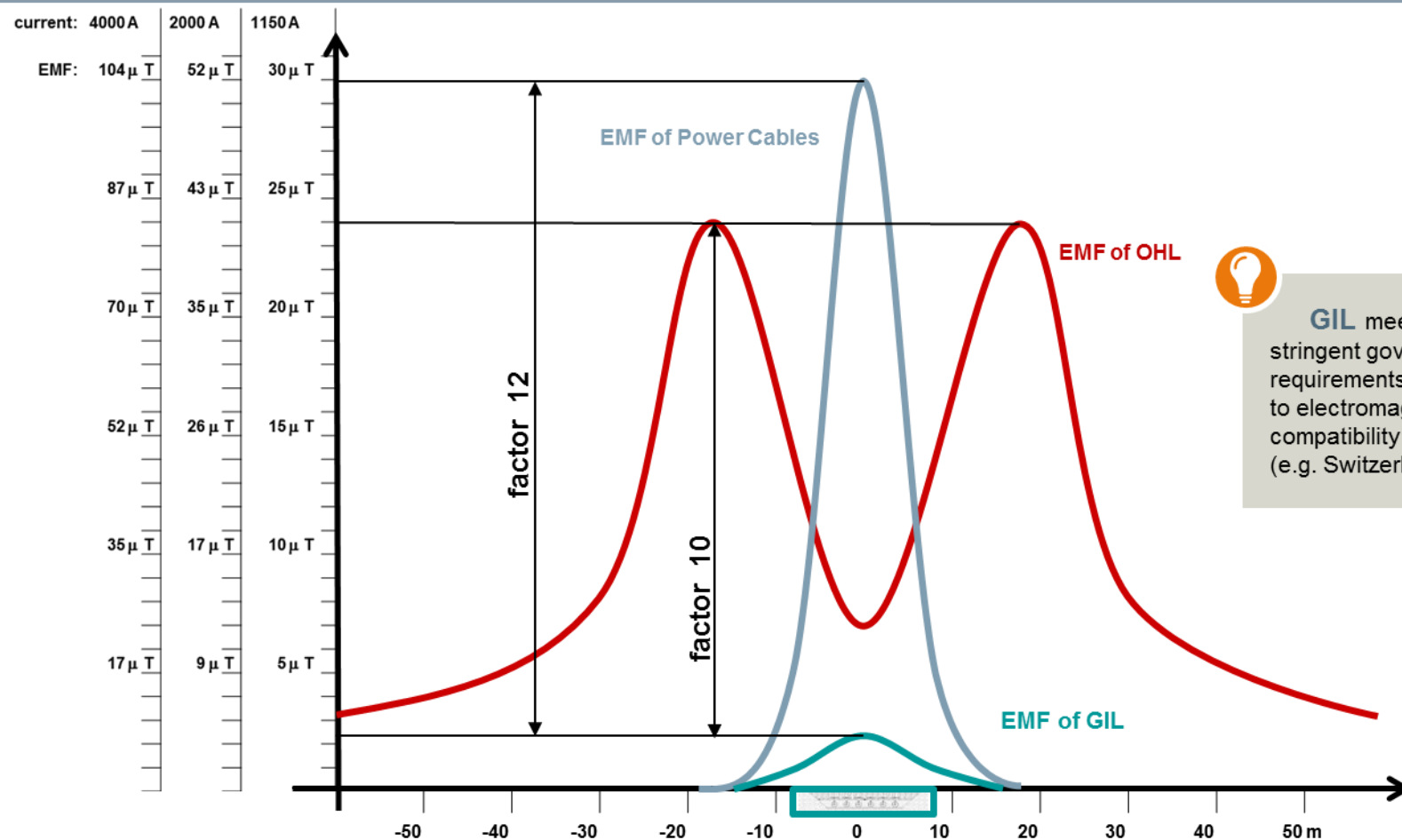
**SAFETY**

with

**Gas  
Insulated  
Lines**

# Benefits of Gas-Insulated Transmission Lines - Low external electromagnetic fields (Details)

Electromagnetic field 1m above ground-level



Value creation

through

**HEALTH & SAFETY**

with

**Gas  
Insulated  
Lines**



## For GIL solutions mainly three laying methods are applicable



### Direct Laying in Ground

Standard solution for open field installation

#### Advantage:

- Low civil works cost
- Environment friendly
- Invisible



### Outdoor Installation

Standard solution for closed premises as switchgear or power plants

#### Advantage:

- Economic
- High transmission rate
- Good access



### Tunnel Installation

Standard solution for cities, HPP, or areas where special protection is needed

#### Advantage:

- Fast installation,
- Independent from public
- High transmission rating
- Good access

# Reference Project

## Kelsterbach 420kV Transmission Line

### Project Details

Customer: *Amprion Gmb*  
Location: *Airport Frankfurt am Main*



Installation type: Buried Installation  
Single phase length: 18,000'  
Date of operation: 2011

Max. power rating: 2 x 2000 MVA  
Operational power: 2 x 1800 MVA  
Rated voltage: 420 kV  
Rated current: 2750 A  
Short time current: 63 kA, 1s  
Rated impulse  
withstand voltage: 1425 kV

#### Key buying factors:

Buried installation  
technology,  
small trench width,  
transmission capacity

#### Specific challenges:

World's first buried GIL



# Reference Project

## Langwied 380kV Transmission Line

### Project Details

Customer: *Stadtwerke München*

Location: *Munich, Germany*



Installation type: Tunnel Installation

Single phase length: 8,600'

Date of operation: 2014

Max. power rating: 2 x 2300 MVA

Operational power: 2 x 2080 MVA

Rated voltage: 420 kV

Rated current: 3160 A

Short time current: 63 kA, 3 s

Rated impulse

withstand voltage: 1425 kV

#### Key buying factors:

Bending radius 1,320',  
restricted space

#### Specific challenges:

Rapid project execution  
( $< 1$  year),  
double bending radius





# Reference Project

## Sai Noi 550kV Transmission Line

### Project Details

Customer:	Electricity Generating Authority of Thailand
Location:	<i>Sai Noi, Bangkok, Thailand</i>
Installation type:	Tunnel Installation
Single phase length:	11,600'
Date of operation:	2002
Maw. power rating:	3810 MVA
Rated voltage:	550 kV
Rated current:	4000 A
Short time current:	50 kA, 1s
Rated impulse withstand voltage:	1550 kV



Key buying factors:  
Transmission capacity

Specific challenges:  
Integration in existing  
substation without  
shut-down




# Reference Project



## 420 kV Transmission Line Schluchseewerk Wehr

### Project Details

Customer:	Schluchseewerk AG	 Schluchseewerk
Location:	Germany, Laufenburg	
Installation type:	Tunnel Installation	
Single phase length:	11,680'	
Date of operation:	1975	
Max. rated power:	1450 MVA	
Rated voltage:	420 kV	
Rated current:	2000 A	
Short time current:	53 kA	
Rated impulse withstand voltage:	1640 kV	
Key buying factor:	Transmission capacity, fire protection requirements	
Specific challenges:	Highest reliability requirements	



# GIL is sealed for life



## 420 kV Transmission Line Schluchseewerk Wehr

“The Schluchseewerk AG [...] is operating two 400-kV SF<sub>6</sub> gas insulated transmission lines in the pump storage plant Wehr over **35 years without failure**.

They were erected and put into operation in 1975 by Siemens AG Germany.

The insulated bus bars have a length of 1,780 and 2110' with a **gas volume of 55,000 lbs in total**. The outages occurred only at old feedthroughs, otherwise there were **no nameable leakages measurable**.”



Siemens AG  
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Laufenburg, 13. Februar 2013

Sehr geehrter Herr Steiner,  
anbei wie gewünscht Schreiben zur Gas Isolierten Leitung Kraftwerk Wehr.

The Schluchseewerk AG, located at Säckingerstrasse 67; 79725 Laufenburg in Germany, is operating two 400-kV SF<sub>6</sub> gas insulated transmission lines in the pumped storage plant Wehr over 35 years without failure. They were erected and put into operation in 1975 by Siemens AG Germany. The insulated bus bars have a length of 540 and 640 m with a gas volume of 25000 kg in total. The gas outages occurred only at old feedthroughs, otherwise there were no nameable leakages measurable.



Mit freundlichen Grüßen

SCHLUCHESEWERK AKTIENGESELLSCHAFT

*C. A. Steiner*

*Peter Humboldt*

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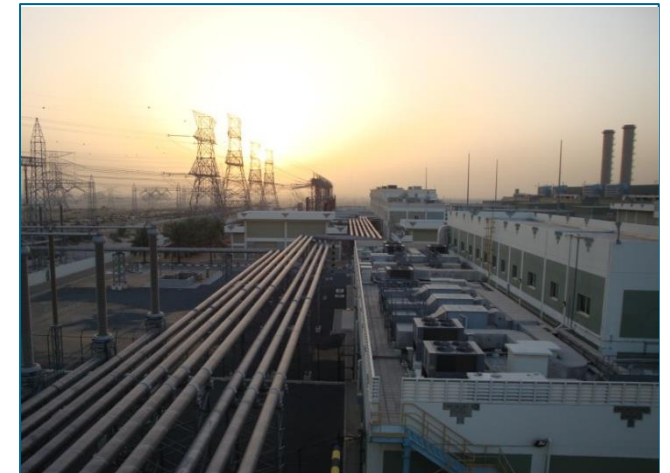
## Reference Project



### 400 kV New Warsan S/S Transmission Line

#### Project details

- Customer: DEWA
- Location: Dubai, United Arab Emirates
- Installation type: Above ground Installation
- Single phase length: 13, 365'
- Date of operation: 2007
- Rated voltage: 400 kV
- Rated current: 2500 A
- Short time current: 63 kA
- Rated impulse withstand voltage: 1425 kV
- Key buying factor: Restricted space, fire protection requirements, transmission capacity
- Specific challenges: Extreme weather conditions



# Reference Project

## 300 kV GIL Palexpo Fair Building

### Project Details

Customer: *énergie ouest suisse*



Location: *Airport Geneve*

Installation type: Tunnel Installation

Single phase length: 8,450'

Date of operation: 2001

Max. power rating: 2 x 1040 MVA

Operational power: 2 x 600 MVA

Rated voltage: 300 kV

Rated current: 2000 A

Short time current: 50 kA, 1s

Rated impulse  
withstand voltage: 1050 kV

Key buying factor: Low electromagnetic field, restricted space

Specific challenges: Bending radius



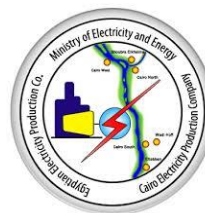
# Reference Project



## Cairo North 245 kV Transmission Line

### Project Details

Customer:	<i>Cairo Electricity Power Corporation</i>
Location:	<i>Cairo, Egypt</i>
Installation type:	Above ground Installation
Single phase length:	6,100'
Date of operation:	2004
Max. power rating:	1.335 MVA
Rated voltage:	245 kV
Rated current:	3150 A
Short time current:	50 kA, 1s
Rated impulse withstand voltage:	1050 kV
Key buying factor:	Restricted space where cable solution was not possible
Specific challenges:	Special electrical requirements in combination with power plant and existing network environment



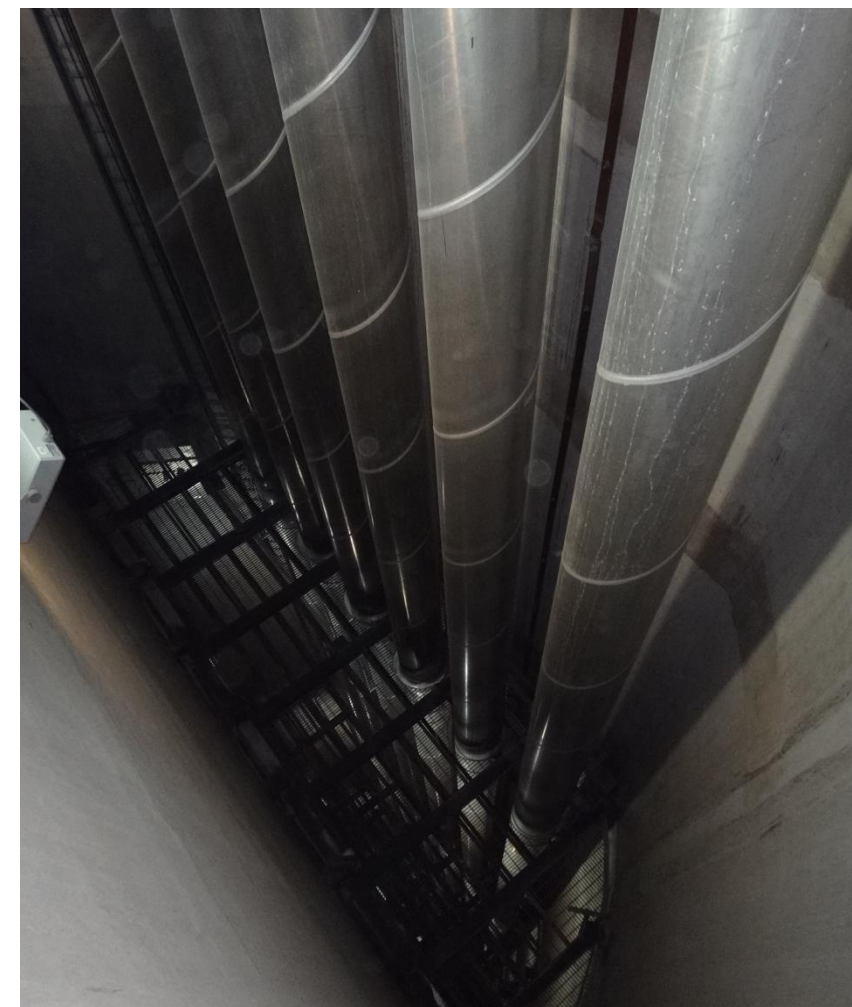


# Reference Project

## Xiluodu 550 kV Transmission Line

### Project Details

Customer:	China Three Gorges Corporation
Location:	Province Sichuan, XiLuoDu
Installation type:	Tunnel Installation
Single phase length:	42, 000'
Date of operation:	2013
Max. power rating:	4280 MVA
Operational power:	3 x 2220 MVA (left bank) 4 x 1665 MVA (right bank)
Rated voltage:	550 kV
Rated current:	4500 A
Short time current:	50 kA, 1s
Rated impulse withstand voltage:	1675 kV
Key buying factor:	Vertical welding technology, highest reliability
Specific challenges:	Vertical installation procedure



# Reference Project

## Jinping I HPP 550kV Transmission Line

### Project Details

Customer:	Yalong Hydro
Location:	Sichuan Province
Installation type:	Tunnel Installation
Single phase length:	11,111'
Date of operation:	2013
Max. power rating:	3810 MVA
Power plant rating:	3600 MW
Rated voltage:	550 kV
Rated current:	4000 A
Short time current:	63 kA, 3s
Rated impulse withstand voltage:	1675 kV
Key buying factor:	Vertical welding technology, highest reliability
Specific challenges:	Vertical installation procedure; installation on critical path



# Reference Project

## 🇬🇧 420 kV Penwortham Transmission Line with GIL

### Project Details

Customer: *National Grid*



Location: *Penwortham, United Kingdom*

Installation type: Above ground installation

Single phase length: 2,525'

Date of operation: QB2: 2012, QB1: 2015

Maw. power rating: 2900 MVA

Rated voltage: 420 kV

Rated current: 4000 A

Short time current: 36 kA, 1s

Rated impulse

withstand voltage: 1425 kV

Key buying factor: N2 / SF6 gas mixture, advantages in plant integration



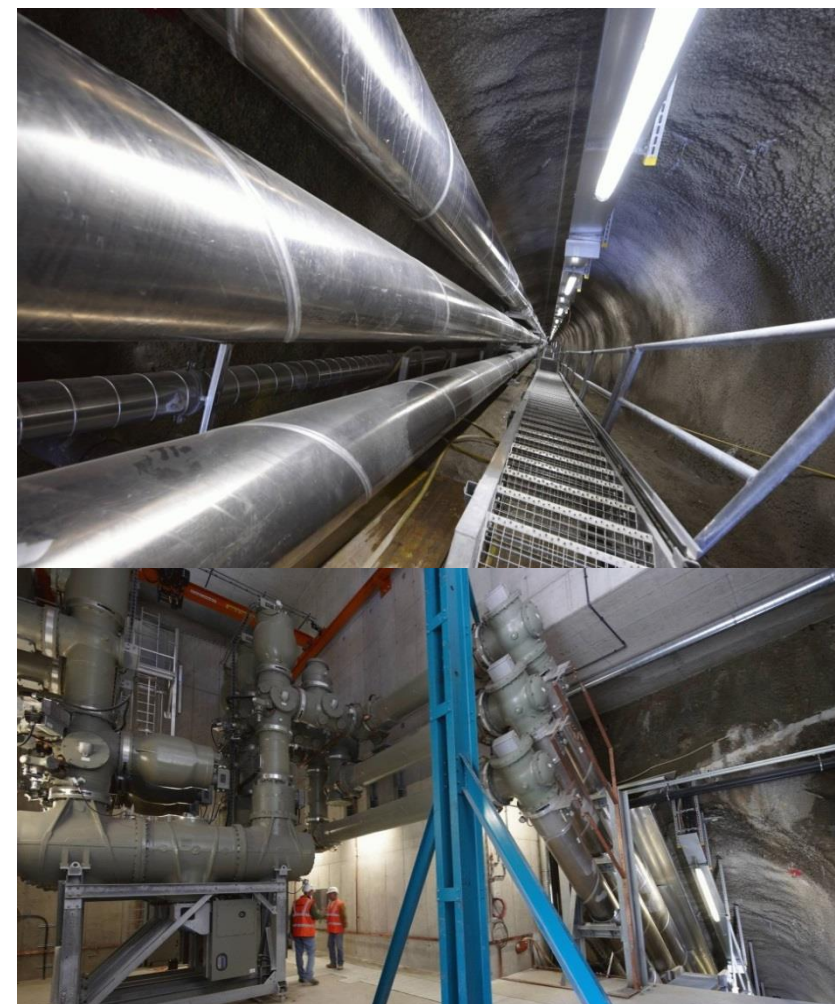


# Reference Project

## 420 kV Transmission Line Limberg II

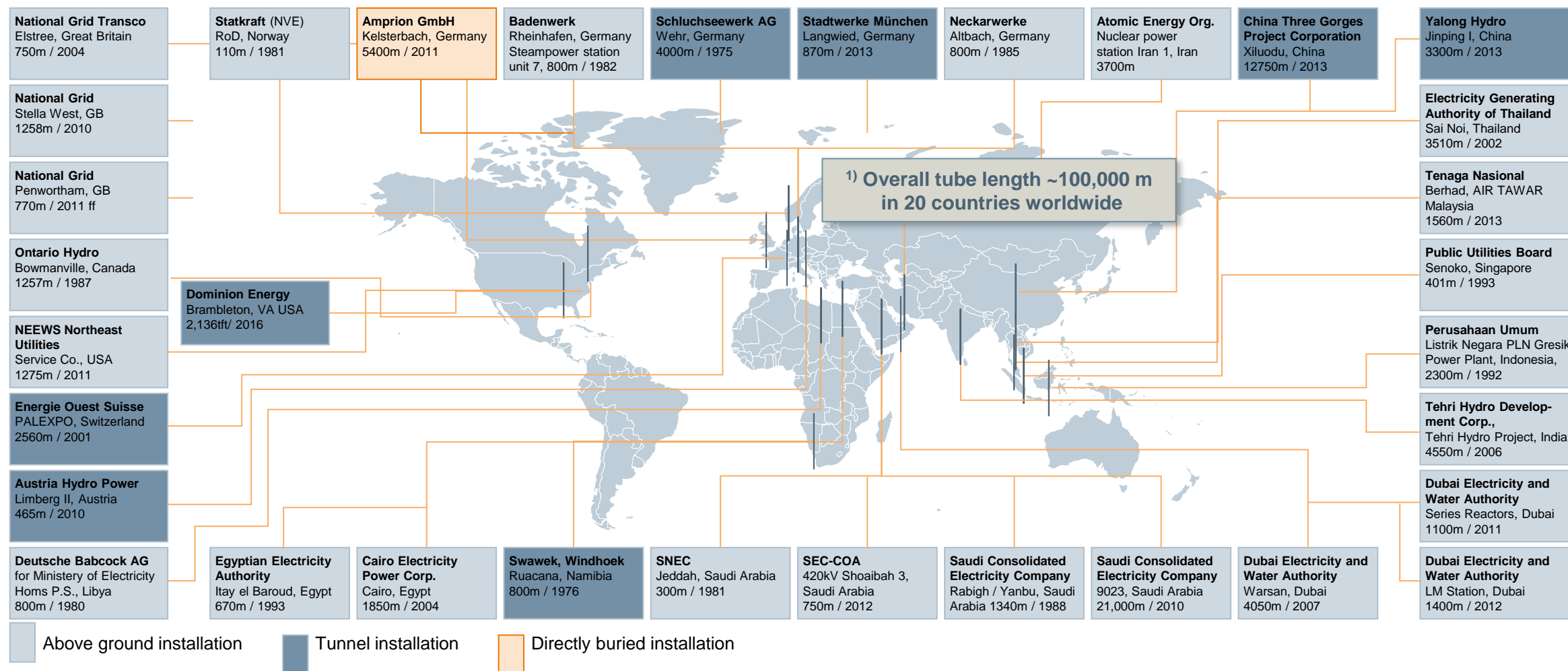
### Project Details

Customer:	Verbund Austrian Hydro Power AG
Location:	Austria, Kaprun
Installation type:	Tunnel Installation
Single phase length:	790'
Date of operation:	2009
Max. power rating:	725 MVA
Rated voltage:	420 kV
Rated current:	1000 A
Short time current:	63 kA, 3s
Rated impulse withstand voltage:	1425 kV
Key buying factor:	Transmission capacity, fire protection requirements
Specific challenges:	Highest reliability requirements



# Selected References

## Gas Insulated Lines, Status December 2016<sup>1)</sup>



# Benefits of Gas-insulated Transmission Lines - Overview of technical features with positive commercial aspects

## Siemens GIL solution

1 High transmission power

2 High reliability

3 Sealed for lifetime

4 Low losses

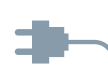
5 No ageing of insulating gas & long lifetime through particle trap

6 Low capacitance

7 Automatic reclosure functionality

8 Low external electromagnetic fields

9 High safety (no fire hazard)



## Customer benefit

Low land usage

Low invest for redundancy

Low maintenance cost

Low operation cost

No cost for replacement

No expensive reactors

No invest for new protection

Optimized short routing possible

No invest for fire protection needed. Possibility to share civil cost with other utilities

**Siemens is the technology leader for GIL**



## Contact us



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