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SEERC

Submarine projects in the Mediterranean Sea. Technology developments and future challenges

2-01

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AC submarine cable types

CHARACTERISTICS	MV THREE CORE	HV THREE CORE	HV SINGLE CORE	
				
Insulation	EPR or XLPE	XLPE	XLPE	Self Contained Fluid Filled
Maximum voltage	72.5 kV	245 kV	420 kV	525 kV
Maximum power per circuit	90 MVA	400 MVA	1000÷1200 MVA	1200 MVA
Maximum operating temperature	90 °C	90 °C	90 °C	90 °C
Maximum length	Limited by voltage drop and/or power losses: ~ 150 km	Limited by power losses and/or capacitive current: ~ 100-150 km	Limited by capacitive current: ~ 100 km	~ 60 km due to hydraulic system limits

Some major HV-EHV Submarine AC cable projects

Country	Project name	Voltage	Conductor		Insulation	N° of circuits and length km	Water depth m	Year
		kV	mm^2	material				
Spain	Mallorca-Menorca	132	500	CU	SCFF	1 x 42	90	1973
Canada	Vancouver island	525	1600	CU	SCFF	1 x 39	400	1984
USA	Long Island Sound	345	2000	CU	SCFF	1 x13	35	1991
Philippines	Leyete – Cebu	230	630	CU	SCFF	1 x 33	280	1995
Malaysia	Penang isl.	275	800	CU	SCFF	2 x 14	20	1996
Spain	Spain Morocco	400	800	CU	SCFF	1 x 26	630	1997
Egypt	Gulf of Aqaba	400	1000	CU	SCFF	1 x 13	840	1997
UK	Isle of Man	90	3x300	CU	XLPE	1 x 105	40	2000
USA	Galveston Isl	138	3x630	CU	XLPE	1 x 5	15	2001
Denmark	Horns Rev wind farm	150	3 x630	AL	XLPE	1 x 21	20	2002
Denmark	Seas Roedsand wind farm	132	3x760	CU	XLPE	1 x 22	20	2003
Italy	Sardinia –Corse island	150	3x400	CU	XLPE	1 x 15	75	2005
Norway	Gossen isl.	400	1600	CU	XLPE	1x3.2	200	2007
Spain	Mallorca-Ibiza	132	3x300 3x500	CU	XLPE	1x115	800	2016
Italy	Sicily - Malta	220	3x630	CU	XLPE	1x97	160	2014
Italy	Sicily - Mainland	400	1600	CU	SCFF	2 x 38	350	2015
Turkey	Çanakkale	400	1600	CU	XLPE	2x4	90	2015

DC submarine cable types

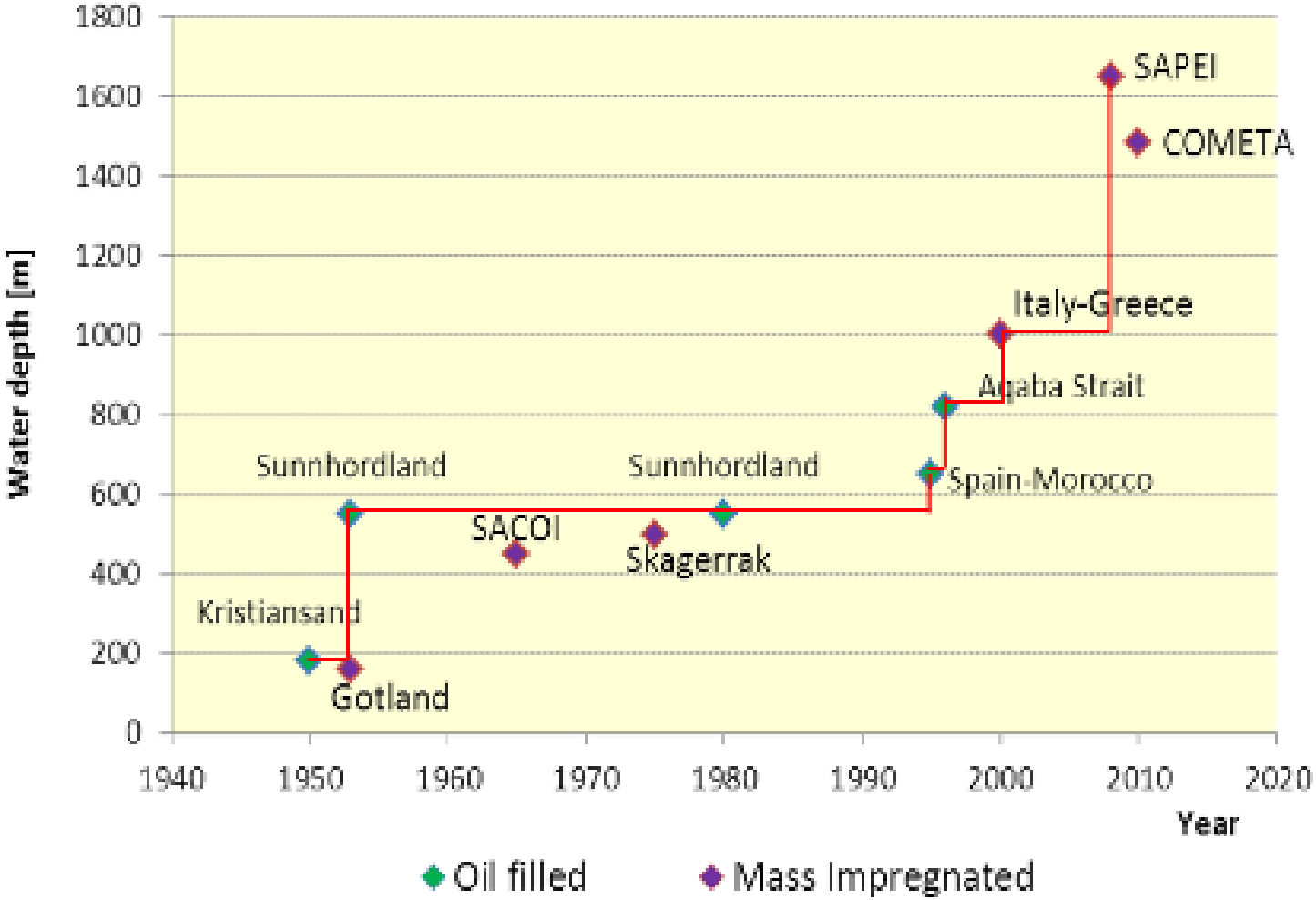
CHARACTERISTICS	SINGLE CORE				
					
Insulation	XLPE	P-Laser	Self Contained Fluid Filled	MI paper	MI-PPL
Maximum voltage	±600 kV	±525 kV	±600 kV	±525 kV	±700 kV
Maximum power per bipole	2700 MW	3000 MW	2500 MW	2400 MW	3400 MW
Maximum length	Not limited by cable technology	Not limited by cable technology	~ 60 km due to hydraulic system limits	Not limited by cable technology	Not limited by cable technology
Compatible converter	VSC any voltage LCC up to 250 kV	Both LCC and VSC	Both LCC and VSC	Both LCC and VSC	Both LCC and VSC

NOTE 1: Submarine cables may have different armouring design mainly depending on water depth
NOTE 2: rating depends on ambient and installation parameters

Some major Submarine DC cable projects

Name of the project	Year	Voltage (kV)	Power (MW)	Length (km)	Max. Water Depth (m)	Type
Gotland 1	1956	100	20	100	160	MI
Italy – Sardinia	1965	200	100	2 x 118	450	MI
Konti-Skan 1	1965	285	300	64	80	MI
Vancouver Is. 1	1969	300	156	3 x 27	200	MI
Skaggerak 1,2	1976	263	250	2 x 125	600	MI
Vancouver Is. 2	1976	300	185	2 x 35	200	MI
Hokkaido/Honshu	1980	250	150	2 x 42	290	SCFF
Gotland 2,3	1983	150	160	2 x 100	160	MI
Cross-Channel 2	1986	270	250	8 x 50	55	MI
Konti-Skan 2,3	1988	285	300	2 x 64	80	MI
Fenno-Skan	1989	400	500	200	117	MI
Cook Strait 2	1991	350	500	3 x 40	300	MI
Skagerrak 3	1993	350	500	125	500	MI
Cheju (Korea)	1993	180	150	2 x 96	160	MI
Baltic Cable	1994	450	600	250	60	MI
Sweden – Poland	1999	450	600	253	90	MI
KII Channel Japan	2000	500	2800	4 x 49	70	SCFF
Italy – Greece	2001	400	500	1 x 160	1000	MI
Moyle (UK)	2001	250	500	2 x 55	100	MI
Cross Sound (USA)	2002	150	330	2 x 42	40	XLPE
Bass Link (Aus)	2005	400	500	1 x 290	75	MI
Norway-Netherlands	2007	450	700	1 x 580	410	MI
Sardinia-Italy	2008 2010	500	500 500	1 x 420 1 x 420	1650	MI
Trans Bay S. Francisco	2009	200	400	2 x 83	30	XLPE
Borwin 2	2015	300	900	2x200	40	XLPE
Helwin 1	2015	250	576	2x135	40	XLPE
Sylwin 1	2015	320	864	2x205	40	XLPE
Helwin 2	2015	320	690	2x135	40	XLPE

Maximum installation depth reached on different projects worldwide



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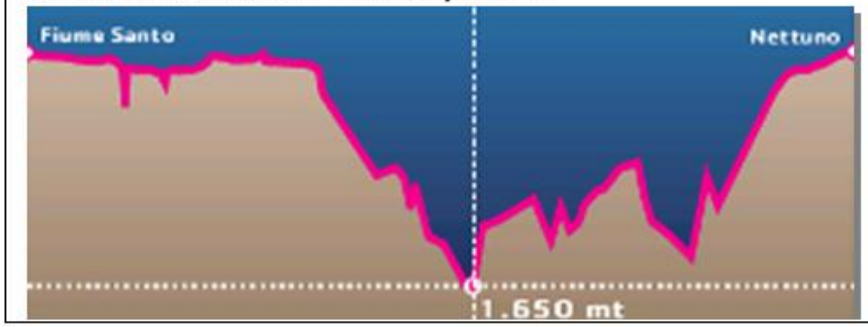
Submarine cable route

Submarine cable route profile



HVDC cable system main features

- Rated Power: 1000 MW
- Rated Voltage: 500 kV DC
- Submarine length: 2x425 km
- Maximum water depth: 1650 m (world record)
- Land length: 2x15 km
- Bipolar system, can be operated in monopolar operation with sea return (electrodes)
- Submarine cables designs

Insulation material		Mass Impregnated	
Deep water	Cross section	(mm^2)	1150
	Conductor material	Aluminium	
Medium-shallow water	Cross section	(mm^2)	1000
	Conductor material	Copper	
Land	Cross section	(mm^2)	1400
	Conductor material	Copper	

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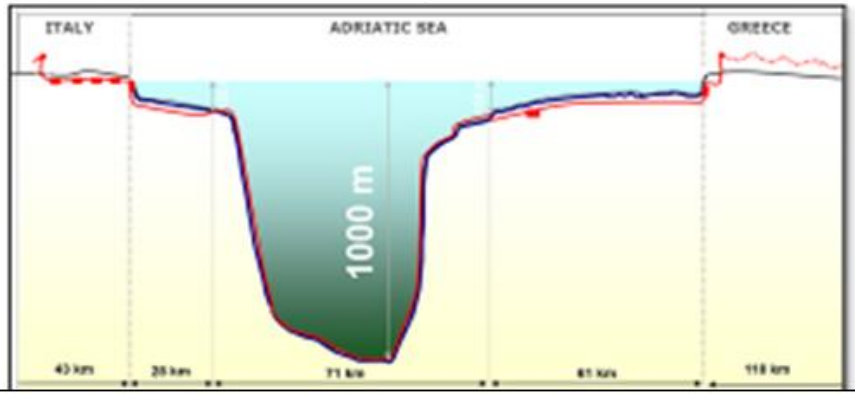
Submarine cable route

Submarine cable route profile



HVDC cable system main features

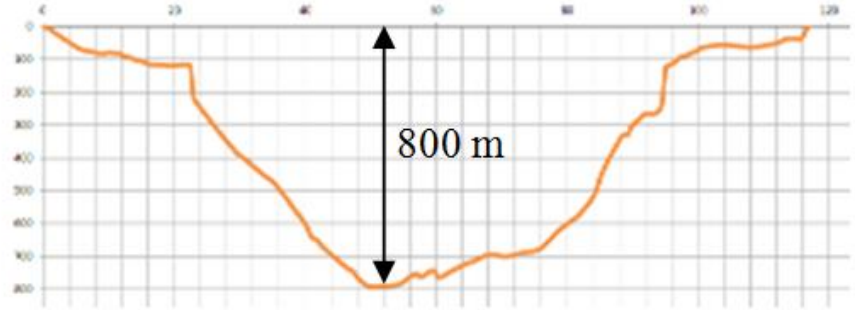
- Rated voltage: ±400 kV DC
- Rated Power: 500 MW
- Scheme: monopolar configuration with sea return
- Submarine length: 160 km
- Maximum water depth: 1000 m
- Land length: 43 km
- Submarine cable design:

Cross section	(mm^2)	1250
Conductor material	Copper	
Insulation material	Mass Impregnated	

Mallorca-Ibiza

Submarine cable route

Submarine cable route profile



HVAC cable system main features

- Rated Voltage: 132 kV
- Rated power: 118 MVA
- Submarine length: 115 km
- Maximum water depth: 800 m
- Land length: 8 km
- Submarine cables designs
  - XLPE 3x500mm^2 Cu SWA (shallow water)
  - XLPE 3x300mm^2 Cu DWA (depth >100m)

Sorgente-Rizziconi

Submarine cable route

red: existing 400 kV; blue: future 400 kV; green: existing 220 kV

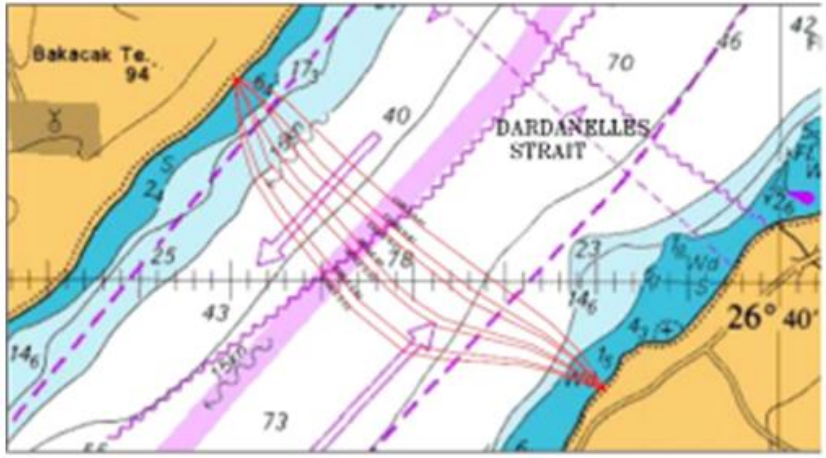
HVAC cable system main features

- Rated power: 2x1000 MW
- Rated Voltage: 400 kV
- Submarine section: 38 km
- Sicily land part: 2km
- Italy land part: 3km
- Submarine cable design

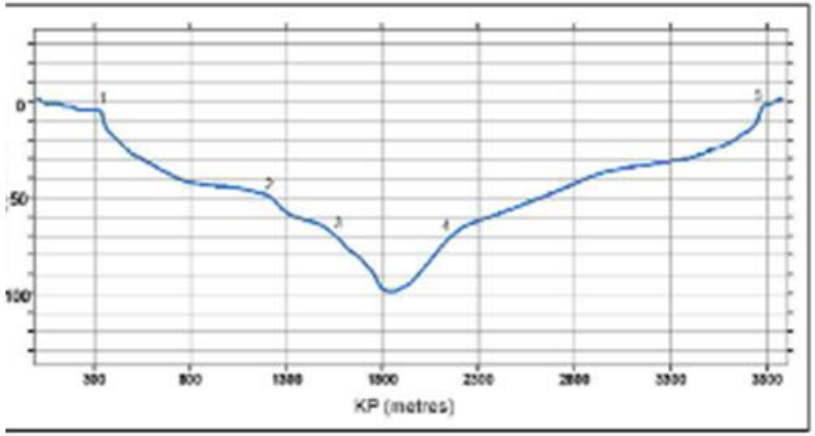
  1500 mm^2 Cu Oil filled-PPL insulated
- Land cable design: 2500 mm^2 Cu XLPE insulated

Lapseki-Sutluce

Submarine cable route



Submarine cable route profile



HVAC cable system main features

- Rated voltage: 400 kV
- Rated power: 2x1000 MVA
- Route length: 6 km
- Maximum water depth: 100 m
- Number of cables: 7 (2x3 phase system + 1 spare redundancy)
- Submarine cable design:
  1600 mm^2 Cu conductor XLPE insulated

Conclusion

- After more than one century of application the submarine cables are today a mature technology that can offer a viable support to the implementation of high voltage power transmission systems.
- In the last years, submarine transmission cable technologies have benefited from the introduction of numerous innovative solutions, in terms of increasing the performances, reliability, safety, availability, and feasibility of the projects.
- As reported by the CIGRE TB 379 survey, a high intrinsic level of reliability has been reached for submarine connections. The same survey evidenced a certain rate of failures due to the external damages generally of mechanical nature and caused by third party activities. The precaution and rules adopted during the last years for the installation of submarine cables will likely reduce strongly these kinds of failures.
- It is expected that a considerable increase of DC submarine cable connections will happen in the next years that will contribute to develop a well meshed European and Mediterranean transmission system enabling an optimal deployment of renewable power resources.
- Recent technology developments ensure the feasibility of submarine cables to be installed at depth of 3000 m and beyond, for HVDC transmission of power in the range of 1000 MW per bipole. These developments will make possible the installation of ultra-deep water high-power transmission cables.