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Prospective 21OO

JICABLE / WETS *Workshop*

A.C. Electric power

Long insulated power cable links throughout the world. Reactive power compensation achievement

Results of the WETS'05 study - November 2005

Lucien DESCHAMPS

JICABLE / WETS *Workshop*

PROSPECTIVE 21OO

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1. Aims of the study
2. International survey
3. Selection of HV and EHV links
4. Reactive power involved in the links
5. Why is compensation necessary?
6. Service feedback
7. Economical aspects
8. To sum up

1. Aims of the study

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Aims of the study

Synthesize the service experience throughout the world upon the building and the operation of long links (>10km) to transmit A.C. electrical power through insulated cables:

- Main achievements
- With and without compensation
- Operating feedback
- Costs
- Future potentialities

2. International Survey

International Survey

- **Set-up of the survey**
  - **First step: January 2004**
    - Sending letters on January 22nd 2004
    - Set up of a questionnaire project
    - Set up of a list of experts: 134 experts from 37 countries
  - **Second Step: February 2004 to June 2004**
    - Sending of the questionnaire to the experts
  - **Third Step: End of 2004 / beginning of 2005**
    - Collection of the answers to the questionnaire and follow up,
    - Synthesis of the answers,
    - Meeting on January 5th and February 24th 2005,

- **Set-up of the survey**
  - **Fourth Step: 2005**
    - Additional information and presentation of the results:
      - Meeting with JICABLE partners
      - Information of the JICABLE steering committee on September 9th 2005
      - Distribution of the results to the experts involved in the study

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QUESTIONNAIRE

Form #:

Reactive power put in HV and EHV insulated power cables

Link considered in the survey: Length >10 km

Contact :

Name & First name:

Company :

Address:

Phone :	Fax :

Email :

1 - Geographical situation of the link:
- Country
- Area

2 - Characteristics of the link:
- Network
- Link name
- Nominal power
- Nominal voltage
- Length

3 - Characteristics of the cables:
- Cable type
- Installation : buried, in ducts, subsea…
- Forced cooling : yes (type) - no
- Insulating material
- Metallic screen bonding
- Distributed linear inductance
- Distributed linear capacity

4 - Is a compensation of the reactive power achieved?
- Yes ? No ?
- Why ?
- Position of the compensation: at the terminations, intermediary, …

5 - Characteristics of the compensation:
- Nominal power
- Technology
- Space occupied (m^2)
- Cost ($ or €)

6 - Operating results of the compensated link (if an option):
- Technical and economical performances
- Possible emerging problems: harmonics, transitory stability,

7 - Publications or available documents dealing with the link.

The answers

- **58 answers for 54 links,**
- **From 22 countries ,**
- **Nominal voltage: 50 to 500 kV,**
- **Maximum length of the links: 39.8 km**

Answers from 22 countries:

Australia, Belgium, Brazil, Canada, Croatia, Denmark, France, Germany, Israel, Italy, Japan, Korea, Morocco, The Netherlands, Norway, Portugal, Russia, Singapore, Spain, Sweden, Tunisia, United Kingdom.

3 – Selection of HV, VHV and EHV links

Selection of HV, VHV, and EHV links (1/6)

Answer #	Country of the link	System	Power Voltage Length	Lineic characteristics	Compensation
1	**Spain / Morocco (1998)**	REE Spain / Morocco Line	700 MW 400 kV 29 km	Submarine: Solid bonded l = 271 μH/km C = 250 nF/km Land: Cross bonded l = 828 μH/km C = 310 nF/km Cable: OF	150 MVAr Spanish side 2 x 125 MVAr Morrocan side 800 m²/reactor bank 2.4 M€/re actor bank
3	**Canada**	B.C. Hydro British Colombia to Vancouver-Island Line	…MVA 500 kV 37 km	Information expected Cable: OF	8 x 135 MVAr + SVC 135 MVAr inductive to 165 MVAr capacitive 2900 m²
4	**Singapore**	PUB Singapore	…MVA 230 kV …km	Information expected	SVC TCR 100 MVAr inductive (500 m²) 50 MVAr inductive (400 m²)

Selection of HV, VHV, and EHV links (2/6)

Answer #	Country of the link	System	Power Voltage Length	Lineic characteristics	Compensation
6	**Spain**	REE San Sebastian de los Reyes - Loeches - Morata Line	2 liaisons 1390 MW / 1720 MW 400 kV 12.7 km	Cross bonded l = 554 à 688 µH/km C = 220 à 230 nF/km Cable: XLPE	150 MVAr at each end 800 m^2/ reactor bank 2.4 M€/reactor bank
10	**Italy**	ENEL Network Calabria - Sicilia Line	1000 MVA 380 kV 8.3 km	Submarine: Solid bonded l = 172 µH/km C = 327 nF/km Land: Cross bonded l = 628 µH/km C = 372 nF/km Cable: OF	150 MVAr = 50 MVAr / phase (56 m^2 / phase + 7.8 m^2 neutral reactor) 1 M€

Selection of HV, VHV, and EHV links (3/6)

Answer #	Country of the link	System	Power Voltage Length	Lineic characteristics	Compensation
15	**Japan**	Honshi Interconnecting Transmission Line	2 x 1200 MW 500 kV 22.2 km	Cross bonded l = …… µH/km c = 280 nF/km Cable: OF	250 MVAr - 240 m²
16	**Japan**	TEPCO Shin Toyosu Line	900 MW (future: 1200 MW) 500 kV 39.8 km	Cross bonded l = 390 µH/km c = 230 nF/km Cable: XLPE	2 x 300 MVAr at the end 180 m² and 220 m² 760 MJPY and 960 MJPY
17	**Japan**	TEPCO Katsusnan Setagaya Line	302 MW 275 kV 32.5 km	Cross bonded l = ….. µH/km c = 200 à 220 nF/km Cable: XLPE	150 MVAr 120 m² 360 MJPY

Selection of HV, VHV, and EHV links *(4/6)*

Answer #	**Country of the link**	**System**	**Power Voltage Length**	**Lineic characteristics**	**Compensation**
21	**Korea (Seoul)**	KEPCO 345 kV Sin Seongdong Trans. Line	523 MVA 345 kV 17 km	Cross bonded l = … μH/km c = 370 nF/km Cable: OF	2 x 100 MVAr 2 x 128 m^2 525 000 $
22	**Korea (Busan)**	KEPCO 345 kV Nam Busan Trans. Line	523 MVA 345 kV 22 km	Cross bonded l = …μH/km c = 370 nF/km Cable: OF	2 x 200 MVAr 2 x 150 m^2 1 083 000 $
23	**Korea (Seoul) (2003)**	KEPCO 345 kV Yeongseo - Yeongdeungpo Trans. Line	955 MVA 345 kV 10 km	Cross bonded l = 380 μH/km c = 240 nF/km Cable: XLPE	200 MVAr at one end. 150 m^2. 1.1 M$

Selection of HV, VHV, and EHV links (5/6)

Answer #	Country of the link	System	Power Voltage Length	Lineic characteristics	Compensation
24	**Denmark (Northern Jutland) (2004)**	ELTRA 400kV. 140km Aarhus-Aalborg Trans. Line	1300 MVA (2000 MVA) 400 kV 4.5+2.5+7 km = 14 km x 2 circuits. (3 siphons) Cable: XLPE	Cross bonded l = 390 μH/km C = 180 nF/km	2 inductive reactors: 100 and 140 MVAr at the end of two cable sections.
26	**Germany (Berlin) Diagonal**	Bewag 380kV Berlin Diagonal	1120 MVA/circuit 2 circuits 380 kV 15.7 km (7.6 + 8.1) OF cables	Cross bonded l = 730μH/km C = 290 nF/km	80 MVAr Oil filled shunt reactor 90 m² + 50 m² (Cooling Equipment)
27	**Germany (Berlin) Diagonal (1999)**	Bewag 380 kV Berlin Diagonal	1150 MVA / cct 2 circuits 380 kV 11.9 km (6.5 + 5.4) XLPE cables	Cross bonded l = 700 μH/km C = 180 nF/km	80 or 120 MVAr Oil filled shunt reactor 90 m² + 50 m² (Cooling Equipment)

Selection of HV, VHV, and EHV links (6/6)

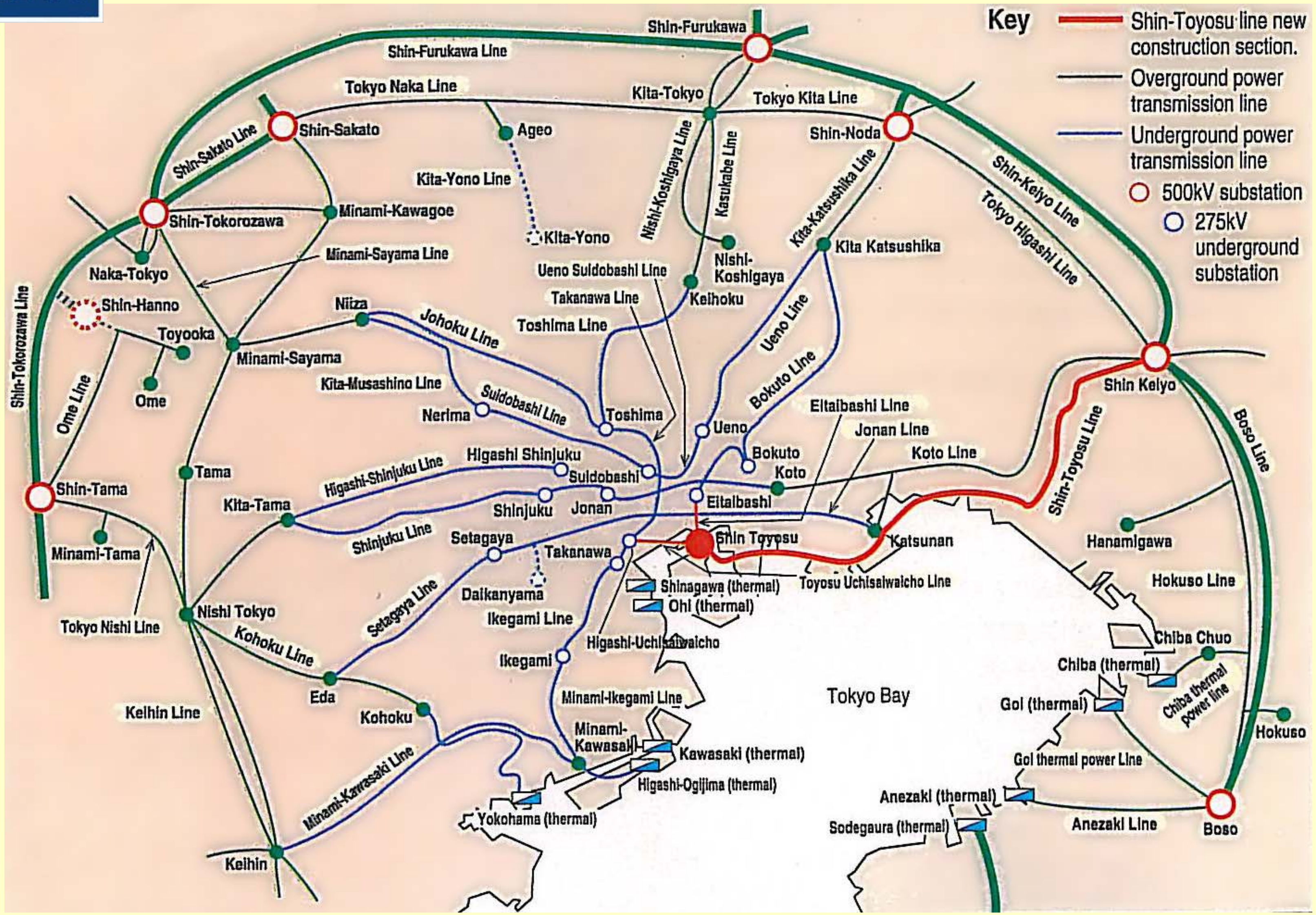
Answer #	Country of the link	System	Power Voltage Length	Lineic characteristics	Compensation
37	**Japan**	TEPCO Yokohama-Kouhoku Line	700 MW 275 kV 20 km	Cross bonded l = ….. µH/km c = 200 à 280 nF/km Cable: XLPE	150 MVAr 190 m^2 260 MJPY
38	**Australia (Sydney)**	Transgrid 330 kV Sydney South-Beaconsfield West Line	660 MVA 330 kV 19.7 km	Cross bonded Information expected Cable: OF	Yes via switched shunt reactors. 330 kV: 150 MVAr 132 kV: 100 MVAr
39	**Australia (Sydney)**	Transgrid 330 kV Sydney South-Haymarket Line	900 MVA 330 kV 28 km	Cross bonded Information expected Cable: OF	Yes via switched shunt reactors. 330 kV: 250 MVAr 132 kV: 100 MVAr
43	**Belgium (Brussels)**	150 kV Tihange - Avernas Line	285 MVA / link 150 kV 2 x 30 km	Cross bonded l = 329 µH/km c = 331 nF/km Cable: XLPE	No compensation

Selection of HV, VHV, and EHV links

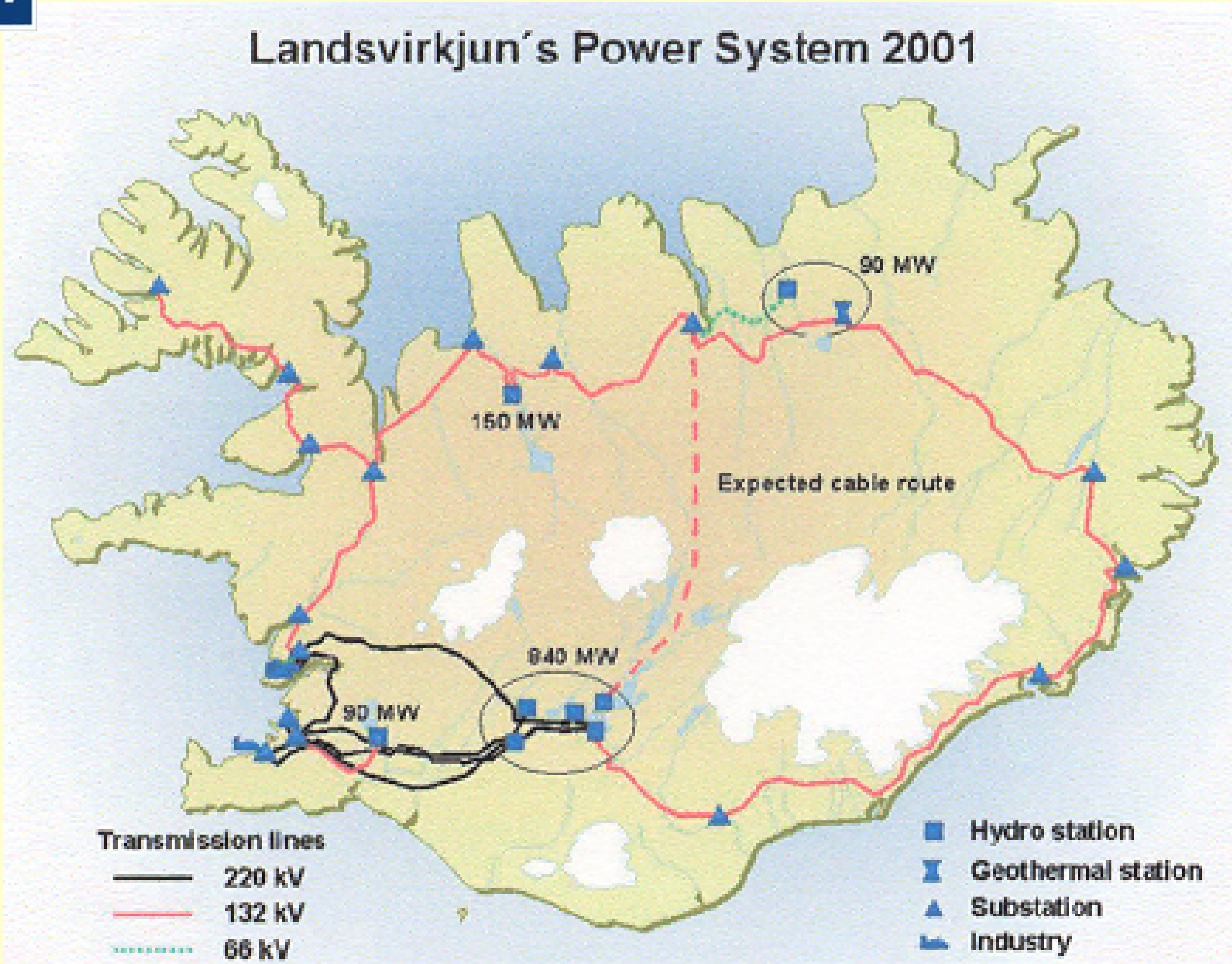
Longest link: 39.8 km in Japan

- **Network: TEPCO (Tokyo Electric Power Co), Japan,**
  - **Link: Shintoyosu (Tokyo),**
  - **Characteristics: 900 MW, 500 kV, …**
  - **Cable: XLPE, 2500 mm² Copper,**
  - **Installation: buried,**
  - **External metallic screens: « Cross bonding »,**
  - **Forced cooling forecasted,**
  - **Length of the link: 39.8 km, 2 circuits,**
  - **Compensation (for each circuit):**
    - **2 x 300 MVAr (at the ends),**
    - **180 m² + 220 m²**
    - **760 JPY + 960 JPY = 12.86 M€**

Shi-Keiyo – Toyosu Link



The ICELAND PROJECT (2002)



The ICELAND PROJECT (2002)

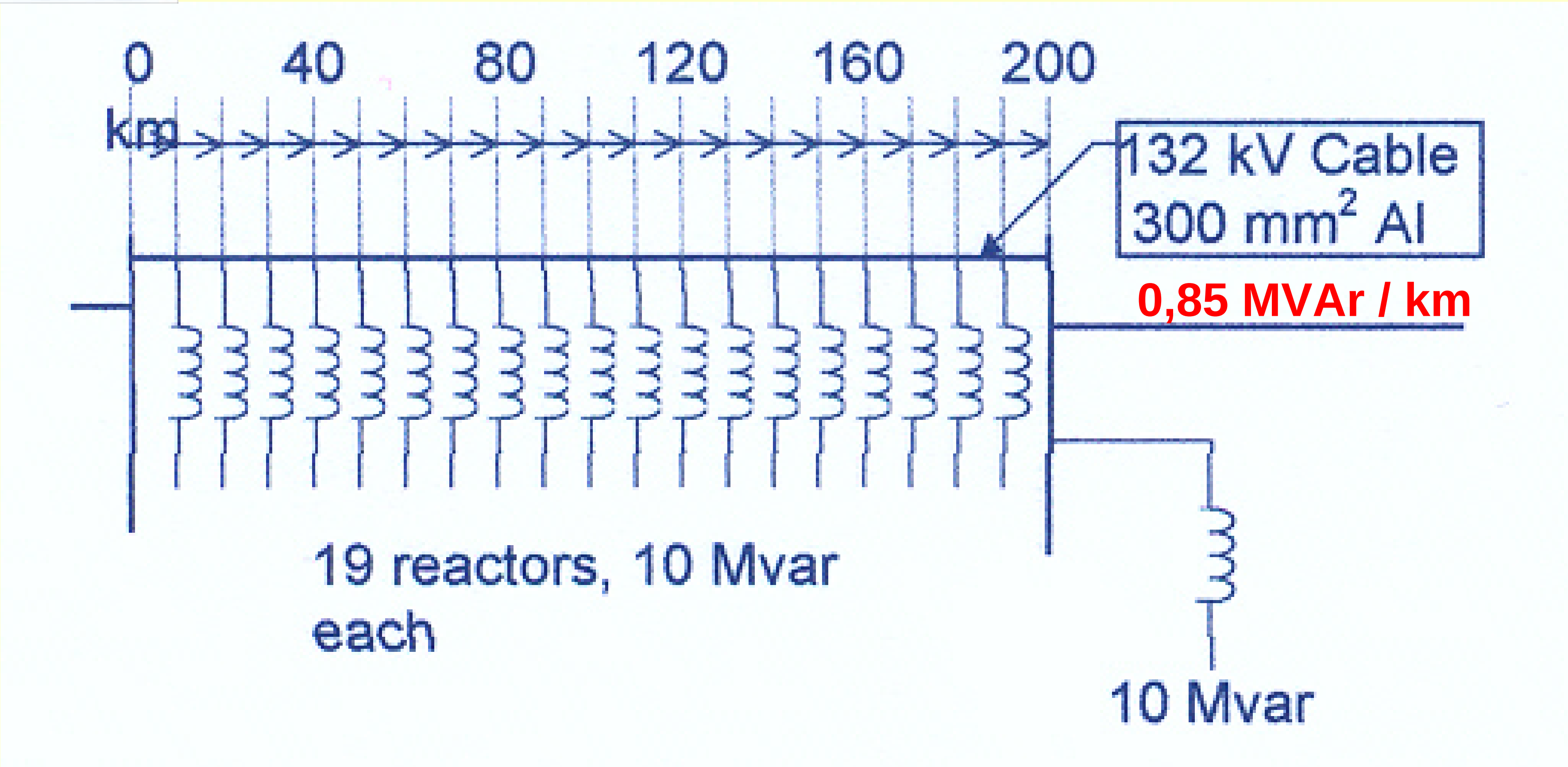
Research of a solution for the 132 kV energy loop of the Icelandic network taking into account the heavy climatic constraints: winds, ice….

First objective: Stability and reliability of the supplied power: 55 MVA, 132 kV, 242 A

The proposed solution:

A 200 km insulated power cable link,
Cable: XLPE, 300 mm² Aluminium,
Drum capacity: 2000m,
Compensation by 19 shunts reactors of 10 MVAr installed every 10 km + one at the north end,
Dimension of one reactor: 2.2 x 3.5 x 1.8 m

The ICELAND PROJECT (2002)



The capacitive current of a 132 kV, 300 mm² Alu, cable at full capacity is close to 800 A, the nominal current being only 242 A, compensation is compulsory !

4 – Reactive Power

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Answer # / Country	P: MVA U: kV L: km	Qc = CωU²xL MVAr	Ql = 3LωI²xL MVAr	Compensation MVAr
1 / Spain / Morroco (1998)	700 MW 400 kV 28,5 km	**365 MVAr** (cables) (329 + 36)	**9,5 MVAr** (Cables : 7,5+2)) In = 1060 A	150 + 2 x 125 **= 400 MVAr**
3 / Canada (Vancouver Island / Main Land) **(1993)**	…..MVA 500 kV 37 km	**1160 MVAr**		8 shunt reactors 135 MVAr **= 1080 MVAr** + (SVC / TSR = 135 MVAr inductive 165 MVAr capacitive)
4 / Singapore (1988)	…. MW 230 kV ….km			100 + 50 = **150 MVAr** (SVC / TCR)
6 / Spain (San Sebastian de los Reyes – Loeches – Morata) **(2003)**	2x1720 MVA 400 kV 12,7 km	146,7 MVAr per circuit **= 293 MVAr**	50,7 MVAr per circuit **= 101,4 MVAr** Imax = 2482 A	2 x 150 = **300 MVAr**
10 / Italy (Calabria / Sicilia) **(1984)**	1000 MW 400 kV 8,3 + 1,8 km	**170 MVAr** 136,4 + 33,6	**5,0 MVAr** 2,8 + 2,2 In = 1443 A	**150 MVAr**

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Answer # / Country	P: MVA U: kV L: km	$Qc = C\omega U^2 xL$ MVAr	$Ql = 3L\omega I^2 xL$ MVAr	Compensation MVAr
15 / Japan	2x1200 MW 500 kV 22,2 km	**488 MVAr** par circuit	-	2 x 250 = **500 MVAr** (to be verified: is it for the two links?)
16 / Japan (Shin-Keiyo Toyosu)	900 MW 2 circuits 500 kV 39,8 km	**718,6 MVAr** per circuit	**15,8 MVAr** per circuit In = 1040 A	2 x 300 = **600 MVAr** per circuit : 1 to each end
17 / Japan (Katsusnan Setagaya Line)	302 MW 275 kV 32,5 km	**162 MVAr**	-	**150 MVAr**
21 / Korea (Sin Seongdong)	523 MW 345 kV 17 km	**235,1 MVAr**	-	2 x 100 **= 200 MVAr**
22 / Korea (Nan Busan)	523 MW 345 kV 22 km	**304,2 MVAr**	-	2 x 200 **= 400 MVAr**

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Answer # / Country	P: MVA U: kV L: km	Qc = $C\omega U^2 xL$ MVAr	Ql = $3L\omega I^2 xL$ MVAr	Compensation MVAr
23 / Korea (Sin Yeongdeungpo) **(2004)**	955 MW 345 kV 10 km	**89,7 MVAr**	**9.1 MVAr** In = 1598 A	**200 MVAr**
24 / Denmark **(2004)**	2 x 1000 MVA 400 kV 14 km	126,6 MVAr par circuit **= 253 MVAr**	3,35 MVAr/ circuit **= 6.7 MVAr** In= 1400 A	100 +140 **= 240 MVAr**
26 / Germany (Berlin Diagonal)	2x1120 MVA 380 kV 15,7 km	206 MVAr par circuit **= 412 MVAr**	31,2 MVAr/ circuit **= 62.4 MVAr** In= 1700 A	80 MVAr/cct **= 160 MVAr** **(to be verified)**
27 / Germany (Berlin Diagonal) **(1999)**	2x1150 MVA 380 kV 11,9 km	97 MVAr par circuit **= 194 MVAr**	23,9 MVAr/ circuit **= 47.8 MVAr** In= 1747 A	80 MVAr/cct **= 160 MVAr** **(to be verified)**

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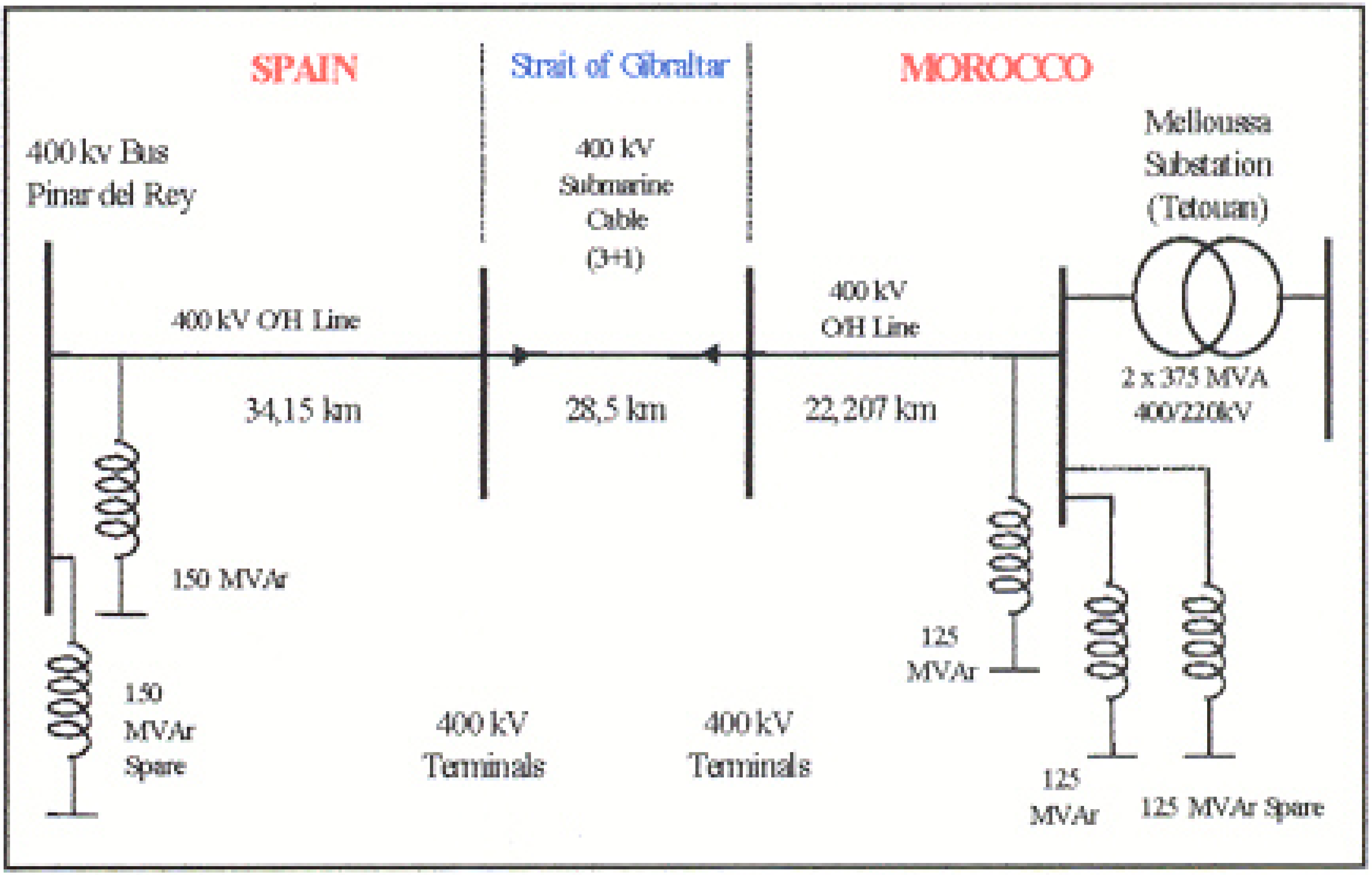
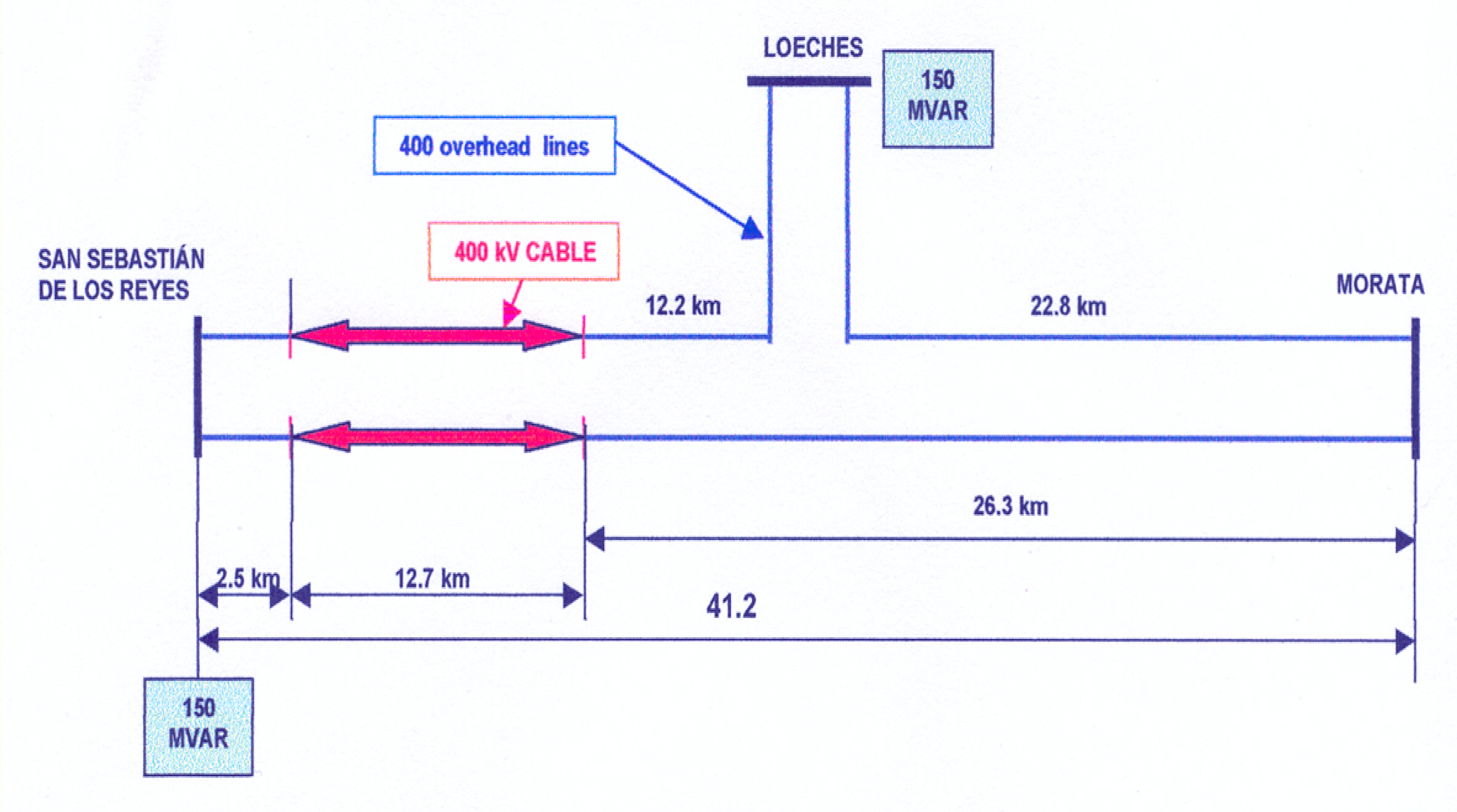
Answer # / Country	P: MVA U: kV L: km	$Qc = C\omega U^2xL$ MVAr	$Ql = 3L\omega I^2xL$ MVAr	Compensation MVAr
37 / Japan (Yokohama-Kouhoku)	700 MW 275 kV 20 km	**133 MVAr**		**150 MVAr**
38 / Australia (1970)	660 MVA 330 kV 19,7 km	**247.9 MVAr**		100 et 150 **= 250 MVAr**
39 / Australia (1970)	900 MW 330 kV 28 km	**332 MVAr**		100 + 250 **= 350 MVAr**
43 / Belgium (2004)	2 x 285 MVA 150 kV 30 km	**70.1 MVAr** per circuit	**11.2 MVAr** per circuit	**No compensation**

Spain / Morocco #1



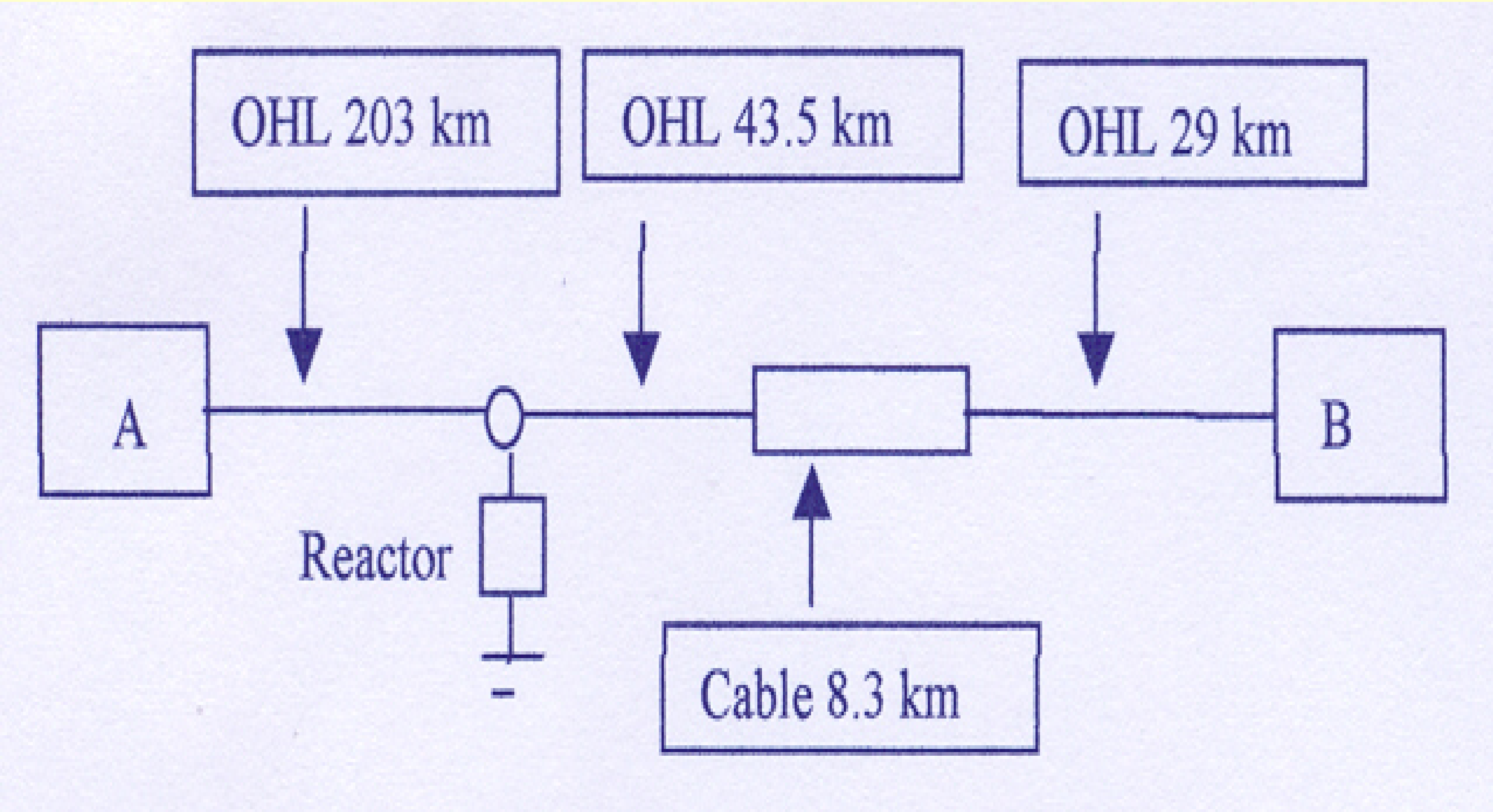
Spain / Madrid #6

Link « San Sebastian de los Reyes – Loeches – Morata »



South Italy #10

Link « Calabria - Sicilia», 400kV, 1000 MVA



5 – Why a compensation?

Why a compensation?

Answer # / Country	Why is a compensation of the reactive power achieved?
1 / Spain / Morocco	Compensation of the reactive power and voltage control
3 / Canada	To limit overvoltage during normal network conditions. Stabilize 132 kV voltage on Vancouver island in conjunction with major faults in the mainland power supply
4 / Singapore	Automatic Compensation of the load variations on a continuous basis. Stabilise 230kV network under abnormal load. Less need for operating of circuit breakers, with subsequent savings of maintenance costs as well as increasing operational reliability.
6 / Spain (San Sebastian de los Reyes – Loeches – Morata)	Steady state condition: to maintain the same voltage profile as before the insertion of the cables and to maintain the previous load flow configuration
10 / Italy (Calabria / Sicilia)	To limit the capacitive power of the OH Line further increased by the presence of the 8 km long cable. The compensation was performed to solve the following problems: - steady state condition: the weakness of the network in 1986 from Load Flow Analysis. - Transient conditions: switching and temporary overvoltage due to: energising; single phase reclosing; load rejection (and fault cleaning)

Why a compensation?

Answer # / Country	Why is a compensation of the reactive power achieved?
15 / Japan	
16 / Japan (Shintoyosu)	To control reactive power and to compensate for charging capacitance in light load
17 / Japan (Katsunan-Setagaya)	To control reactive power and to compensate for charging capacitance in light load
21 / Korea (Sin Seongdong)	Prevention of voltage rising at receiving end by Ferranti Effect
22 / Korea (Nan Busan)	Prevention of voltage rising at receiving end by Ferranti Effect
23 / Korea (Sin Yeongdeungpo)	Prevention of voltage rising at receiving end by Ferranti Effect
24 / Denmark	To avoid voltage problems in the network and to compensate for the excess of capacitive reactive power generated in the network.
26 / Germany	

Why a compensation?

Answer # / Country	Why is a compensation of the reactive power achieved ?
27 / Germany	
37 / Japan (Yokohama-Kouhoku)	To control reactive power and to compensate for charging capacitance in light load
38 / Australia	The shunt reactors are switched on to avoid excessive charging Vars flowing into the 330 kV and 132 kV systems at times where the system is at a light load. Otherwise at times of high loads, the shunt reactors may be switched off to take advantage of the high cable charging MVArs to support the Sydney area voltage.
39 / Australia	The shunt reactors are switched on to avoid excessive charging Vars flowing into the 330 kV and 132 kV systems at times where the system is at a light load. Otherwise at times of high loads, the shunt reactors may be switched off to take advantage of the high cable charging MVArs to support the Sydney area voltage.
43 / Belgium	No compensation: there is a need of reactive power on the network

Why a compensation? To Sum Up:

- **The reactive capacitive current of a cable loads the conductor and limits its active transmission capacity.**
  - **Control and compensation of the cable capacity**
- **Overvoltage Limitation by Ferranti effect.**
  - **Control of the voltage in steady state conditions(10%), temporary or transient**

But, in some cases, the cable capacity is used at low load to compensate the inductive power and to maintain the network voltage
(see for instance the Belgium link # 43)

6 – Operating Results

Operating Results

Answer # / Country	Experience in service
1 / Spain / Morocco	Dimensioning of the reactor was done to avoid overvoltage due to resonance and transient phenomena.
3 / Canada	
4 / Singapore	
6 / Spain (San Sebastian de los Reyes – Loeches – Morata)	Dimensioning of the reactor was done to avoid overvoltage due to resonance and transient phenomena.
10 / Italy (Calabria / Sicilia)	Dimensioning of the reactor was done to avoid overvoltage due to resonance and transient phenomena.
15 / Japan	
16 / Japan (Shintoyosu)	L-C oscillations may occur
17 / Japan (Katsunan-Setagaya)	L-C oscillations may occur

Operating Results

Answer # / Country	Experience in service
21 / Korea (Sin Seongdong)	No problem
22 / Korea (Nan Busan)	No problem
23 / Korea (Sin Yeongdeungpo)	No feedback from the operating company
24 / Denmark	The operation started on March and August 2004, so it is too early to get information about the operating behaviour.
26 / Germany	No problem
27 / Germany	No problem
37 / Japan (Yokohama-Kouhoku)	L-C oscillations may occur
38 / Australia	The cable has been installed at the end of the 70's, i.e; some thirty years ago!
39 / Australia	The cable has been installed at the end of the 70's, i.e; some thirty years ago!
43 / Belgium	New link.

7 – Economical Aspects

Some preliminary economical data

Answer # / Country	Compensation MVAr	Occupied space m^2	Cost en M€ 1€ = 1,27 $ 1€ = 134 JPY On February 7th 2005	Compensation cost k€ / km of the link
1 / Spain / Morocco	150 + 2 x 125 = 400	3 x 800 (6 m^2 / MVAr)	2,4 M€ / réactance 16 to 19 k€/MVAr	248 k€ / km (700 MW, 400 kV, 29 km)
3 / Canada	8 x 135 + SVC = 1080 + SVC	2900 (2.7 m^2 / MVAr)	-	
4 / Singapore	100 + 50 SVC = 150	500 + 400 (6 m^2 / MVAr)	-	
6 / Spain (San Sebastian de los Reyes – Loeches – Morata)	2 x 150 = 300	2 x 800 (5.4 m^2 / MVAr)	2,4 M€ / reactor 16 k€/MVAr	378 k€ / km (2 x 1720 MW, 400 kV, 12.7 km)
10 / Italy (Calabria / Sicilia)	150	180 (1.2 m^2 / MVAr)	1 M€ 6.7 k€/MVAr	120 k€ / km (1000 MW, 380 kV, 8.3 km)

Some preliminary economical data

Answer # / Country	Compensation MVAr	Occupied space m^2	Cost en M€ 1€ = 1,27 $ 1€ = 134 JPY On February 7th 2005	Compensation cost k€ / km of the link
15 / Japan	250	240 (1 m^2 / MVAr)	-	-
16 / Japan (Shintoyosu)	2 x 300 = 600	180 + 220 (0.7 m^2 / MVAr)	12,86 M€ (760 MJPY+ 960 MJPY) 21.4 k€/MVAr	323 k€ / km (900 MW, 500 kV, 39.8 km)
17 / Japan (Katsunan-Setagaya)	150	120 (0.8 m^2 / MVAr)	2,69 M€ (360 MJPY) 17.9 k€/MVAr	83 k€ / km (302 MW, 275 kV, 32.5 km)
21 / Korea (Sin Seongdong)	2 x 100 = 200	2 x 128 (1.3 m^2 / MVAr)	0,41 M€ (0.525 M$) 2 k€/MVAr	24 k€ / km (523 MW, 345 kV, 17 km)
22 / Korea (Nan Busan)	2 x 200 = 400	2 x 150 (0.8 m^2 / MVAr)	0,85 M€ (1,083 M$) 2.1k€/MVAr	38,6 k€ / km (523 MW, 345 kV, 22 km)

Some preliminary economical data

Answer # / Country	Compensation MVAr	Occupied space m^2	Cost en M€ 1€ = 1,27 $ 1€ = 134 JPY On February 7th 2005	Compensation cost k€ / km of the link
23 / Korea (Sin Yeongdeungpo)	200	150 (0.8 m^2 / MVAr)	O,864 M€ (1,1 M$) 4,32 k€/MVAr	86,4 k€ / km (955 MW, 345 kV, 10 km)
24 / Denmark	100 + 140 = 240	-	-	
26 / Germany	80	140 (1.75 m^2 / MVAr)	-	
27 / Germany	120	140 (1.17 m^2 / MVAr)		

Some preliminary economical data

Answer # / Country	Compensation MVAr	Occupied space m^2	Cost en M€ 1€ = 1,27 $ 1€ = 134 JPY On February 7th 2005	Compensation cost k€ / km of the link
37 / Japan (Yokohama-Kouhoku)	150	190 (6 m^2 / MVAr)	1.94 M€ (260 MJPY) 12.9 k€/MVAr	97 k€ / km (700 MW, 275 kV, 20 km)
38 / Australia	100 + 150 = 250			
39 / Australia	100 + 250 = 250			
43 / Belgium	No compensation			

Some costs in rural area ("Piketti" report)

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Insulated cables / Overhead lines

Costs	63 / 90 kV	225 kV	400 kV
Investments / km	300 - 600 k€ 140 - 200 k€	600 - 900 k€ 200 k€	6 600 k€ 500 k€
Losses / km	30 - 60 k € 28 - 40 k €	120 - 180 k€ 200 k€	1320 k€ 500 k€
Maintenance / km	6 k€ 25 k€	6 k€ 25 k€	6 k€ 25 k€
Reparations / exceptional damages /km	0 k€ 2 k€	0 k€ 2 k€	0 k€ 5 k€
Taxes	0 k€ … k€	0 k€ 34 k€	0 k€ 28 k€

Hypothesis for Cost Calculation of losses: operation 6000 h/y,
Cost of losses: 0,035 €/kWh, discount rate 8%, discount factor for 45 years: 13.

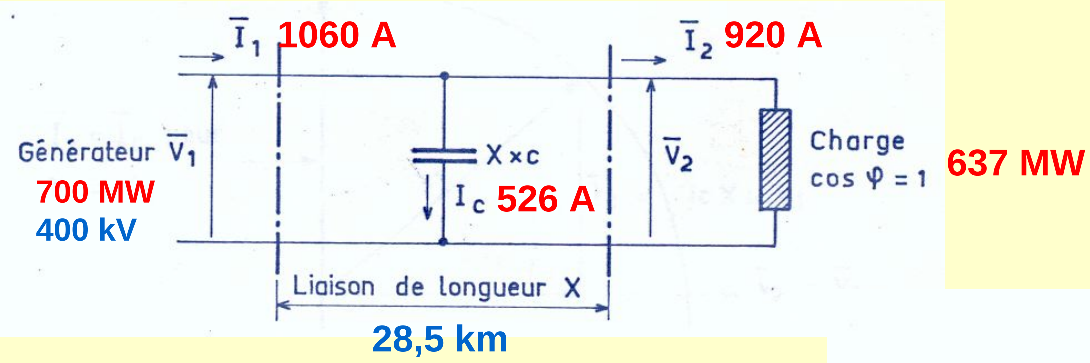
Simplified Case Study: Spain / Morocco

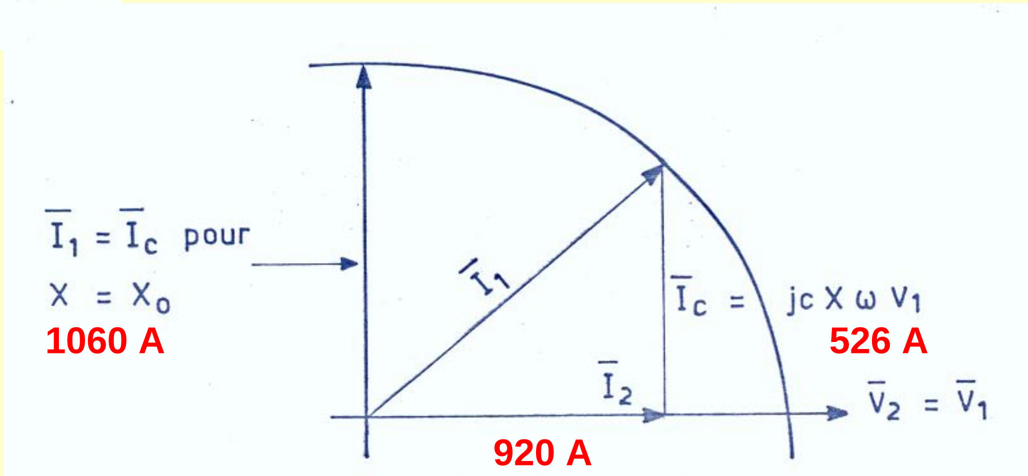
Link Spain/Morocco

Power: 700 MW

400 kV, 1060 A,

28.5 km





Active power losses: 700 MW - 637 MW = 63 MW
Cost: 63 000 kW x 6000h/an x 13 x 0,035 €/kWh = 172 M€
Compensation investment: 7,2 M€

8 – To Sum Up

To Sum Up

1. About 50 HV to EHV insulated power cable link longer than 10 km are operated throughout the world.
   The longest one are installed in Canada (500 kV, 37 km, 1993) and in Japan (500 kV, 39.8 km, 2000).
2. The longest links require fixed or adjustable compensations of the reactive power obtained by means of trusted technologies
3. Space occupation and costs of these compensations are still very different depending on the technologies, the links, and the countries: (1 to 6 m^2/MVAr et 2 to 20 k€ / MVAr for 345 or 400 KV). These costs remain low when compared to the energy saving. (to be analysed)
4. Operating conditions and results are satisfactory in steady state as well as in exceptional operating conditions. Some of them are in service for more than 20 years !