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## WETS-07 Reactive Compensation



# Agenda

- What is reactive power?
- Uncompensated cable links – critical length
- Tuned compensation – perfect balance
- The Icelandic story – an example from a pre-study done by ABB
- Some conclusions

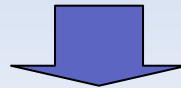
# What, in fact, is reactive power....

- Basic truths:

1. No macroscopic change in energy can be instantaneous
2. Electrical power can only be transmitted with interacting electric and magnetic fields (EM-fields)
3. Electrical active power is created with voltage (electrical field) and current (magnetic field) in phase with each other

- If U and I not in phase, we introduce:

1. Inductance (L) → a constant related to magnetic energy
2. Capacitance (C) → a constant related to electrical energy



- The reactive power is a mathematical (engineering) way to take into account the time lags between voltage and current in a transmission system !

- If U and I in phase: Active Power
- If U and I not in phase: Reactive Power

## ... and which are the consequences for the network, using cables?

- Voltage support during high load conditions
- Too high voltage during low load conditions
- Normally lower losses but for long uncompensated links, higher losses
- Higher short circuit power in the network
- May improve transient stability
- May prevent voltage collapse

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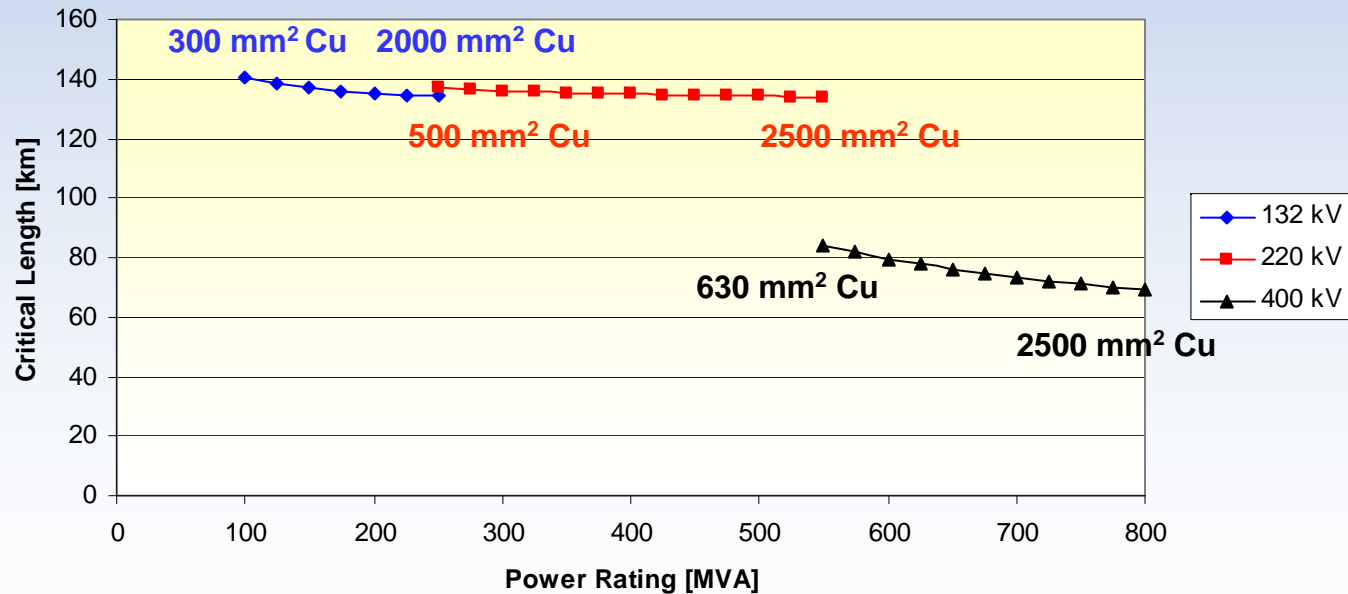
- What is reactive power?
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# Uncompensated Cable Links – Critical lengths (1)

- Typically, the capacitance increases with the rating, i.e. the larger conductor cross-section the higher capacitance (C'):

- 132 kV: 0,13 to 0,34 μF
- 220 kV: 0,13 to 0,27 μF
- 400 kV: 0,13 to 0,23 μF

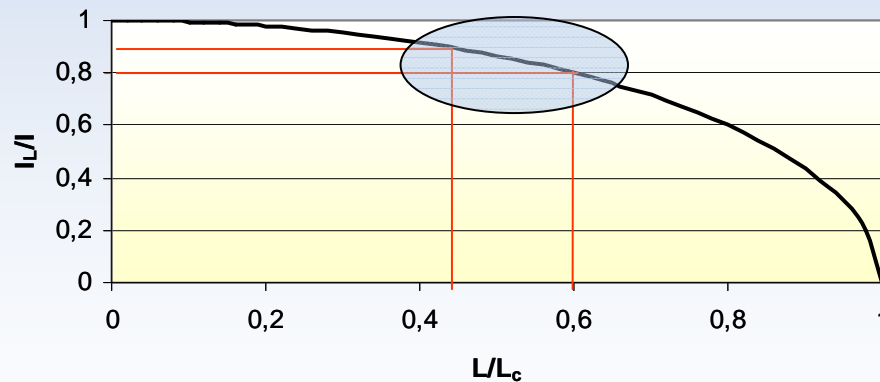
$$L \approx \frac{P_{tot}}{n\omega \cdot C' U_o^2} \quad (\text{Simplified formula})$$



## Uncompensated Cable Links – Critical lengths (2)

U [kV]	132 kV	220 kV	400 kV
Q [MVar/km, and phase]	0,2 – 0,7	0,7 – 1,4	2,2 – 4,2

U [kV]	132 kV	220 kV	400 kV
Critical length [km]	130-150	120-140	60-90



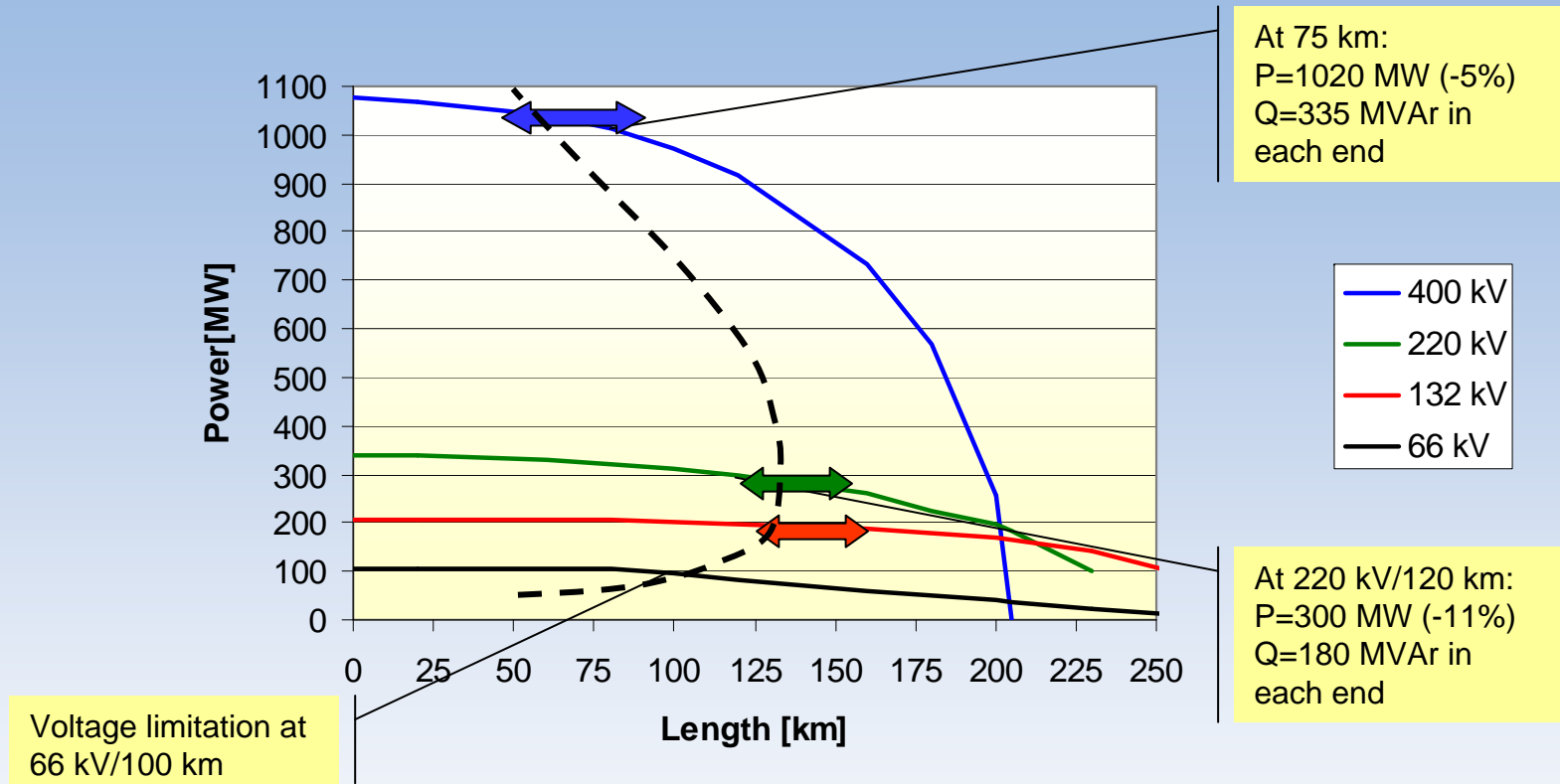
There may be either technical or economical reasons for compensation with 10-20% reduction in current or 40-60% of  $L_c$ !

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# Tuned Shunt Compensated Cable Links

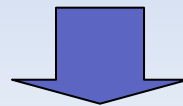


↔ Indicates normal range of critical length

- - - Indicates possible approximate border between AC and DC

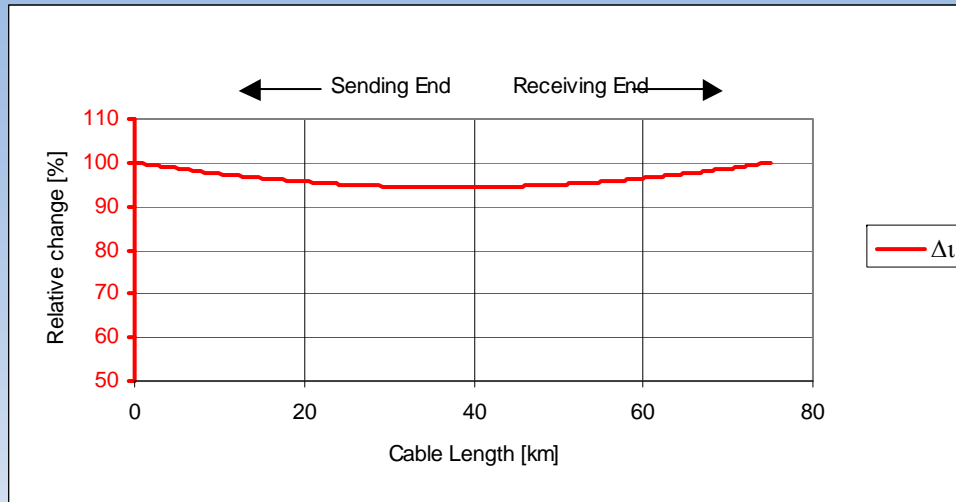
## Cost example for fixed inductive compensation 220 kV/400 MW

- Needed power consumption for 120 km:  $2 \times 180 = 360$  MVar
- Cost for the cable for 60 km ( $0,5 L_c$ ) : 1 curr/MVA
- Cost for fixed shunt compensation: 0,15 curr/MVar
- 10% (=40 MW) decrease in rating: 40 curr
  - $\Rightarrow$  Available MVar's is  $40/0,15 = \underline{267 \text{ MVar} < 360 \text{ MVar}}$
- 20% (=80 MW) decrease in rating: 80 curr
  - $\Rightarrow$  Available MVar's is  $80/0,15 = \underline{533 \text{ MVar} > 360 \text{ MVar}}$

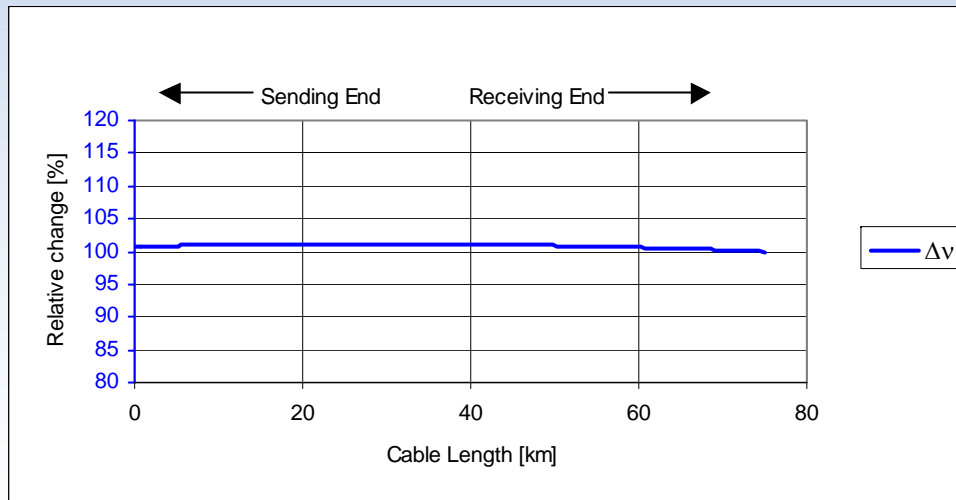


- Conclusion: It may be economical justified with fixed inductive shunt compensation when the derating is between 10-20%.

# Typical voltage and current profiles for a tuned system



Current profile



Voltage profile

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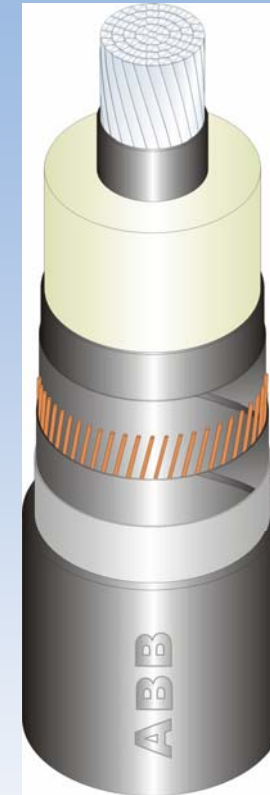
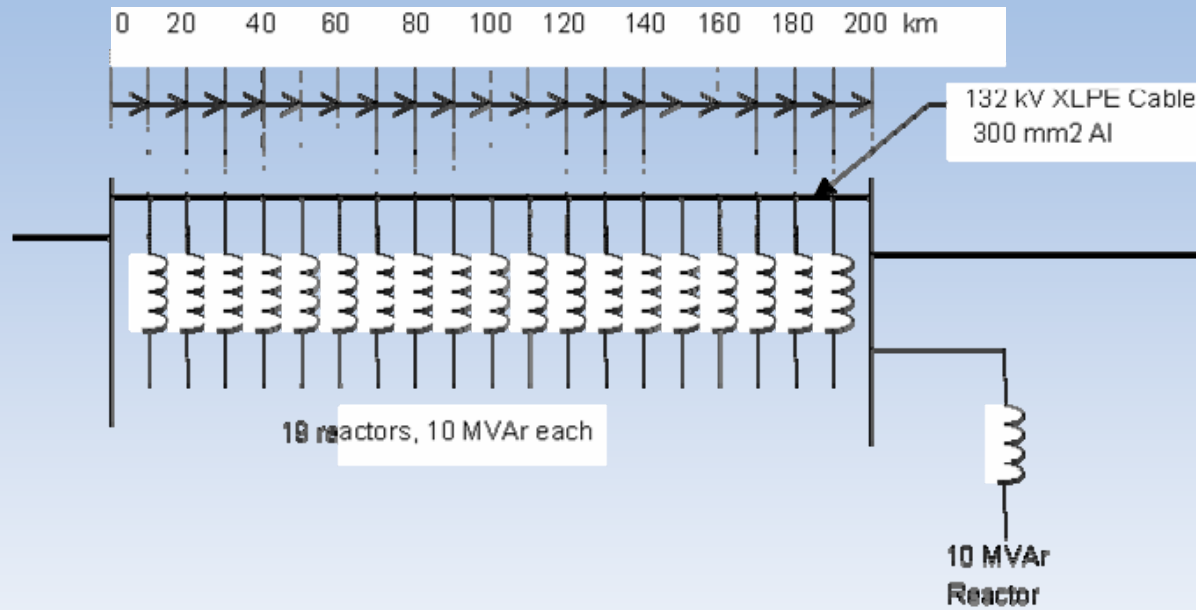
# The Icelandic story – (not a realized project)

Ref. – Cigre' Paper 21-201, 2002



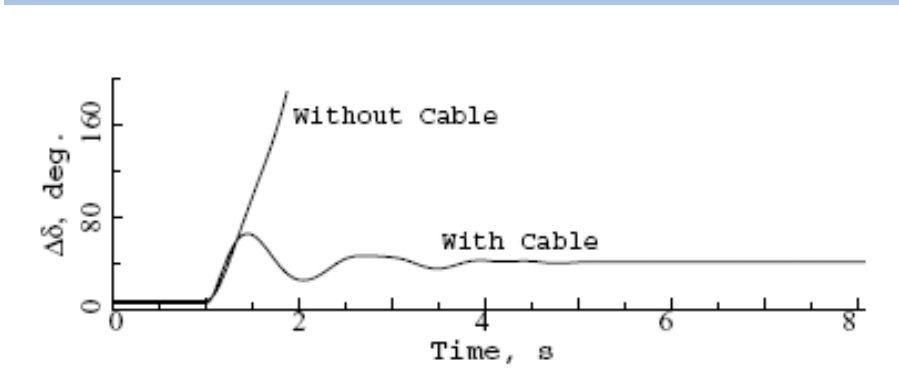
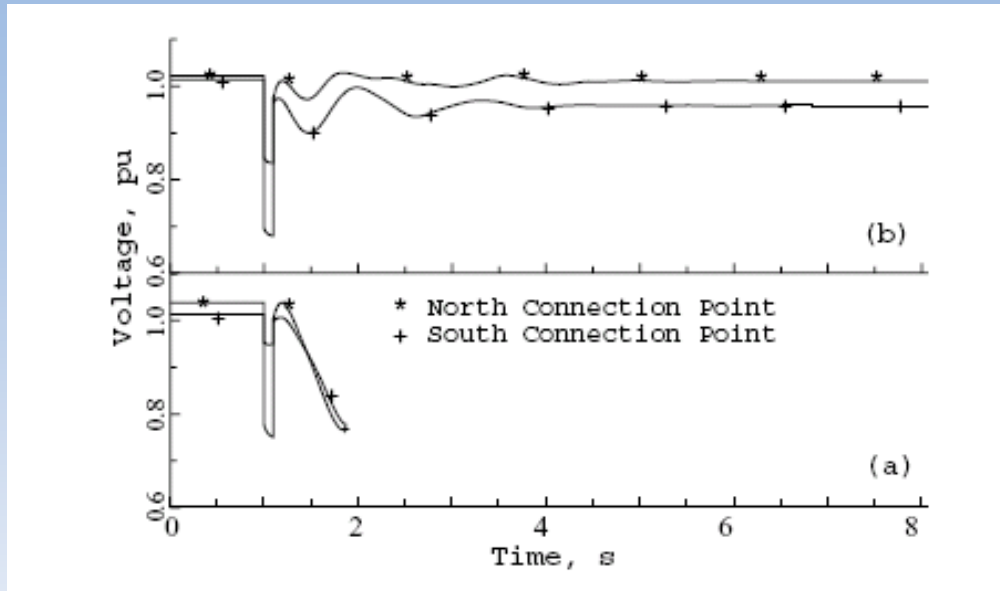
- Severe weather conditions implied a lot of faults on the OH-line ring.
- This implied problems with transient stability in the system.
- **Solution: A purpose-built 200 km long XLPE cable crossing the island.**

# The solution...



1x300, Al  
Ins. thickness: 12 mm  
Cu-wires/Al-laminate  
HDPE-sheath

## ... and the benefits of using the cable here



- The cable links is preventing post fault voltage collapse and improves transient stability for the whole network!

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# Optimum reactive power control - Conclusion

- Degree of compensation changes with the characteristics of the network and the reactive power loads
- If the cable link is operating "far from" the loads (inductive machines etc), the higher degree of compensation you need. Remote synchronous generators has a  $\cos(\phi)$  close to 1.
- In EHV networks it may be sufficient with fixed compensation with a high degree of compensation. For long lengths, a huge amount of reactive power is needed, though.
- In HV networks (which are closer to the loads) a lower degree of compensation may be needed. Additionally, SVC-Classic or SVC-Light control may be needed.
- Voltage limitations (5-10%) are mainly present in HV networks below (100 kV/50-100 km) for tuned systems. For higher voltages/lengths, the charging current, losses etc set the limitations.
- 40-60 % of the critical length (10-20% decrease in rating)– take a look if inductive shunt compensation may be cost efficient!
- There is no extra "MW-loss" for HVDC-Light systems. It is always interesting to look at the extra advantages, which are offered with DC-control as well as the other known benefits from extruded cable systems in general.

Thank You !