Comparison between early electrification grand transmission projects and the study of CIGRE C1.35 on Global Grid for 2050 from economic point of view

Workshop TGEG 19
(Technologies for Global Energy Grid)
C1 Power system development and economics
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Versailles, 27 June 2019
Edited and prepared by Prof. Ahdab Elmorshedy

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Cigre Egypt Site

Moere.gov.eg/cigre
http://130.61.195.178/

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Focus on increasing global interconnections and decarbonization

Electricity is becoming more and more the cornerstone of functioning our society

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PLAN OF PRESENTATION

1. Intention of contribution
2. Early electrification & electricity affordability
3. Cigre study of Global grid with some indications
4. Decarbonization pathway, economy & grand projects
5. Conclusion

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1. Intention of contribution
Importance of transmission

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Experiences in different societies after dissemination process of Cigre WG C1.35 results on global

- Very different views of thinking.
- Some doubts in the grand projects between continents,
- Some thoughts was talking about utopian projects,
- Some thoughts were very positive and believe it will be carried out in near future particularly due to reduction of CO_2 equivalent emissions.

Question?

- What we can learn from the past and what we can do for the future?

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Clean energy and interconnections

INTERCONNECTION CONCEPT

- Supports a balanced coordination of power supply of all interconnected countries.
- Enables clean energy transmission
- Take advantage of diversity of clean energy.

Increase clean energy consumption

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2. Early electrification & electricity affordability

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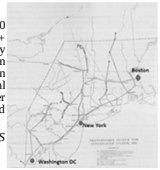
A Superpower System for the Region between Boston and Washington DC

Plan for Superpower system was projected for 1930 with size of 60-300 MW (TPP, HPP) + Transmission 110 kV/220 kV……Murray estimated that, compared with the cost of an unintegrated system supplying the same region, an investment of 1 billion $ would result in an annual savings of more than $200million because of higher load factor and other economies of integrated system……..20% savings

***William S. Murray**, Dept. of the Interior, US Geological survey, paper 123, W,DC, GPO, 1921)*



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Global electricity production in 1900 was 12 TWh and In 2000 about 15000 TWh. In 2019 about 26000 TWh.

Who open the door to electrification? **INNOVATIONS**

1. CONDUCTORS stranded AL conductors 1899, ACSR… 1907, AAAC…1939

2. INSULATORS: New type of suspension and strain types, June 1907….first OHL over 100 kV

3. GENERATORS: 1911…Ludwig Roebel (BBC, Mannheim) Invented stator bars for turbo generator –special method for windings by limiting eddy currents and enables first large generators over 20 MVA.

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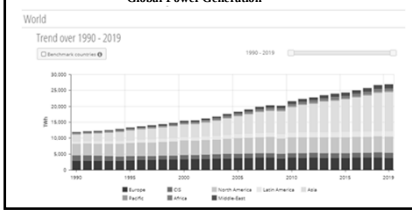
Global Power Generation



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Pan-European Transmission network project by Oscar Oliven, from 1930

- 2nd World Power Conference in Berlin, 1930. German engineer Oscar Oliven proposed pan-European 400 kV Transmission network of 9750 km. Evaluated cost of investment for T&G was 240 billion CHF (Swiss Franc) for 20GW load.
- Value of USD in 1930 was equal 5.16 CHF
- Value of USD in 2019 is almost equal 1 CHF.

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European grand projects in early time of electrification were:

-Georges Viel, 3000 km, 400kV, 79GW, 10,4 GCHF, sav. (10%)

-Ernst Schönholzer, 3800 km, 660kV, 6.4 GW, 25GCHF, sav. 24Mt

-Oscar Oliven, 9750 km, 400kV, 20GW, 240 GCHF

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Comparison Oliven's project vs. CIGRE C1.35

1 USD (1930) = 15 USD (2019) con. consumer price index+inf.

Oliven's project re-evaluated to 2019 value:

Production capacity: 20 GW

Annual generation: 100 TWh

Annual cost: 70 GUSD

Total specific cost: 700 USD/MWh (610 EUR/MWh)

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Electricity was very expensive and not attainable for all.

CIGRE C1.15 GG_1 project evaluation in 2019:

Production capacity: 14 920GW

Annual generation: 40 300TWh

Annual cost: 1820GEUR

Total specific cost: 48 EUR/MWh

non-integrated and integrated intercontinental global electrical grid

GG_1 GG_o

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1975 –Competitive project for Southern Europe / to build coal TPP or import hydro energy from large HPP Inga (Congo river)Project made by prof. Vladimir Slebingerin Ljubljana, Slovenia

Possibility for electricity production in the river Congo are about 1125 TWh

Very short history of the INGA project and researches:

- 1926/1928, Van Deuren, first Belgian project: HPP1 (351 MW)+ HPP2 (3150 MW)
- 1960, Second Belgian project Abelinga (Brussels): 28.850 MW (210 TWh) with Grand Inga dam.
- 1971, Reconstruction of the project and increasing installation on 39.680 MW (288 TWh), with water flow 33.000 m3/s.
- 1975, New variant with increasing on 300 TWh, with calculating cost of 5 USD/MWh.
- With same condition of loans would be cost of energy from z Grand Inga about 8x less than at HPP Djerdap or Asuan.

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Slebinger's new project in 1975

- His proposal for 60 GW in 1975 considered environmental conditions from that time, new ideas for the units of 1000 MVA, transmission with 1500 kV, new concept for submarine cables for deep sea, conversion of AC/DC/AC with thyristors, what was very new for that time.
- Price for new TPP in Southern Europe.
- Considering very low consumption in Sub-Saharian Africa he proposed 80% of production of electricity for new industry in Africa and transit of surpluses to Europe.
- In study, he considered 5 African evacuation cones (N. Africa, Egypt, Israel, Central Africa, S. Africa) and 3 zones for transit to Europe: Direction WEST (Spain + France), EAST (TR, CY, GR) and Central direction from Tunis to Italy.

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- Differently from other proposals he conceived GRAND Inga HPP for 60 X 1000 MW = 60.000 MW with annual production 365 TWh and LF=0.7.
- The largest units in both today largest HPP in the world (Three Gorges & Itaipu) have units of 700 MW and today designers try to make concepts for 1000 MW units.
- Considering to his evaluations of the specific cost for producing MWh and re-evaluate to the present time, the cost should be 14.5 USD/MWh (considering re-evaluation of USD from year 1975 to 2019).

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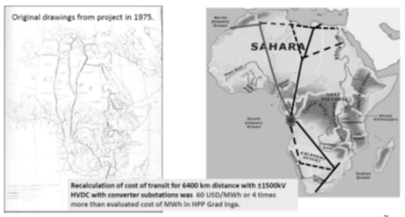

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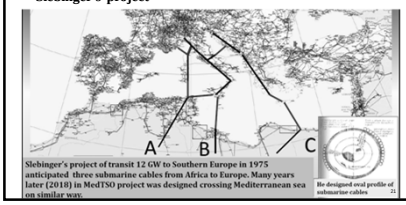
Interconnections between Africa and S. Europe in the Slebinger's project



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GLOBAL HYDRO POTENTIALS:

Gross potential : 38.600 TWh/a

Technically possible to use for HPPs: 14.600 TWh/a

Economical potential for HPPs: 8.770 TWh/a

Total production in 2016: 4.110 TWh (47%)

Average globally utilized: 47 %

Average utilized in Europe: 45 %

Average utilized in Africa: 13 %

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- Africa represent 20% of surface of Earth and is larger than Europe, USA and China together.
- In Africa there are 50% of global hydro potentials and Congo river presenting almost half.
- **Global decarbonization goals** should be a great opportunity for better utilization of the world hydro potentials.
- Great projects from past could be re-designed and prepared as unified global program for decarbonization of energy sector.

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Inga-Kolwezi transmission line, Congo

- **Congo's 1,700km-long Inga-Kolwezi transmission line, formerly known as the Inga-Shaba link.**
- **It transmits power from Inga Falls on the Congo River to the copper mining district of Katanga in the Democratic Republic of Congo (DRC).**
- **The 500kV transmission line, with a rated capacity of 560MW, is owned and operated by Democratic Republic of Congo's (DRC) national electricity utility, Société Nationale d'Electricité (Snel).**

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Main data

Commissioning year:	Upgrade: 2014 1982
Power rating:	560 MW
No. of poles:	2
AC voltage:	220 kV (both ends)
DC voltage:	±500 kV
Length of overhead DC line:	1,700 km
Main reason for choosing HVDC:	Long distance
Application:	Connecting remote loads Upgrade

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3. Cigre study of Global grid with some indications

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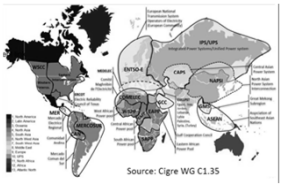
Regional initiatives



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Regional initiatives

- Motivations
  - ➢Reliability and Security
  - ➢Sustainability
  - ➢Competition
- Different stages of development mainly to political issues
- Compromise between national independency and an international weigh provided an economic Community
- In 2050, 13 zones seen internally as "copper plates"

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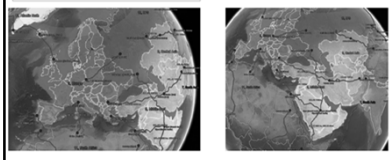
North Atlantic – Europe – UPS – North Africa – Middle East

Europe – North Africa – Middle East – UPS – Central Asia – South Asia



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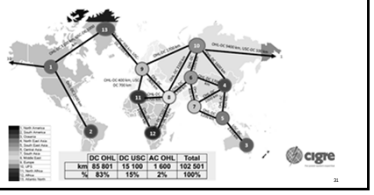
Interconnections selected

20 interconnections, mainly DC links, and OHLs technologies



	DC OHL	DC USC	AC OHL	Total
km	85 801	15 100	1 600	102 501
%	83%	15%	2%	100%

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Comparison between non-integrated and integrated intercontinental global electrical grid

YEAR 2050	Gen capacity GW	Generation TWh/a	Total cost/a G€	Cost €/MWh	RES %	CO_2 equiv. Mt/a
GG_{ni}	13 500	39 850	2 150	54	53	850
GG_{i}	14 920	40 300	1 820	48	76	343
Difference	+10%	+1.1%	-8.5%	-11%	+23%	**-60%**

- Integrated global grid is a good option for global decarbonization goals.
- This is very good message of CIGRE study to the one of the most challenging task of present and future generation of engineers.

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4. Decarbonization pathway, economy & grand projects

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What is present global situation?

CIGRE study C1.35 considered WEC scenario („Unfinished symphony") with global average emissions (2050) per capita: **2 tons/a**. How to reach this level of emissions? ***Do we have Global grand projects for this goal?***

Emissions CO_2 equivalence

10 highest in the world

Country	Emissions Mt, 2018	population	tons/capita
1. China	9839 Mt	1 409 millions	6,99
2. USA	5170 Mt	326 millions	15,27
3. India	2467 Mt	1 330 millions	1,85
4. Russia	1693 Mt	144 millions	11,76
5. Japan	1305 Mt	127 millions	9,85
6. Germany	799 Mt	82 millions	9,74
7. Iran	672 Mt	82 millions	9,20
8. Saudi Arab. & Yem.	635 Mt	33 millions	18,58
9. S. Korea	616 Mt	52 millions	11,85
10. Canada	559 Mt	37 millions	15,49

2017

World Total: 36153 Mt CO_2

Source: Global Carbon Atlas (http://www.globalcarbonatlas.org/en/CO2-emissions)

Global averages ton per capita = 4.8

After 2012 (4.99) decline to 4.5-4.6

Source: WB

1997 – 4,48 t
2000 – 4,02 t

WEC: World Energy Council

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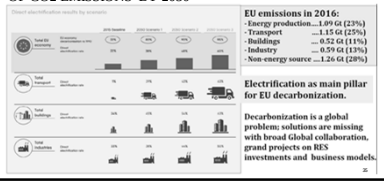
Decarbonization pathways –EU strategy

WITH ELECTRIFICATION THE EU CAN REDUCE80 -95% OF CO2 EMISSIONS BY 2050



EU emissions in 2016:
- Energy production....1.09 Gt (23%)
- Transport ....1.15 Gt (25%)
- Buildings .... 0.52 Gt (11%)
- Industry .... 0.59 Gt (13%)
- Non-energy source ...1.26 Gt (28%)

Electrification as main pillar for EU decarbonization.

Decarbonization is a global problem; solutions are missing with broad Global collaboration, grand projects on RES investments and business models.

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SOURCE: Eurelectric

EU approach plan

WHAT WILL BE NEEDED TO ACHIEVE THIS AMBITIOUS TARGET?

1. Political commitment to deep decarbonization across all regions and sectors of the economy is critical...stronger coordination across European regions.
2. Active involvement of citizens in a more decentralized power market will be a key enabler.
3. Co-operation between economic sectors will be important to make use of synergies ...
4. Efficient market-based investment frameworks and adequate market design to address the investment of high RES system.
5. Smarter and reinforced distribution grid will play an important role in integrating new market participants ...

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5. Conclusions

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What we can learn from the historic and newest grand projects?

- Grand Transmission projects from historic point of view have shown benefits for all, economic, technical and operational, increasing reliability and reinforcing the market conditions. In some historic cases it was evidenced reduction of total needed generating capacity up to 20%.
- Strengthening of transmission network brings cheaper electricity and better affordability. Extending continental macro-interconnection systems to intercontinental network will enables better conditions for decarbonization, as one of the most challenging tasks.
- Message of the CIGRE study C1.35 on Global Grid was very positive presenting many interesting results enabling further study on possible business models and market designs.
- CO_2 price (carbon tax) is a crucial driver for determine economic viability of the global interconnections.
- Decarbonization pathway should be taken more systematically considering global collaboration, new projects and also all ways of human life in the Earth.

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Thank you

"Vision without action is a daydream. Action without vision is a nightmare."

Anonymous

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