Sistemas de transmissão em Corrente Contínua

DC Transmission Systems.

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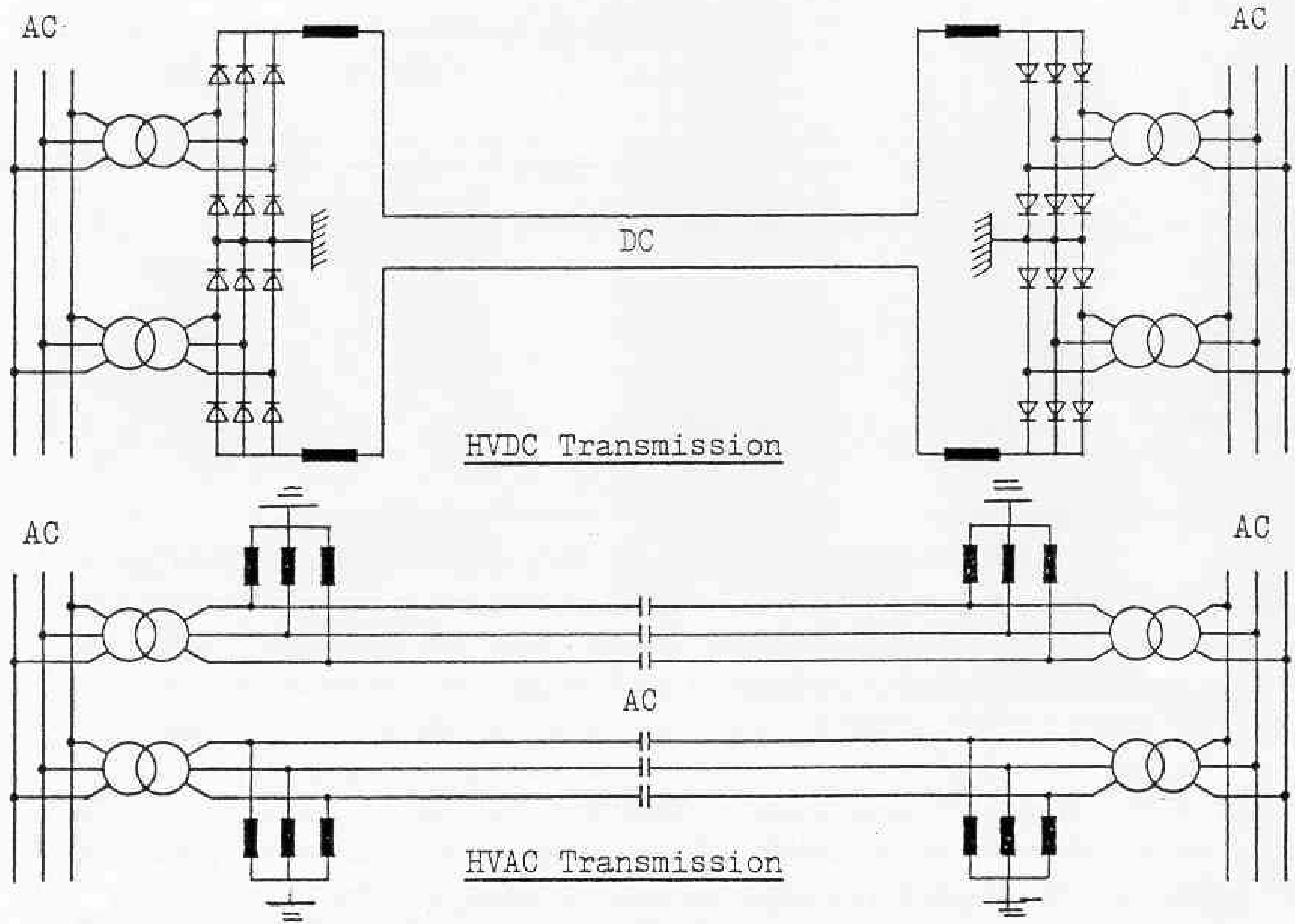
Sumario

- **Como é constituído o sistema CC**
- **Como é constituído o sistema CA**
- **Comparação CA-CC**
- **Princípio de funcionamento**
- **Sistemas CC em operação e futuros**



Additional costs for convertor stations in the HVDC transmission are balanced by savings in the transmission line itself

Corrente Alternada

Custo da linha = (A+B S) L

Custo das perdas = $\frac{C}{S} L = L \quad r \quad \left(\frac{P}{V}\right)^2 \quad \frac{1}{S}$

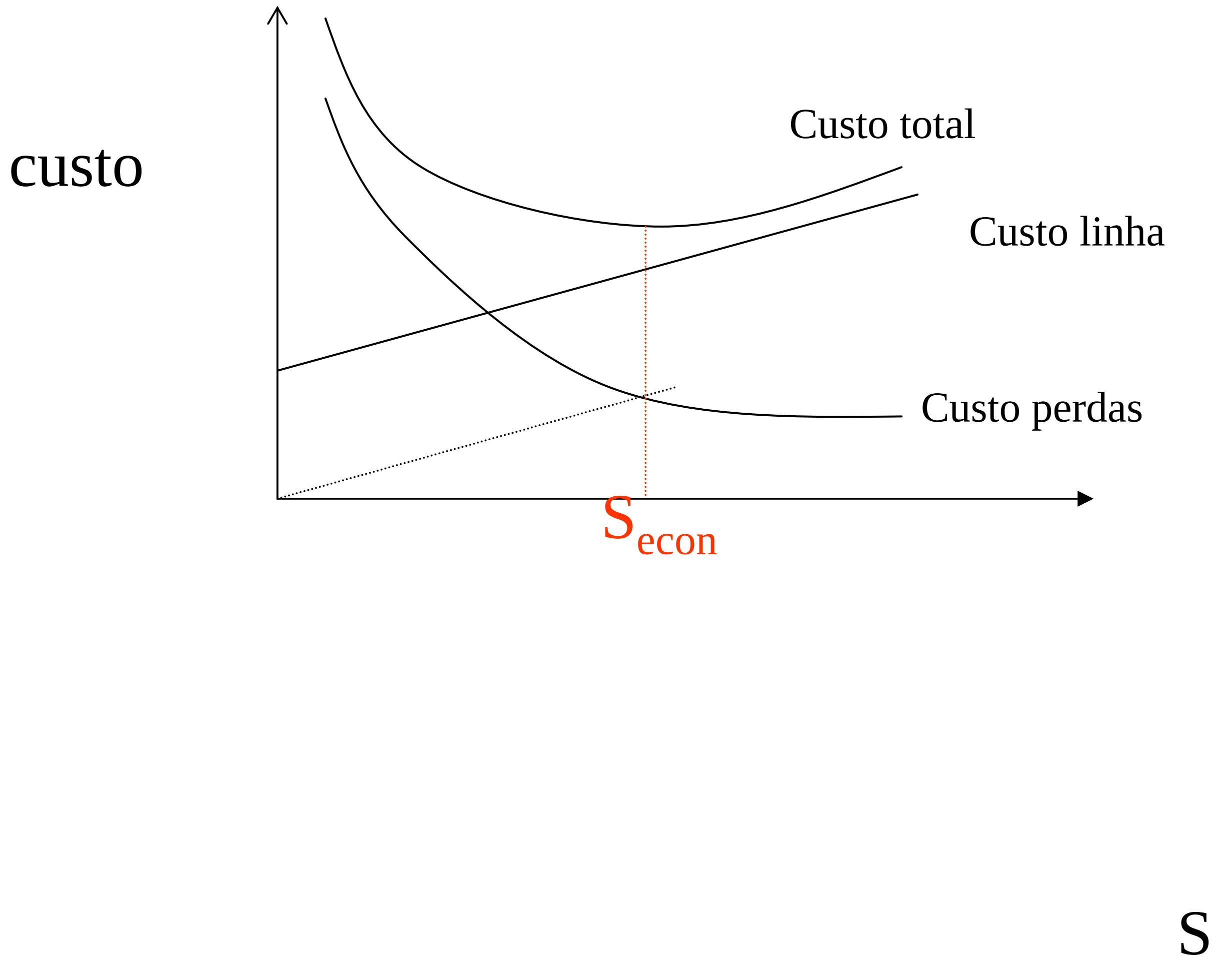
L=comprimento

S= secção Alumínio

Ct = Custo Total = $A + B\,S + \frac{C}{S}$ $\quad \frac{dCt}{ds} = B - \frac{C}{S^2} = 0 \Rightarrow \quad S_{ec} = \sqrt{\frac{C}{B}} = \sqrt{\frac{D}{B}} \left(\frac{P}{V}\right)$

Condutor econômico depende potência e tensão independe do comprimento.

Condutor econômico



Tensão Econômica CA

kV	MW
345/362	500 - 700
500/525	1000 - 1500
760/765	2000 – 3000
1000/1050	4000 - 6000

Corrente Continua

Custo sistema cc = $$C_{conv} + (A + B\,S + \frac{C}{S})\,L = C_{scc}$$

C conv = f (V,P)

Existe também uma tensão econômica

Vecon = $$\frac{dC_{scc}}{dV} = 0$$

Problema

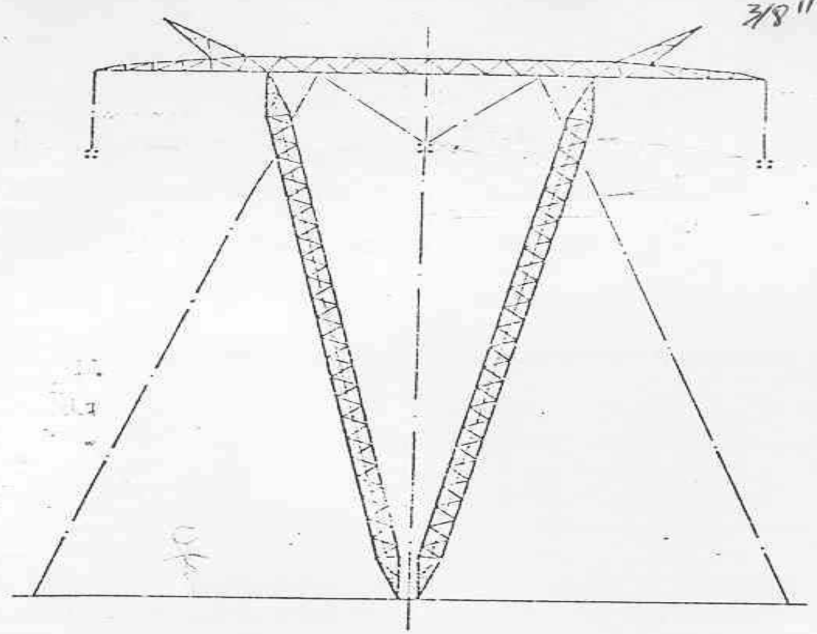
- Transmissão de 3.000 MW
- 2.000 km

CA OU CC?

Itaipu =>CA 6300MW 3X765 kV

..........CC 6300MW 2X600kV

3/8'' EHS



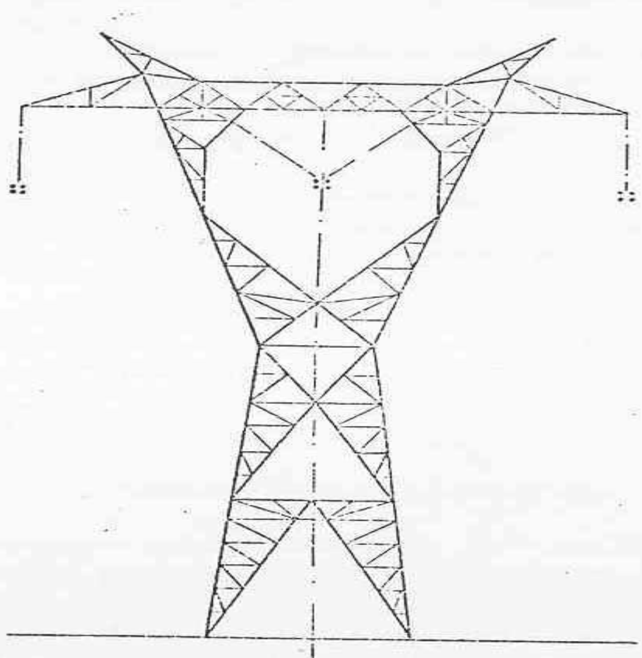
TORRE ESTAIADA
espessura da torre : w = 1,2

564 mm² Al

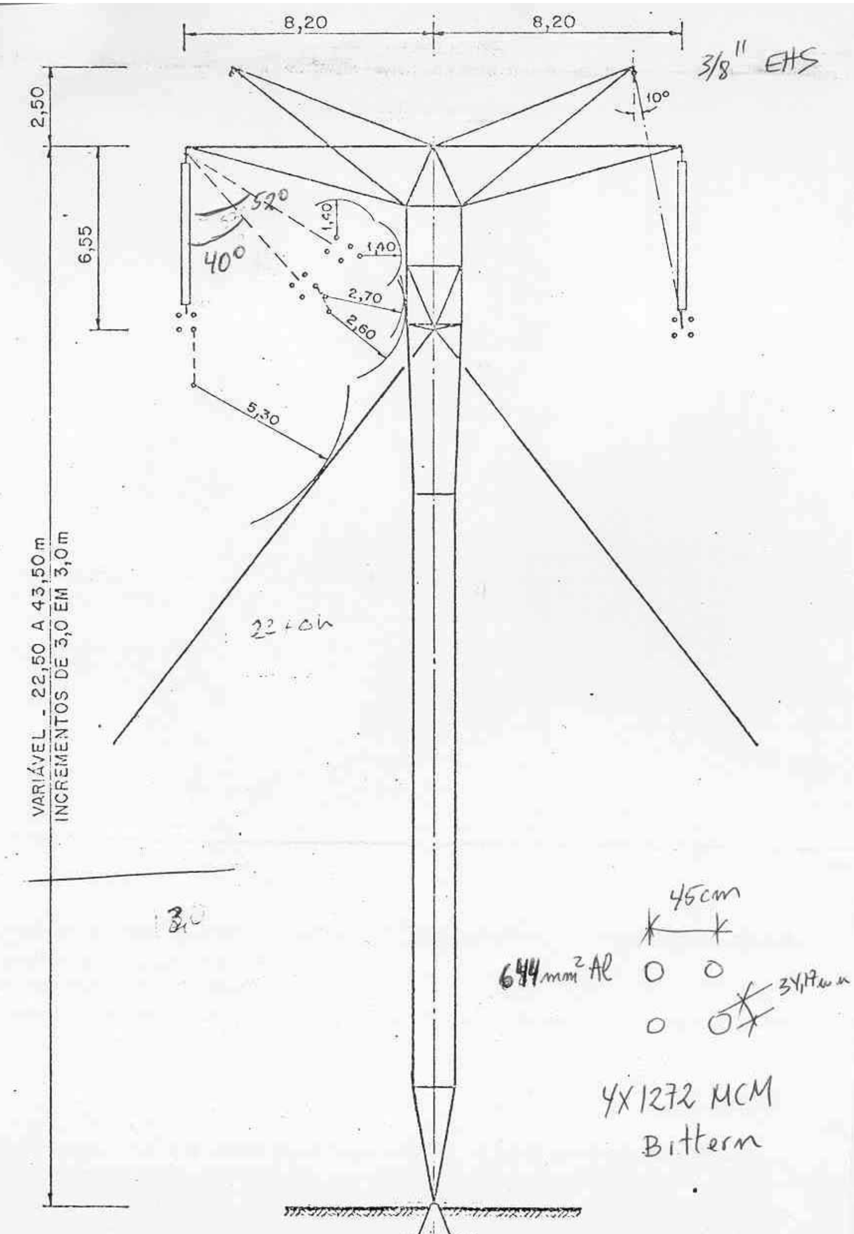
45 cm

31,98 mm

4 X 1113 MCM Bluejay

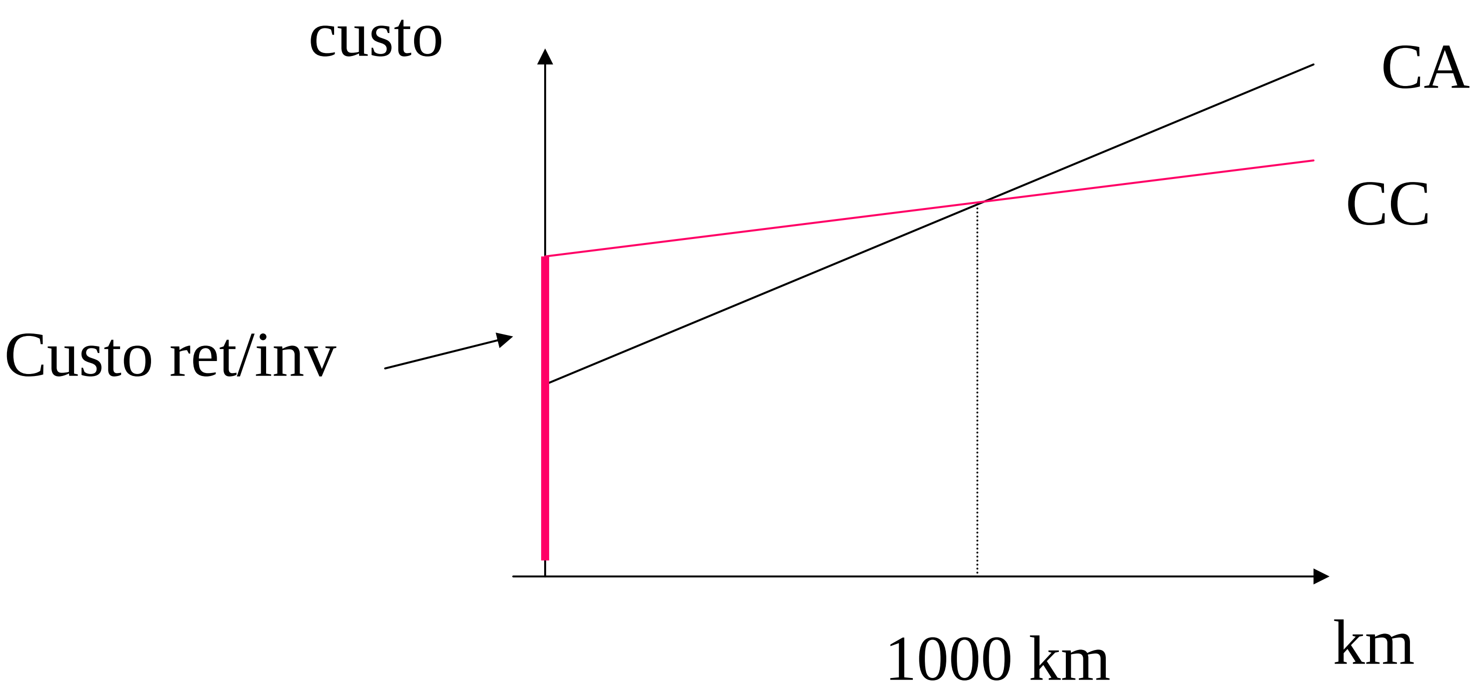


TORRE AUTOPORTANTE
espessura da torre : w = 2,4



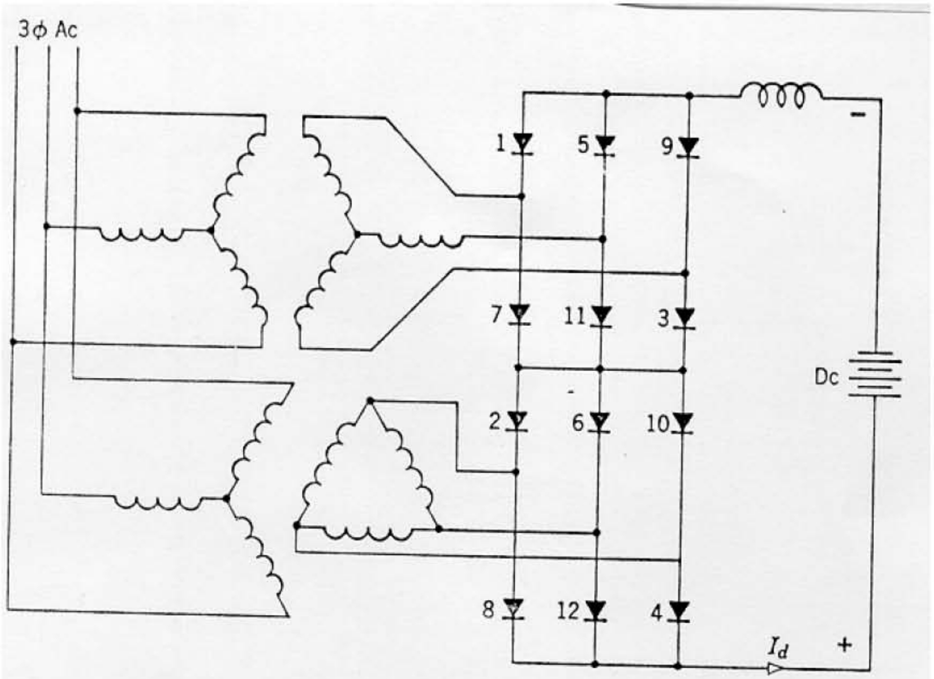
TORRE ESTAIADA TÍPICA

Custos comparativos



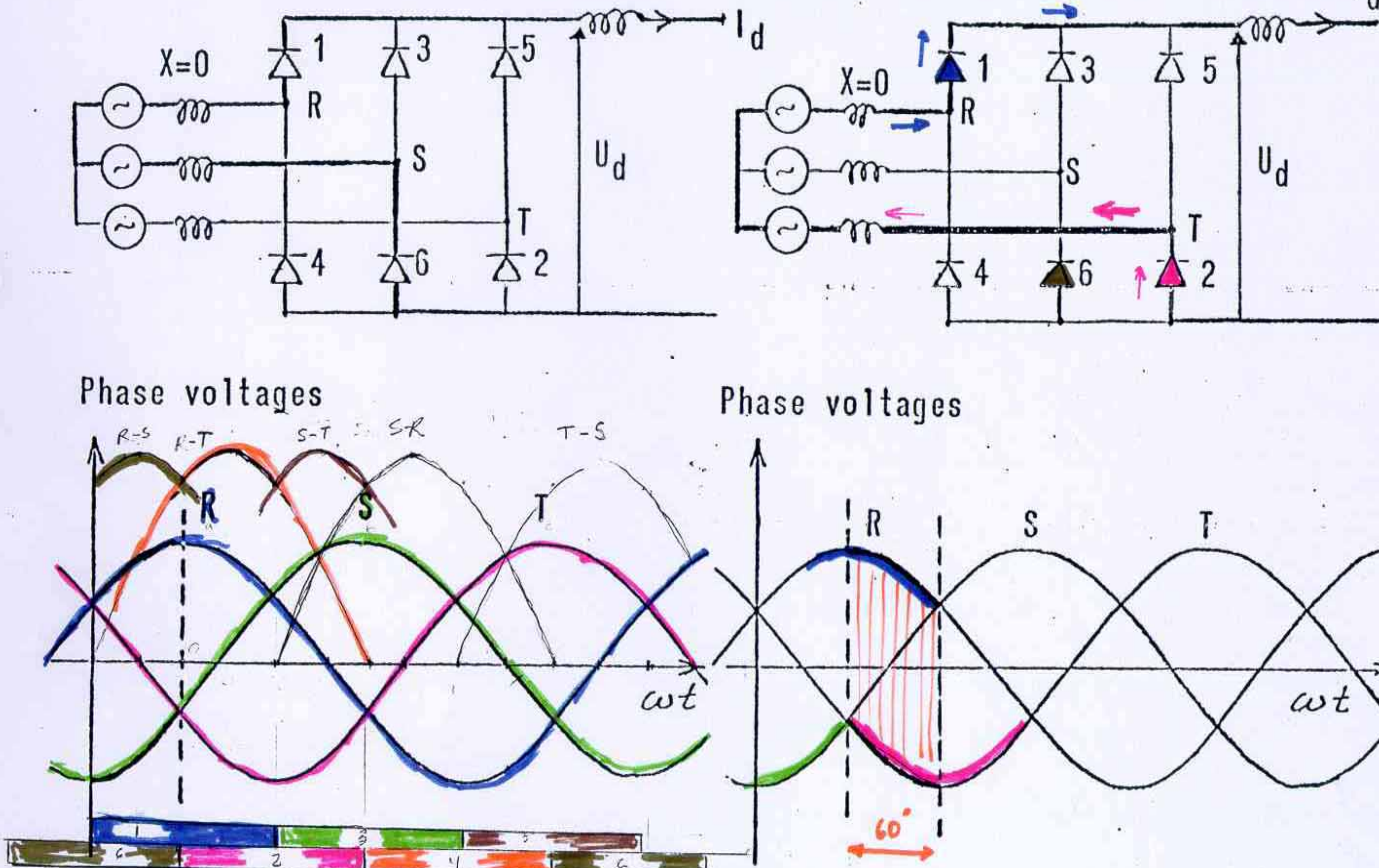
Outras situações onde CC e melhor

- suprimento de energia para ilhas
- sistemas com freqüência diferentes
- sistemas com potencial problemas de estabilidade eletromecânica

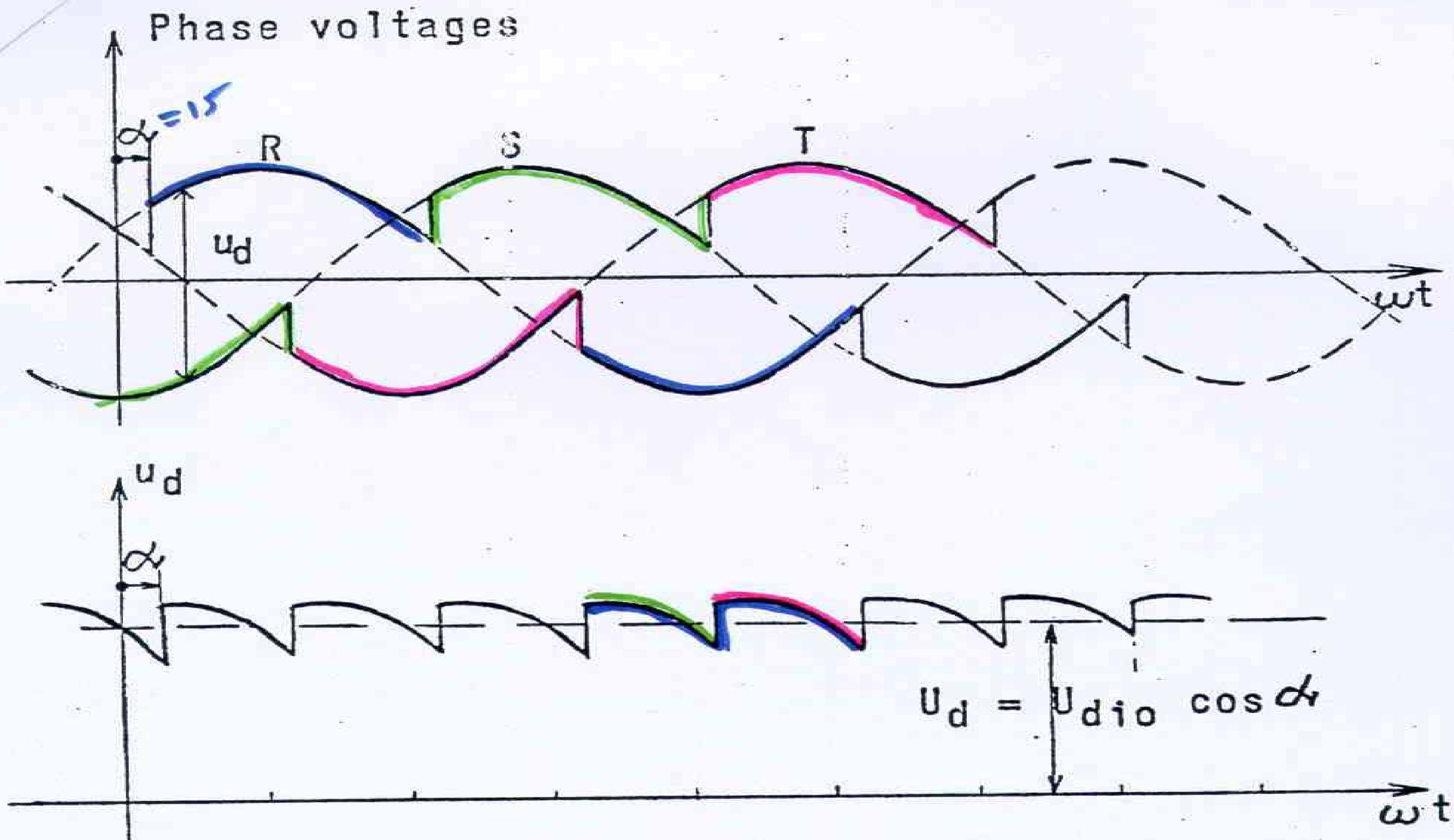


Twelve-pulse cascade of two three-phase bridges.

Figure 3 The two-way 6-pulse convertor with uncontrolled valves.
Commutation from valve 6 → valve 2.

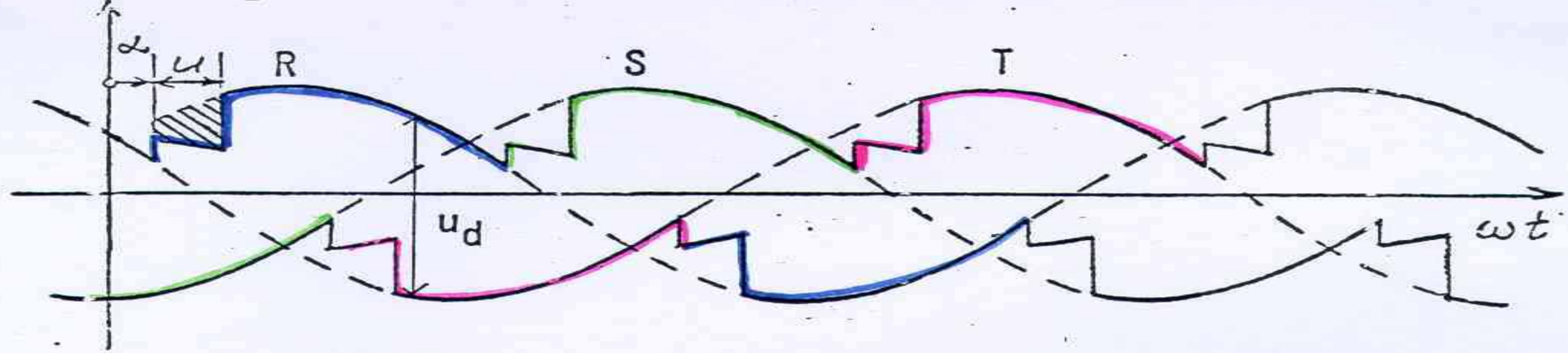


The two-way 6-pulse convertor with controlled valves. $X = 0$, $\alpha \approx 15^{o}$

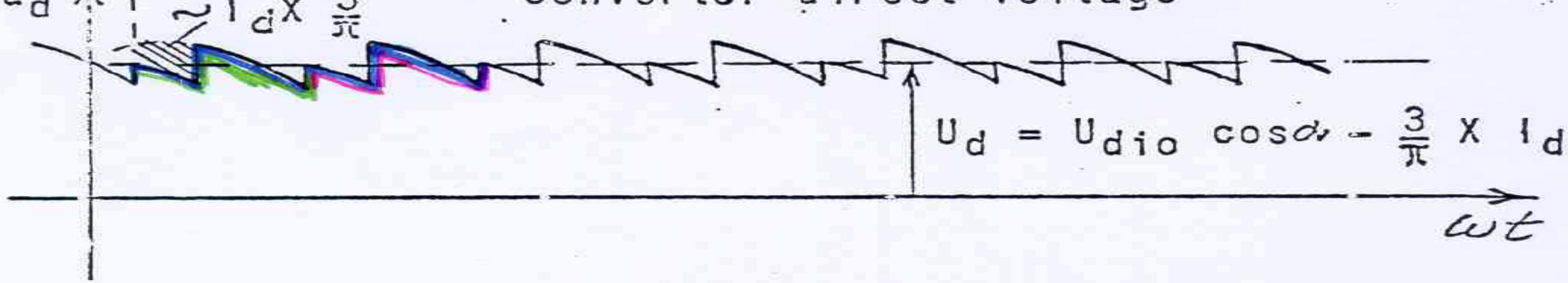


The two-way 6-pulse convertor with controlled valves, $X \neq 0$

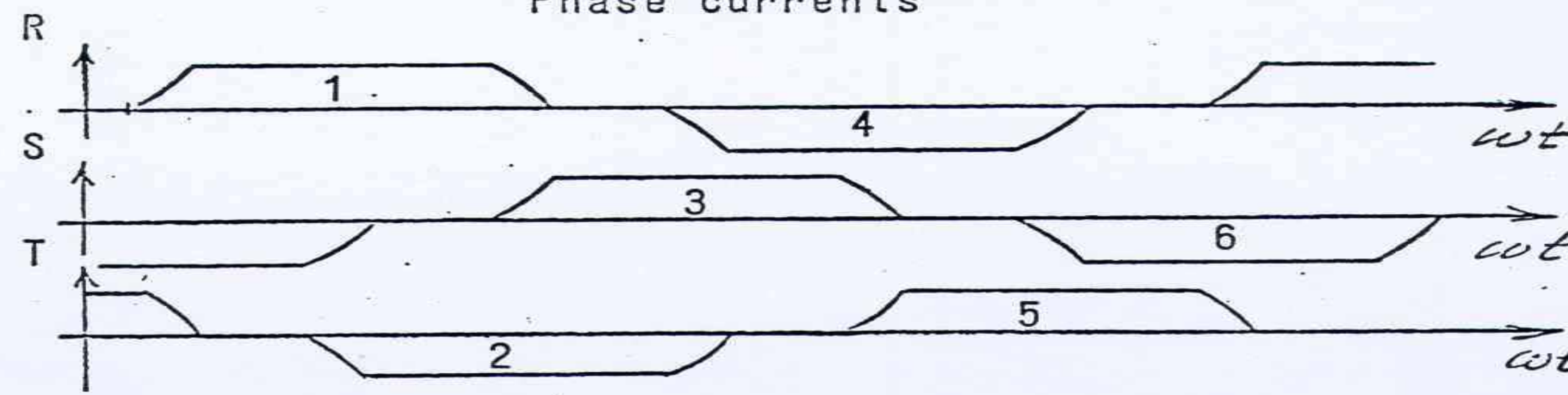
Phase voltages

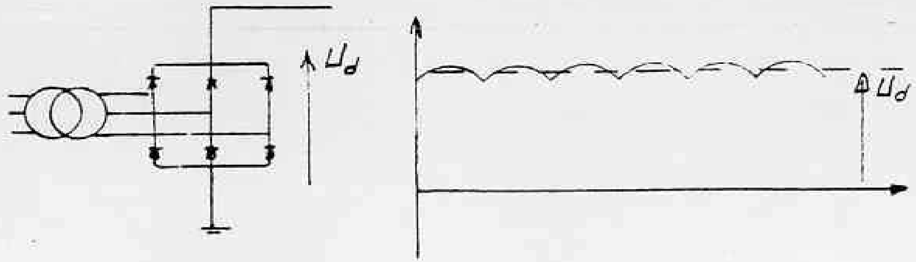


Convertor direct voltage



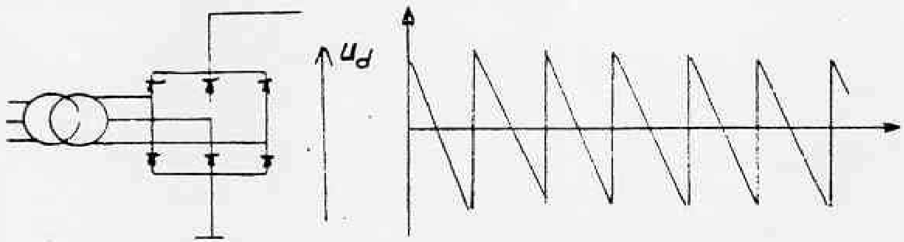
Phase currents





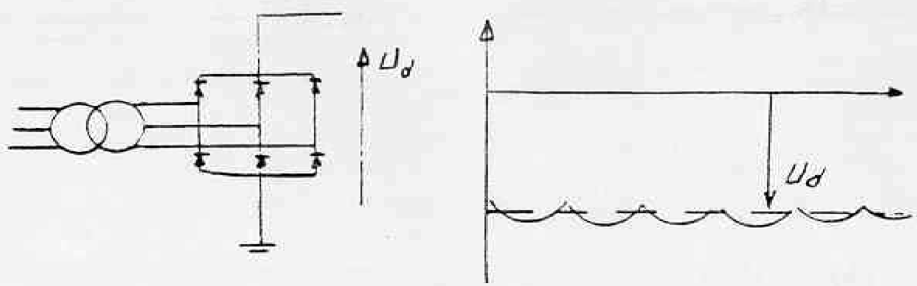
full direct
voltage
no firing del

Fig. 1a
Convertor acts as an active power generator



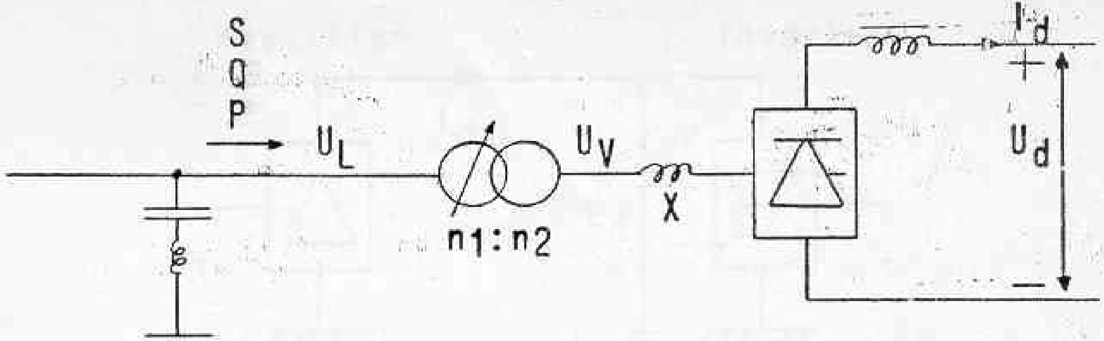
zero direct
voltage
90° firing
delay

Fig. 1b
Convertor acts as synchronous condenser



full direct
reverse voltage
180° firing dela
(theoretical)

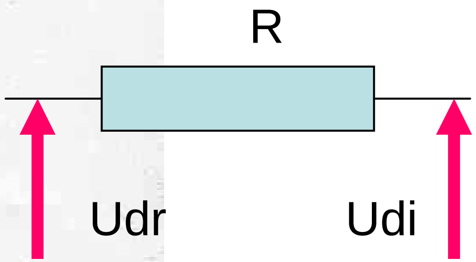
Fig. 1c



$$U_{dio} = \frac{3\sqrt{2}}{\pi} U_V = 1.35\ U_V$$

$$U_V = n_2/n_1 \cdot U_L$$

$$d_x = \frac{3}{\pi} \cdot \frac{X \cdot I_{dN}}{U_{dioN}}$$



Rectifier: $U_d = U_{dio}\left(\cos\alpha - d_x \cdot \frac{I_d}{I_{dN}} \cdot \frac{U_{dioN}}{U_{dio}}\right)$

Udr – Udi = R Id

Inverter: $U_d = -U_{dio}\left(\cos\gamma - d_x \cdot \frac{I_d}{I_{dN}} \cdot \frac{U_{dioN}}{U_{dio}}\right)$

$$P = I_d \cdot U_d$$

$$S = I_d \cdot U_{dio}$$

$$Q = +\sqrt{S^2 - P^2}$$

$$\cos\varphi = \frac{U_d}{U_{dio}}$$

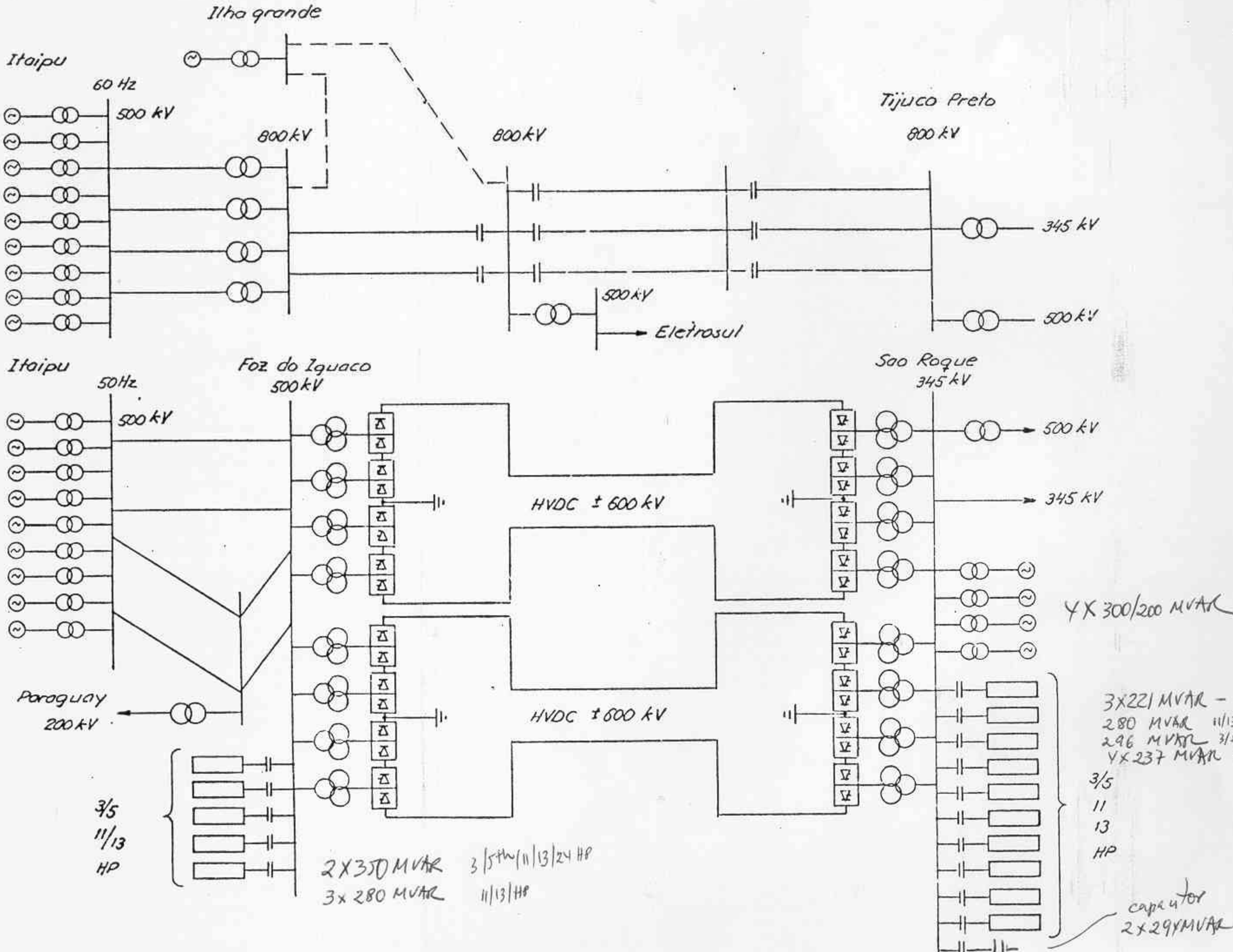
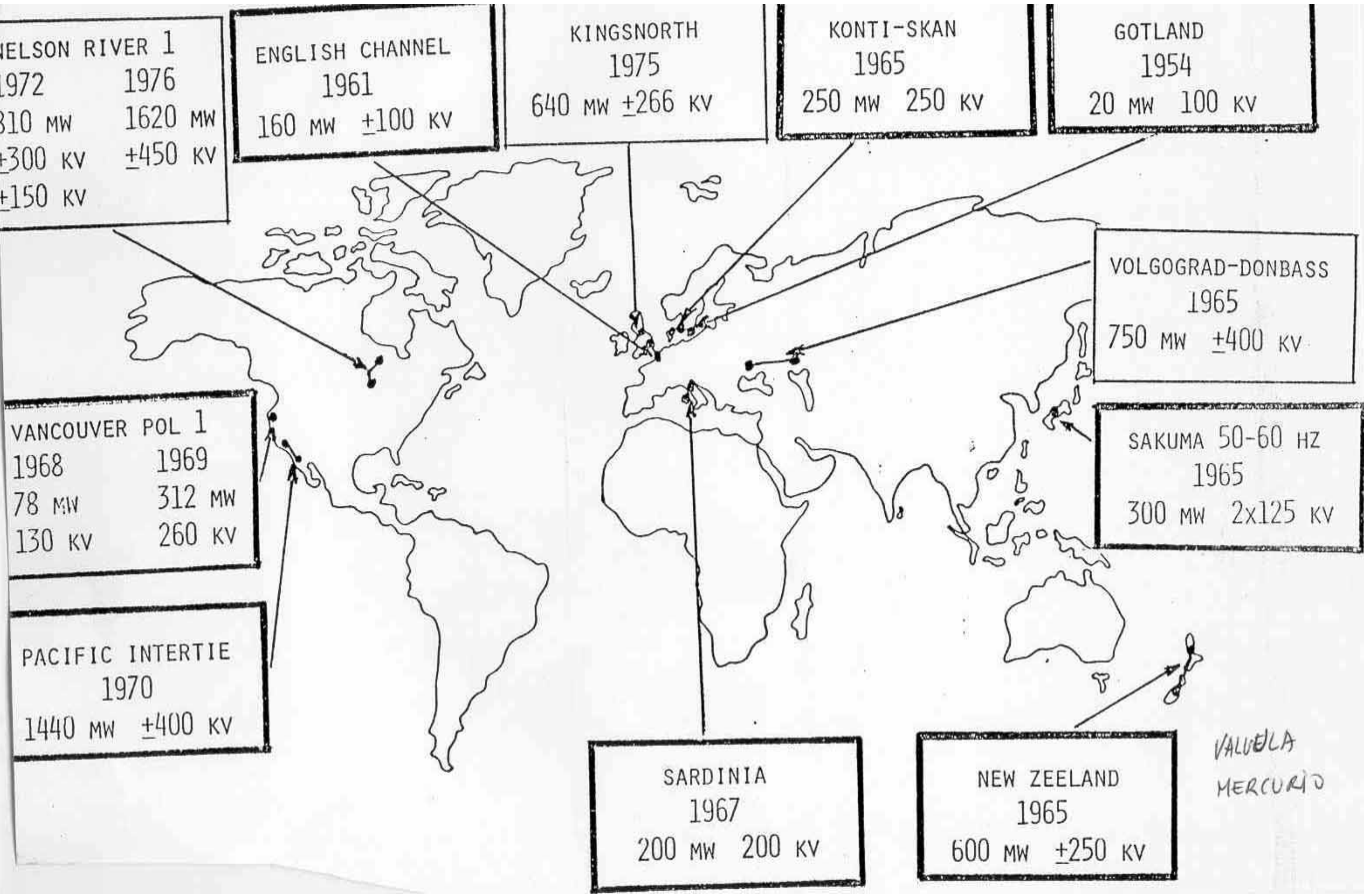

Ilha grande
Itaipu
60 Hz
500 kV
800 kV
800 kV
Tijuco Preto
800 kV
345 kV
500 kV
500 kV
Eletrosul
Itaipu
50Hz
500 kV
Foz do Iguaco
500 kV
Sao Roque
345 kV
500 kV
345 kV
HVDC ± 600 kV
HVDC ± 600 kV
4 X 300/200 MVAR
Paraguay
200 kV
3/5
11/13
HP
2 X 350 MVAR 3/5th/11/13/24 HP
3 x 280 MVAR 11/13/HP
3X221 MVAR - 11/13th
280 MVAR 11/13/3/5
296 MVAR 3/5th
4 X 237 MVAR HP
3/5
11
13
HP
capacitor
2 X 294 MVAR

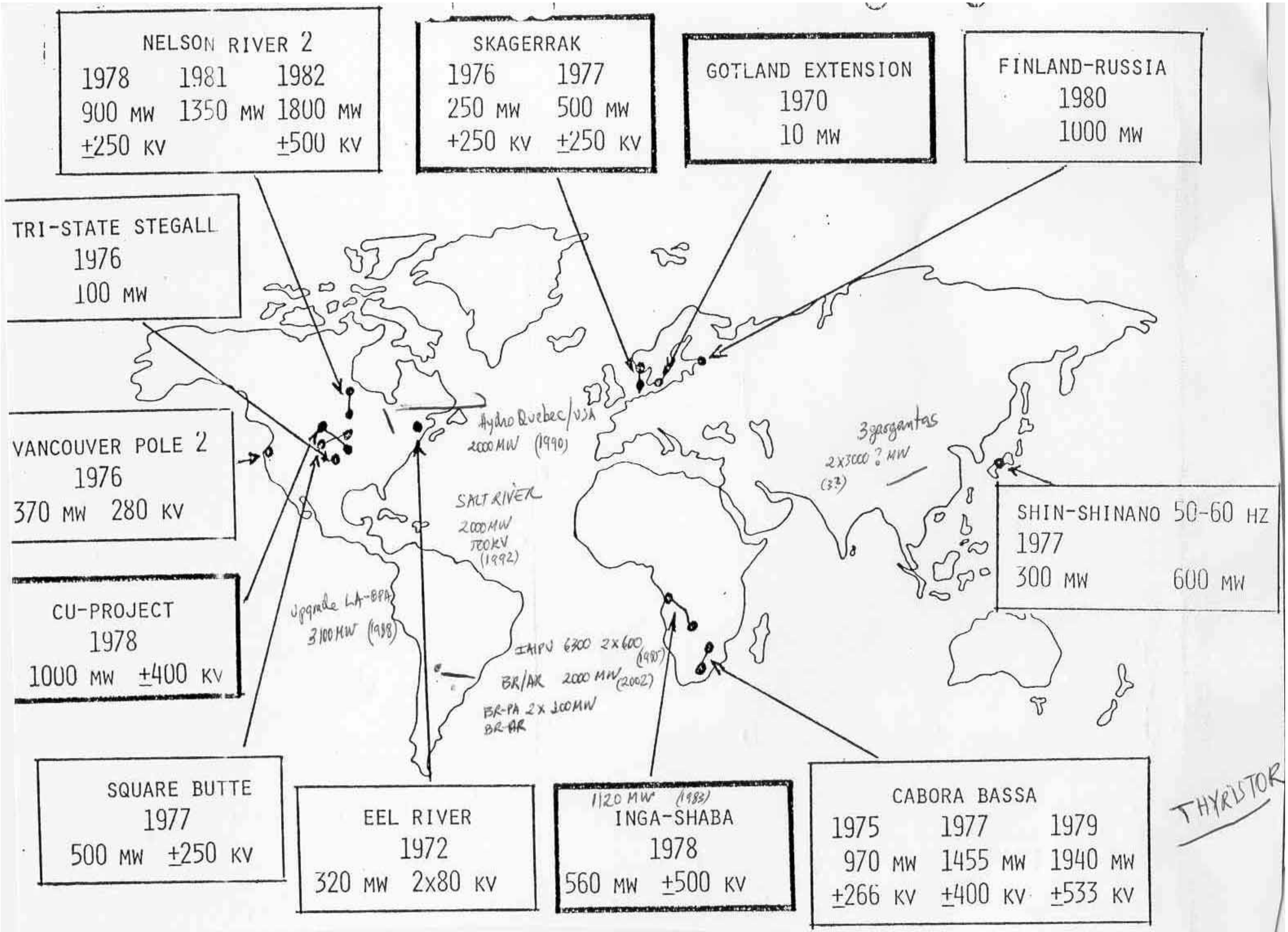
Figure 2

Sistemas CC existentes

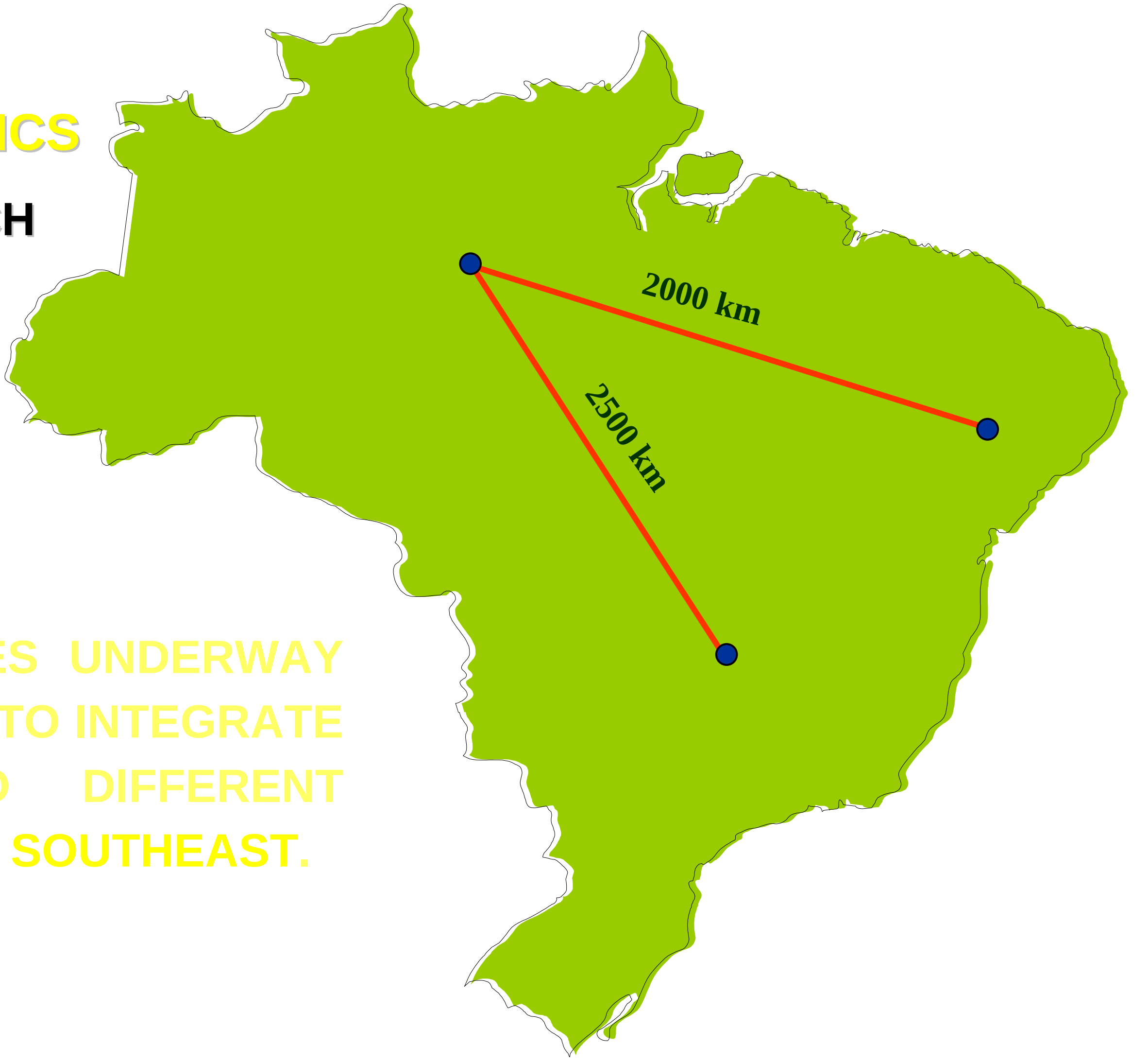
- Válvula de mercúrio

- Tiristor


NELSON RIVER 1
1972 1976
810 MW 1620 MW
±300 KV ±450 KV
±150 KV
ENGLISH CHANNEL
1961
160 MW ±100 KV
KINGSNORTH
1975
640 MW ±266 KV
KONTI-SKAN
1965
250 MW 250 KV
GOTLAND
1954
20 MW 100 KV
VOLGOGRAD-DONBASS
1965
750 MW ±400 KV
VANCOUVER POL 1
1968 1969
78 MW 312 MW
130 KV 260 KV
SAKUMA 50-60 HZ
1965
300 MW 2x125 KV
PACIFIC INTERTIE
1970
1440 MW ±400 KV
SARDINIA
1967
200 MW 200 KV
NEW ZEELAND
1965
600 MW ±250 KV
VALVULA
MERCURIO


NELSON RIVER 2
1978 1981 1982
900 MW 1350 MW 1800 MW
±250 KV ±500 KV
SKAGERRAK
1976 1977
250 MW 500 MW
+250 KV ±250 KV
GOTLAND EXTENSION
1970
10 MW
FINLAND-RUSSIA
1980
1000 MW
TRI-STATE STEGALL
1976
100 MW
VANCOUVER POLE 2
1976
370 MW 280 KV
CU-PROJECT
1978
1000 MW ±400 KV
SHIN-SHINANO 50-60 HZ
1977
300 MW 600 MW
SQUARE BUTTE
1977
500 MW ±250 KV
EEL RIVER
1972
320 MW 2x80 KV
1120 MW (1983)
INGA-SHABA
1978
560 MW ±500 KV
CABORA BASSA
1975 1977 1979
970 MW 1455 MW 1940 MW
±266 KV ±400 KV ±533 KV
Hydro Quebec/USA
2000 MW (1990)
SALT RIVER
2000 MW
(1992)
Upgrade LA-BPA
3100 MW (1988)
2x600
(1987)
BR/AR 2000 MW (2002)
BR-PA 2 x 200MW
BR-AR
3 gargantas
2x3000 ? MW
THYRISTOR

BELO MONTE POWER PLANT CONNECTION



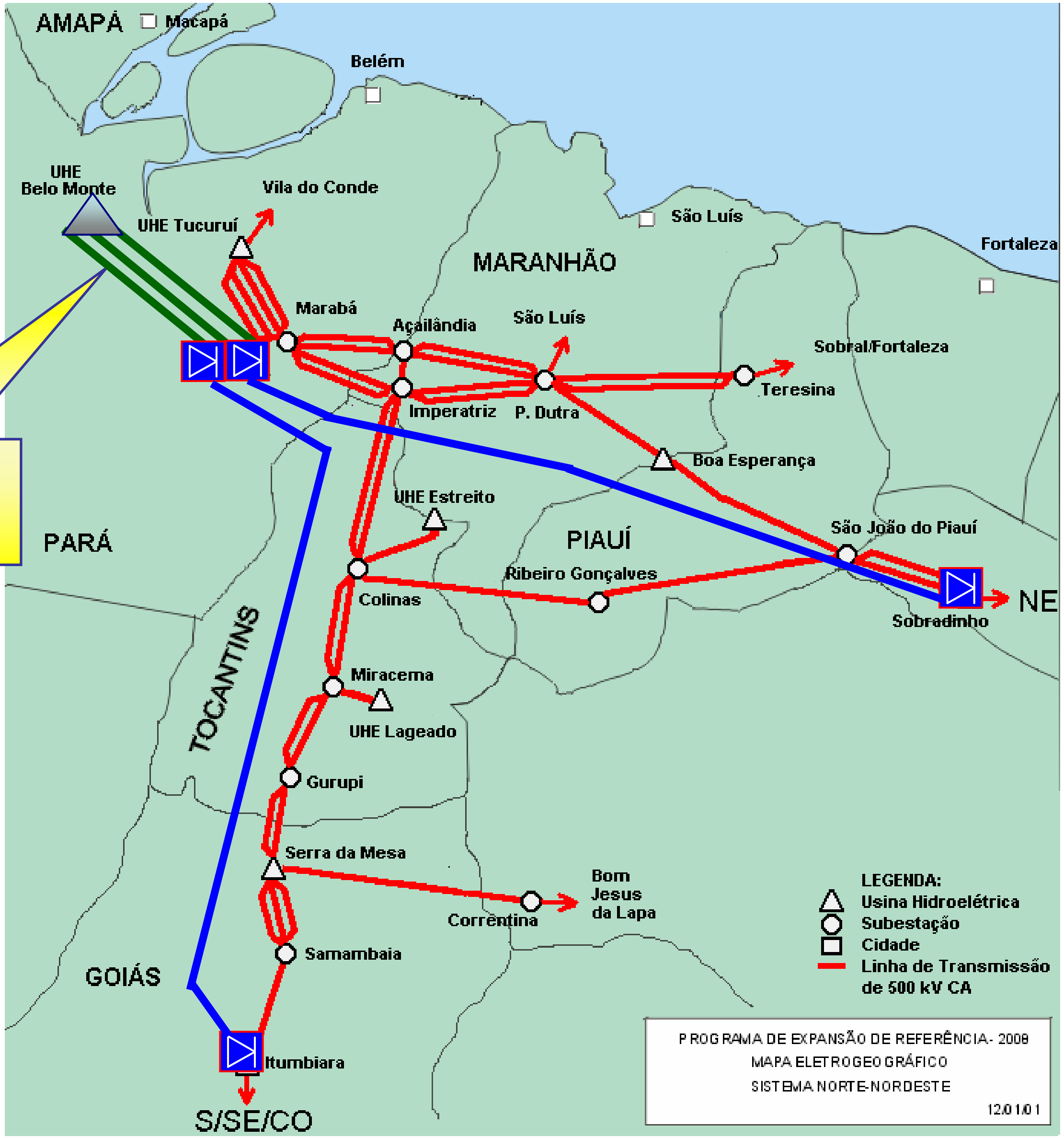
PROJECT CHARACTERISTICS

2 STAGES OF 5500 MW EACH

THE TRANSMISSION STUDIES UNDERWAY CONSIDER THE POSSIBILITY TO INTEGRATE BELO MONTE TO TWO DIFFERENT REGIONS: **NORTHEAST AND SOUTHEAST.**

CONNECTION

765 kV System



MADEIRA POWER PLANTS

PROJECT CHARACTERISTICS

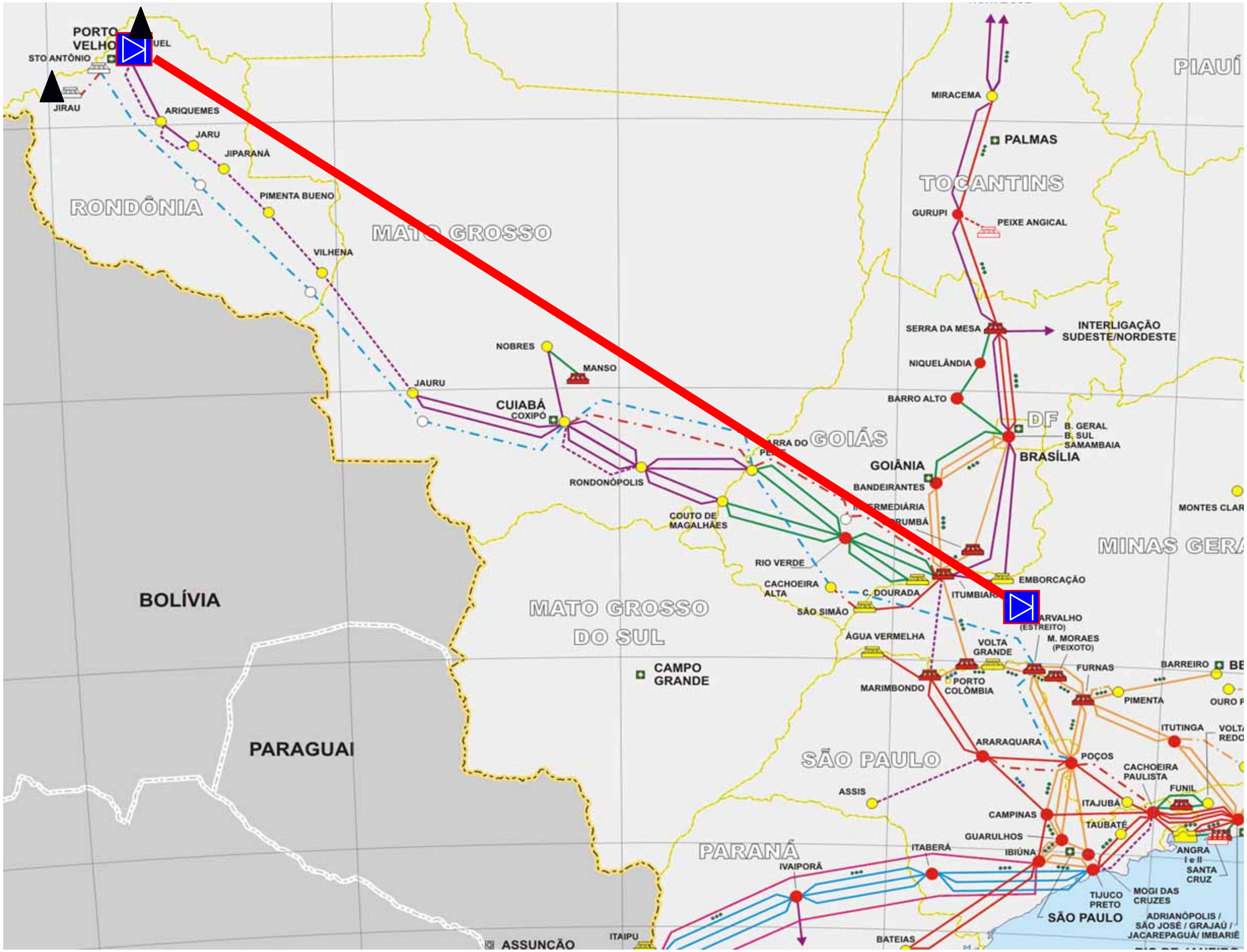
2 POWER PLANTS: JIRAU e S.ANTONIO

TOTAL POWER = 6300 MW

ALTERNATIVES FOR CONNECTION

AC – 500 and 765 kV

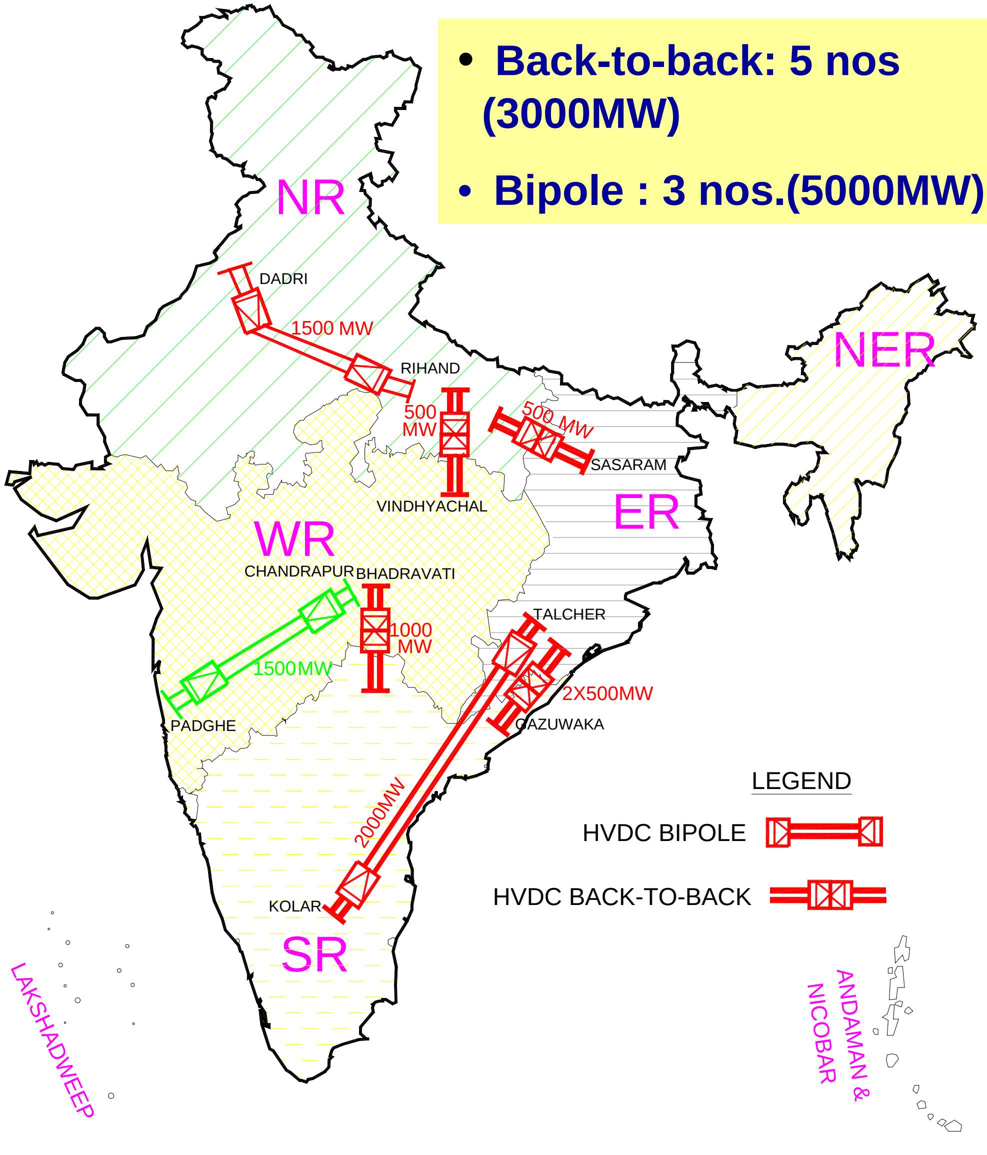
DC – ±600 kV



PORTO VELHO
STO ANTÔNIO
JIRAU
ARIQUEMES
JARU
JIPARANÁ
PIMENTA BUENO
VILHENA
RONDÔNIA
MATO GROSSO
NOBRES
MANSO
JAURU
CUIABÁ
COXIPÓ
RONDONÓPOLIS
COUTO DE MAGALHÃES
GOIÁS
GOIÂNIA
BANDEIRANTES
RIO VERDE
CACHOEIRA ALTA
SÃO SIMÃO
C. DOURADA
ITUMBIARA
EMBORCAÇÃO
ÁGUA VERMELHA
VOLTA GRANDE
M. MORAES (PEIXOTO)
(ESTREITO)
FURNAS
MARIMBONDO
PORTO COLÔMBIA
PIMENTA
BARREIRO
MIRACEMA
PALMAS
TOCANTINS
GURUPI
PEIXE ANGICAL
SERRA DA MESA
INTERLIGAÇÃO SUDESTE/NORDESTE
NIQUELÂNDIA
BARRO ALTO
DF
B. GERAL
B. SUL
SAMAMBAIA
BRASÍLIA
PIAUÍ
BOLÍVIA
PARAGUAI
MATO GROSSO DO SUL
CAMPO GRANDE
SÃO PAULO
ARARAQUARA
POÇOS
ASSIS
CAMPINAS
GUARULHOS
IBIÚNA
ITAJUBÁ
TAUBATÉ
CACHOEIRA PAULISTA
FUNIL
ITUTINGA
ANGRA I e II
SANTA CRUZ
MOGI DAS CRUZES
TIJUCO PRETO
SÃO PAULO
ADRIANÓPOLIS / SÃO JOSÉ / GRAJAÚ / JACAREPAGUÁ/ IMBARIÊ
PARANÁ
IVAIPORÃ
ITABERÁ
BATEIAS
ITAIPU
ASSUNÇÃO

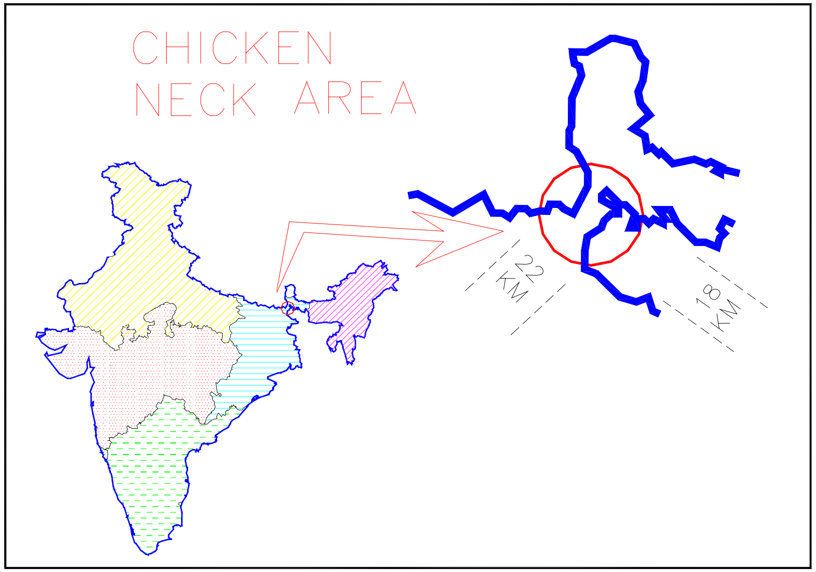
HVDC SYSTEMS- AT PRESENT

- **Back-to-back: 5 nos (3000MW)**
- **Bipole : 3 nos.(5000MW)**

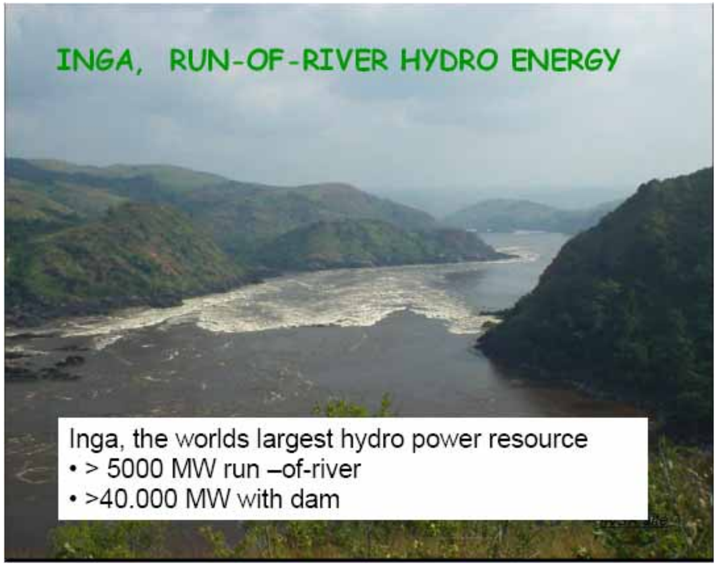


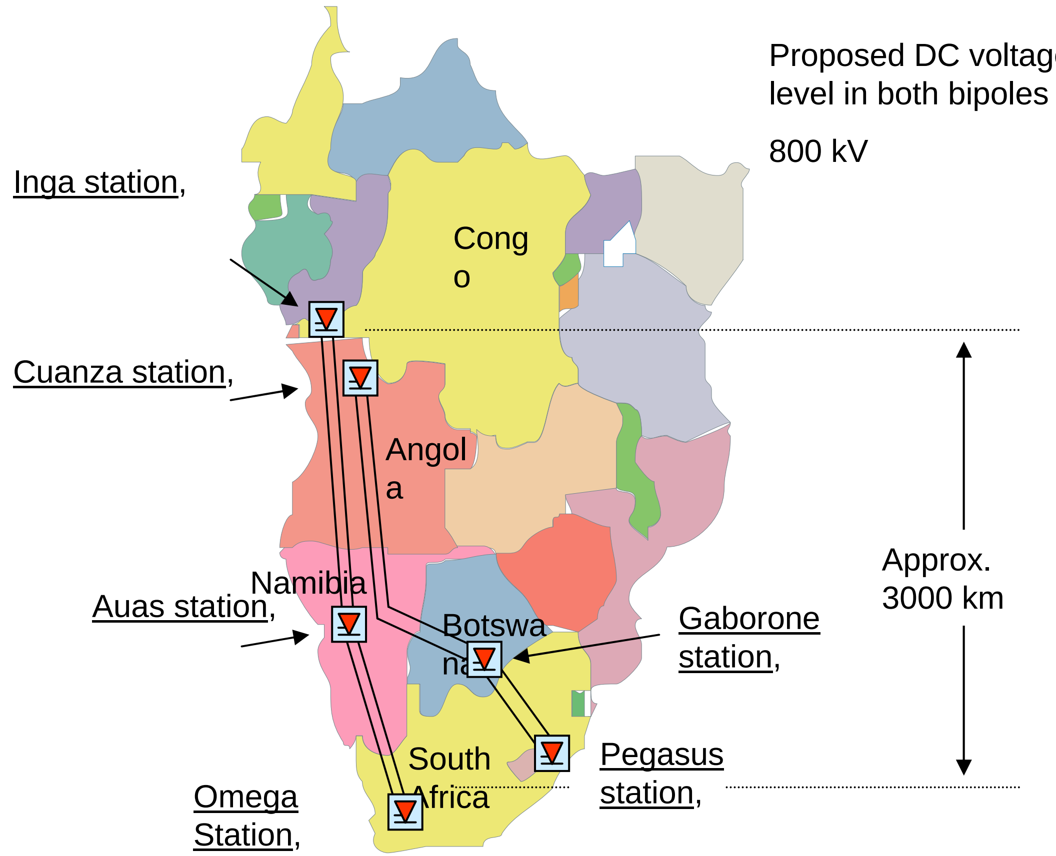
Consideration for Development of Transmission System

- 50000 MW power to be evacuated through Chicken Neck Area in North of West Bengal :
  - ➢ A very narrow (22 km. Wide) patch of land, 18 km near Siliguri having borders of Nepal on one side & Bangladesh on other and largely habited.
  - ➢ All transmission lines, Railway lines, gas pipe-lines, Telecommunication lines etc. have to pass through the Chicken neck area



South Africa: West Cor Line





Proposed DC voltage level in both bipoles :

800 kV

Jinsha River I (Xiluodu, Xiangjiaba), Jingping & Xiaowan Dams, for 800kV UHVDC

Updated 2006-4-14, CNABB-PTSG

Xiangjiaba – Shanghai
800kV, 6400 MW, 1950km
2011

Xiluodu – Zhejiang
800kV, 6400 MW, 1870km
2015

Xiluodu – Hubei (C.China)
800kV, 6400 MW, 1070km
2014

Jingping – East China
800kV, 6400 MW, 2100km
2012

Yunnan – Guangdong
800kV, 5000 MW, 1500km
2009