CAREC

Central Asia Regional Economic Cooperation

Development of priority energy corridor Central Asia- South Asia

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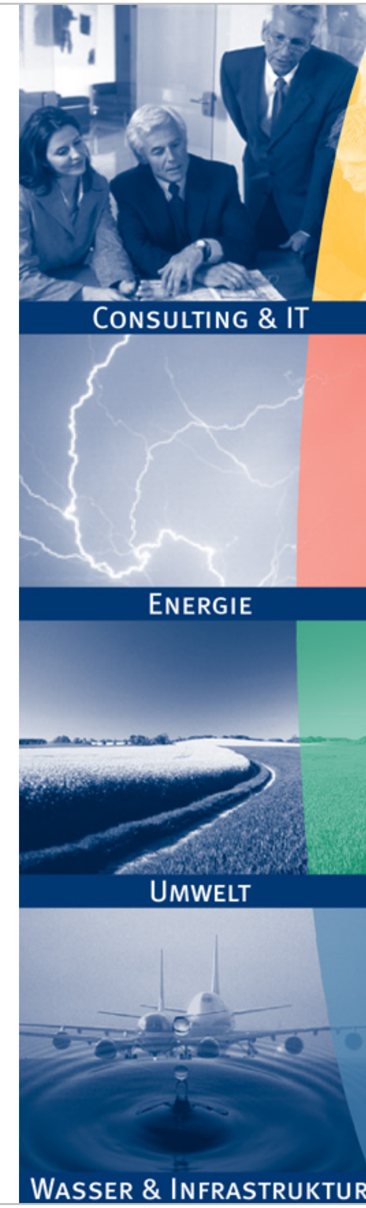

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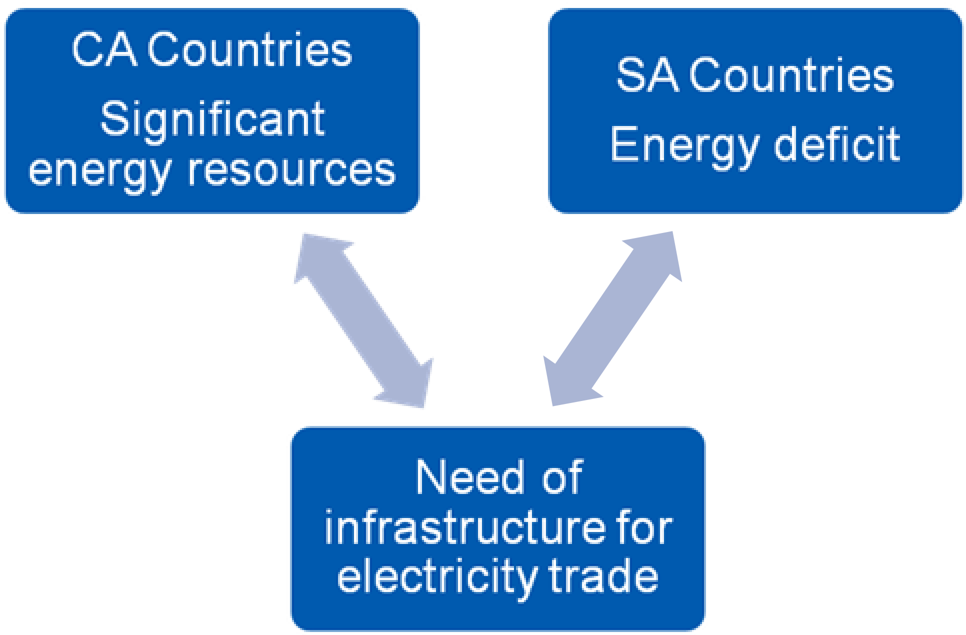
CAREC 2020 VISION

- Energy security
- Market integration
- Trade driven growth

Priority energy corridors enable regional cooperation



Key element in CA-SA energy corridor - Afghanistan

Present situation - Characteristics of Afghan power system

-different parts of the network are supplied as passive island by in-feeds from Uzbekistan, Tajikistan, Turkmenistan

- own grid is very weak, only few generators operate in synchronism, supplying loads in island mode

Constraints in operation

-Afghan own generation may not be utilized at full capacity due to constraints in rearranging the loads to build islands

-no possibility for bulk export or transit of energy from CA countries to Pakistan

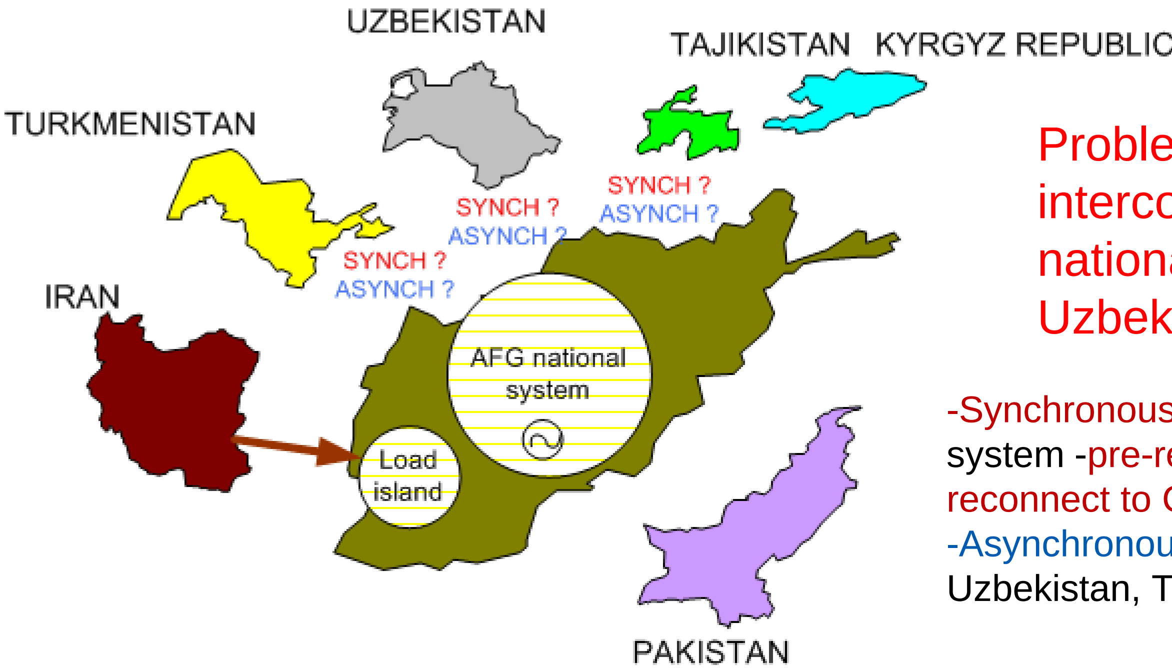
Target - Development of Afghan power system

Creation of an national grid

-majority of the loads to be connected and synchronization of the existing and future generation

Major source for electrical power, besides own generation, will remain the imports from Turkmenistan, Uzbekistan, Tajikistan, Iran

Afghan power system will form the infrastructure backbone for exports from CA to SA



Problem to be solved- interconnection between Afghan national system and Turkmenistan, Uzbekistan, Tajikistan (Kyrgyz Republic)

-Synchronous interconnection of Afghanistan to CA power system -pre-requisite is that Turkmenistan and Tajikistan will reconnect to CAPS

-Asynchronous interconnection with Turkmenistan Uzbekistan, Tajikistan by HVDC back-to-back schemes

Interconnection of electric power systems

Types of interconnections between different power systems:
-Synchronous
-Asynchronous by using HVDC schemes

One of the great achievements of the last century - evolution large synchronous HVAC power grids, in which all interconnected systems maintain the same frequency.

Examples: IPS/UPS synchronous system and ENTSO-E

Alternative for coupling different power systems - HVDC connections

HVDC schemes permit asynchronous coupling of power systems
- for systems which operate at different frequencies or are otherwise incompatible allow them to exchange power without requiring the tight coordination of a synchronous network.

HVDC Schemes

Two typical HVDC arrangements

•long-distance HVDC lines with an HVAC/HVDC converter station at each end of the HVDC line

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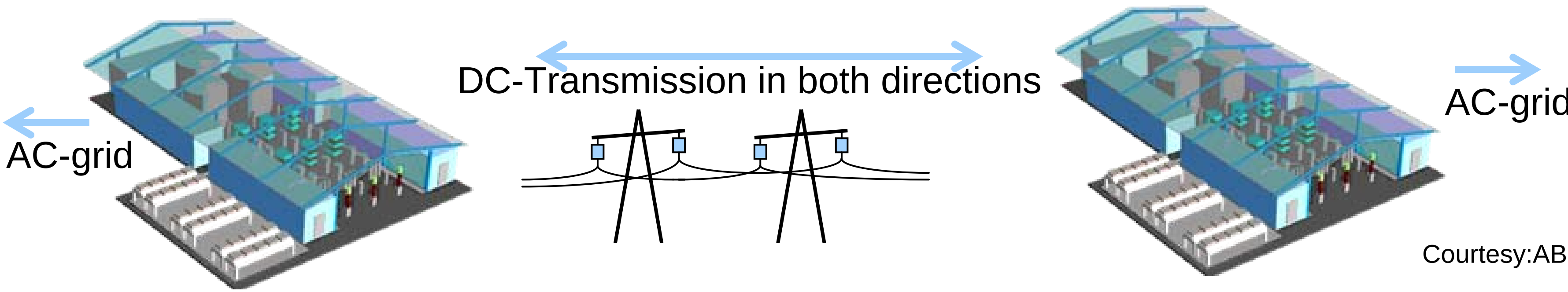
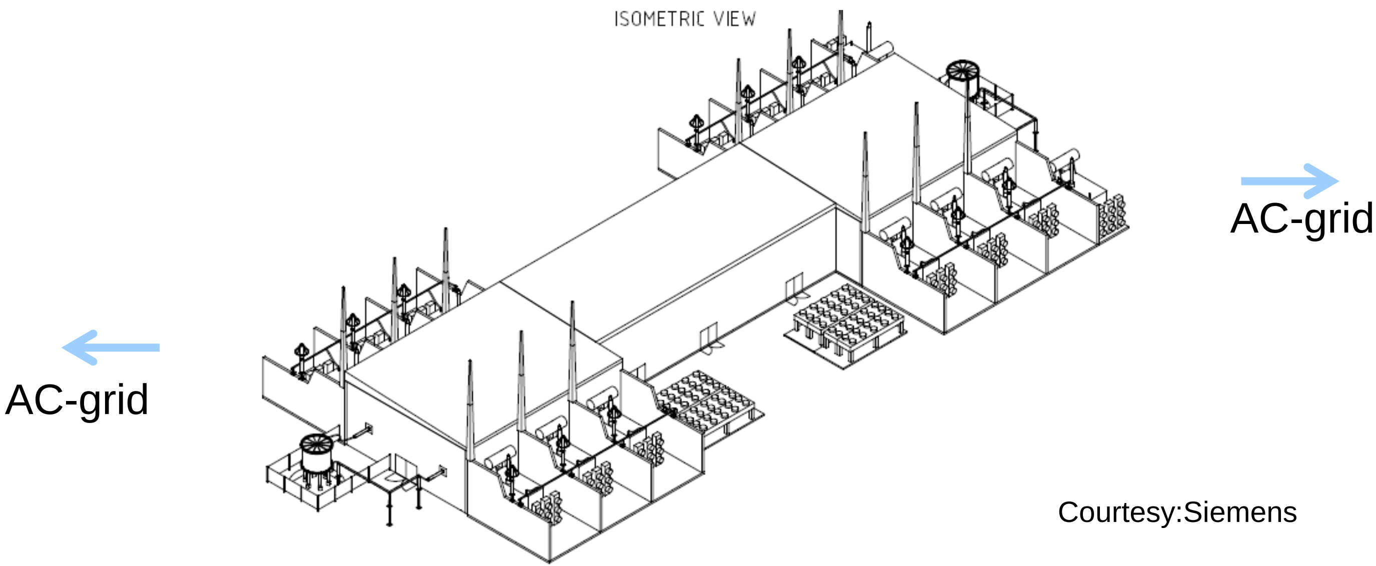


Courtesy:ABB

•both converters in one location without an HVDC line - HVDC back-to-back scheme



Courtesy:Siemens

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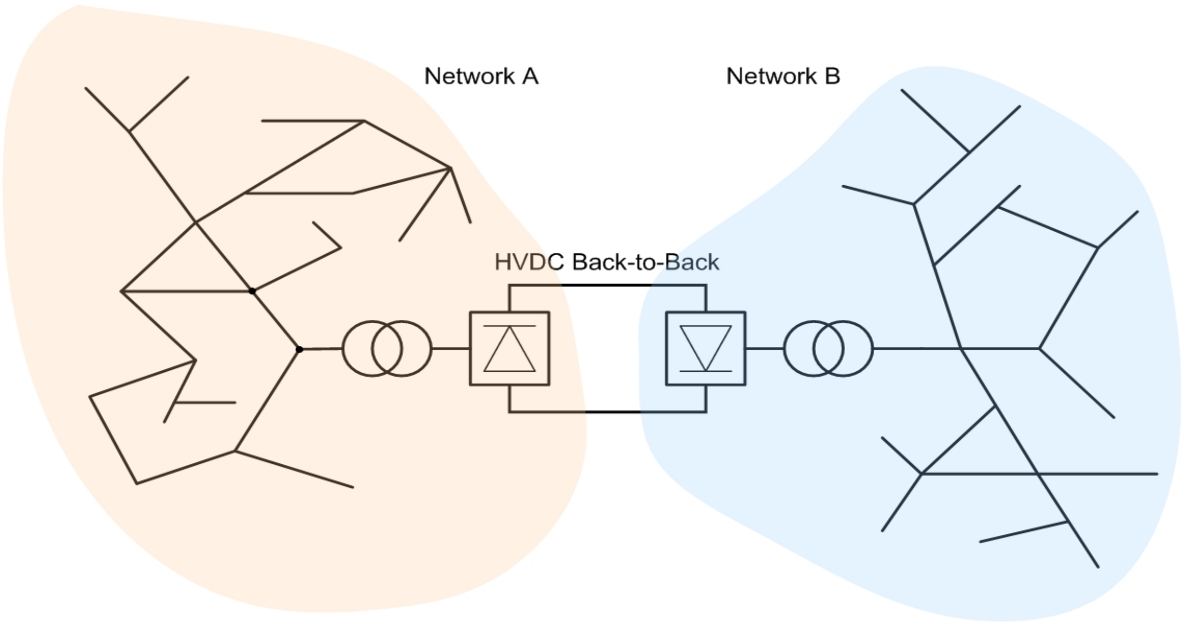
HVDC Back-to-Back Interconnection

Alternative to synchronous interconnection

•normally used in order to create an asynchronous interconnection between two HVAC networks, which could have the same or different frequencies

•simpler than the construction of two separated converter stations for a HVDC transmission projects

•HVDC voltage level can be selected without consideration to the optimum values for an overhead line or cable and is therefore normally quite low, 150 kV or lower



Types of HVDC technologies

HVDC Technologies characteristics

Line commutated converters (LCC)

- Active power control
- Terminals demand reactive power
- Reactive power balance by shunt bank switching
- Minimum system short circuit capacity of twice rated power

→ strong grid required, normally used for remote power supply

Self-commutated converters (Voltage Source Converters VSC)

- Active and reactive power control
- Dynamic voltage regulation
- Modular and expandable
- Black start capability
- No short circuit restriction

→ suitable for weak grids

Courtesy: Alstom

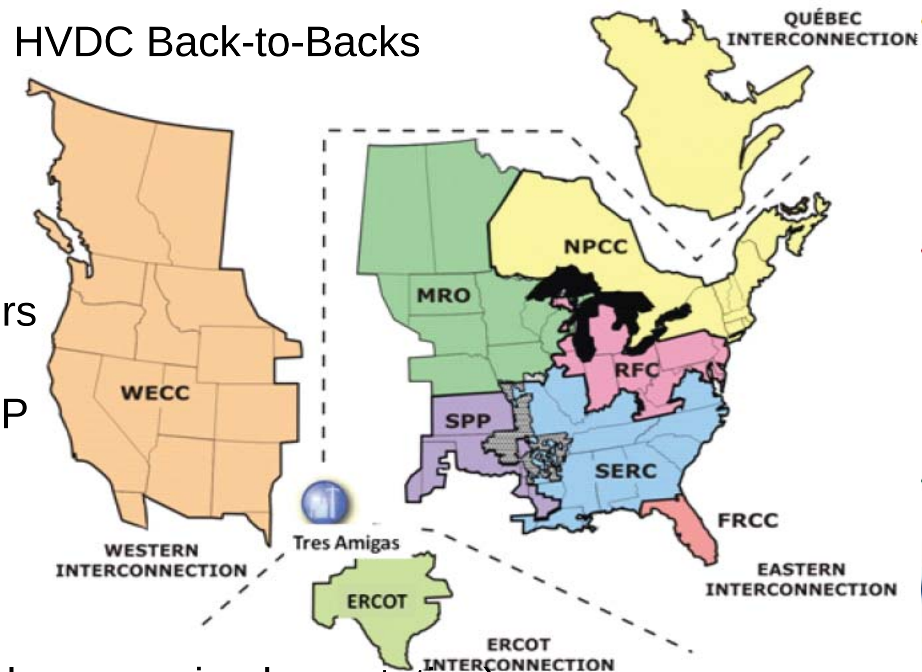
Recommended for Afghan power system- VSC Back-to-Back

Example of HVDC Back-to-Back Hub: Tres Amigas Super Station

Three-way 5000 MW interconnection between three independent power networks in the USA

Today's situation:
•Three asynchronous power systems
•Connected by several old and small dimensioned HVDC Back-to-Backs
•Weak networks in parts

Tres Amigas Super Station:
•One 5000 MW Back-to-Back superstation
•Consisting of 6 independent HVDC B2B converters
•Step-by-step construction and operation
 •Initial Back-to-Back between WECC and SPP
 •Three VSCs support and reinforce networks
 •Three LCCs increase transmission ability



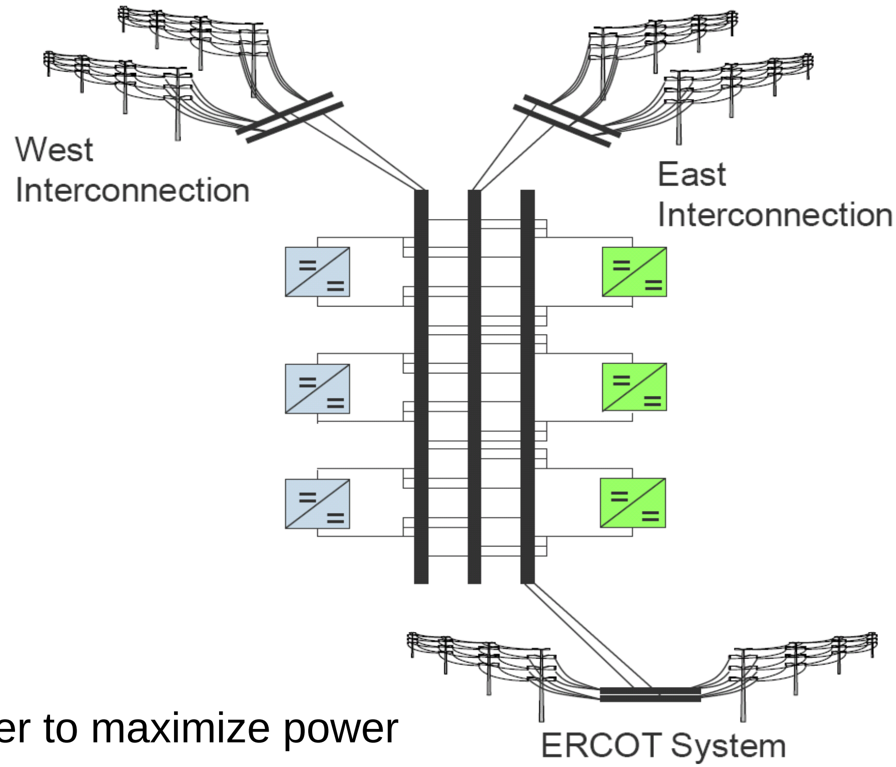
Courtesy:CIGRE

Advantages:
•Increased exchange capacity (allows for renewable energy implementation)
•Reinforcement of weak networks
•Real time power order control

Example of HVDC Back-to-Back Hub:Tres Amicas Super Station

Technical concept

•AC-OHLs of each power network form three separated 345 kV AC busbars
•345 kV GIL and GIS components
•No connection between single bus bars possible
•Access to all busbars by each converter
•Modular expandable



Courtesy:CIGRE

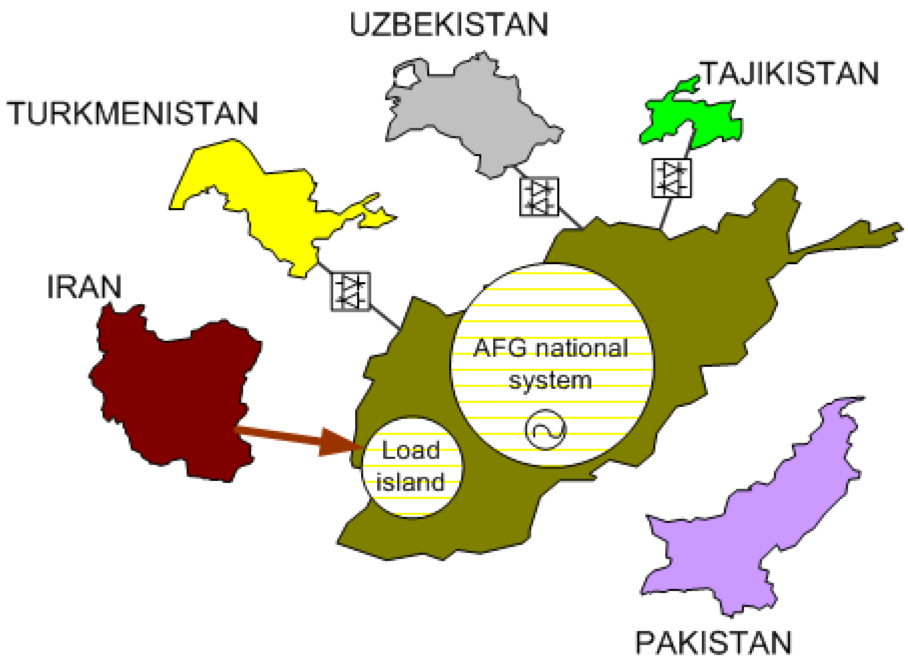
Phase 1 to 3
•three VSC (750 MW each)
  •Modular Multilevel converter
  •Reactive power support for weak networks
  •Enable use of additional LCC systems

Phase 4
•Additional 3x920 MW
  •Built in stages using LCC technology in order to maximize power transfer capability

Afghanistan – Asynchronous interconnection to CA

Advantages of HVDC Back-to-Back interconnections

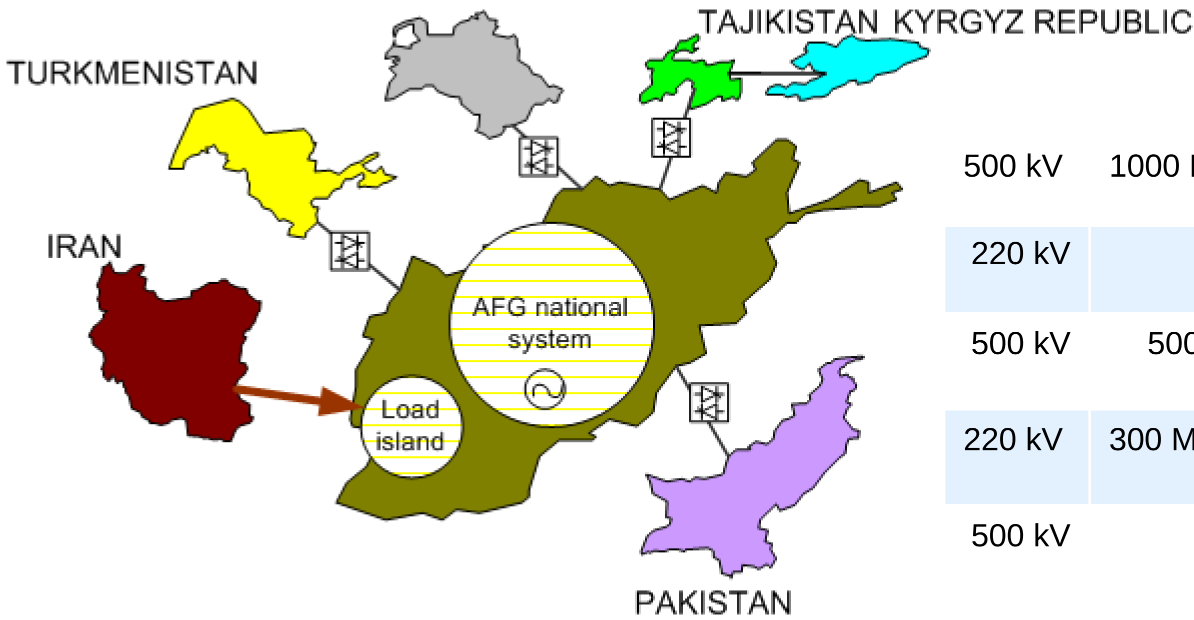
•Facilitates integration of remote diverse resources (In-feed from three different systems within CAPS to Afghanistan national network)
•Controllable -power injected where needed
•No stability distance limitation
•Lower losses than HVAC transmission
•Facilitates power wheeling to Pakistan



TUTAP Project – Infrastructure for energy corridor from CA to SA

Turkmenistan, Uzbekistan and Tajikistan interconnections will be located in the same area of Pul-e-Chomri creating a HVDC hub

Power wheeling through 500 kV line in Afghanistan to Pakistan border



500 kV	1000 MW (500 MW)	HVDC B2B Turkmenistan
220 kV	300 MW	HVDC B2B Tajikistan
500 kV	500 MW (1000 MW)	HVDC B2B Tajikistan (Kyrgyz Republic)
220 kV	300 MW	HVDC B2B Uzbekistan
500 kV	1000 MW	HVDC B2B Pakistan

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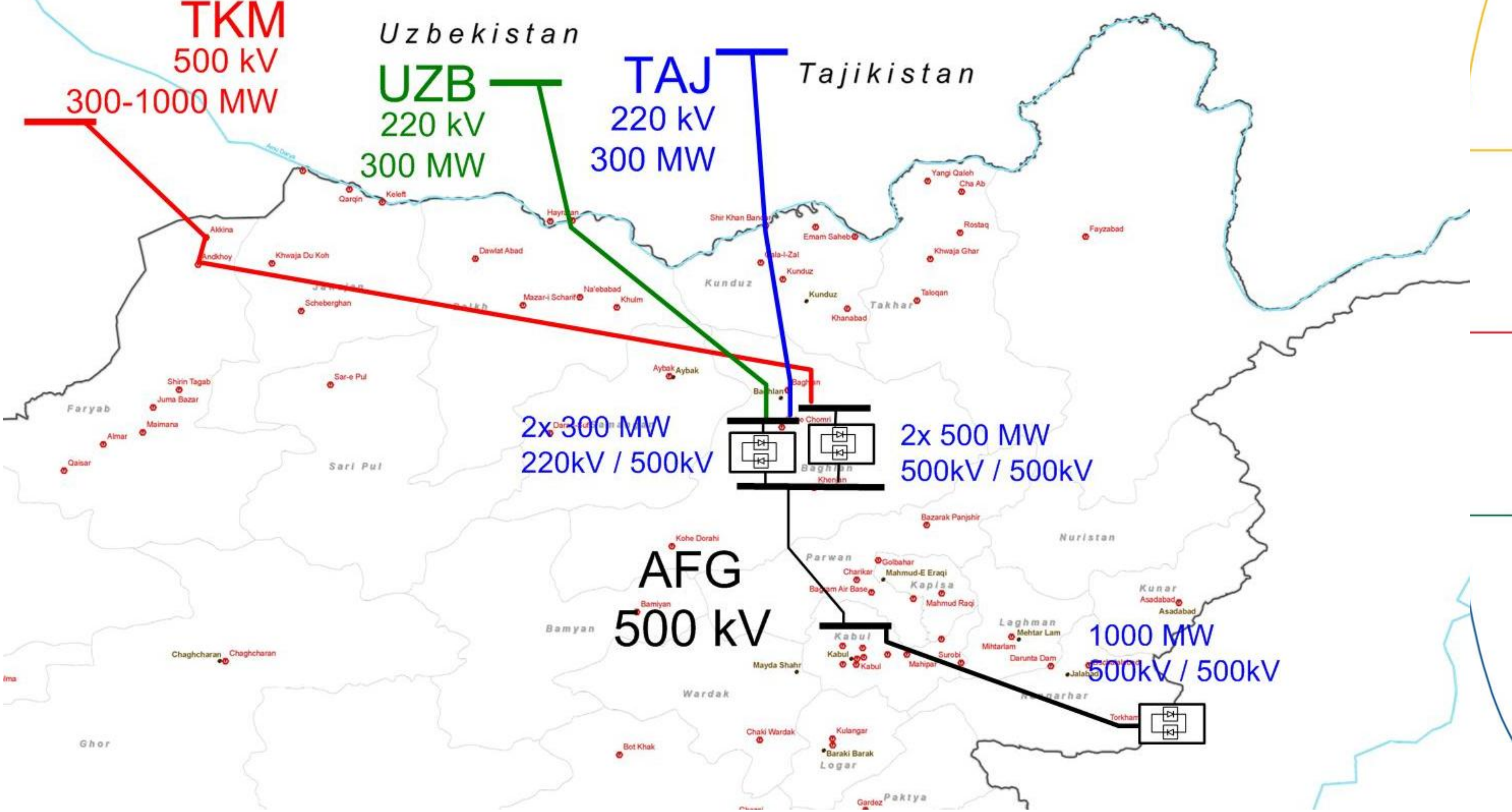
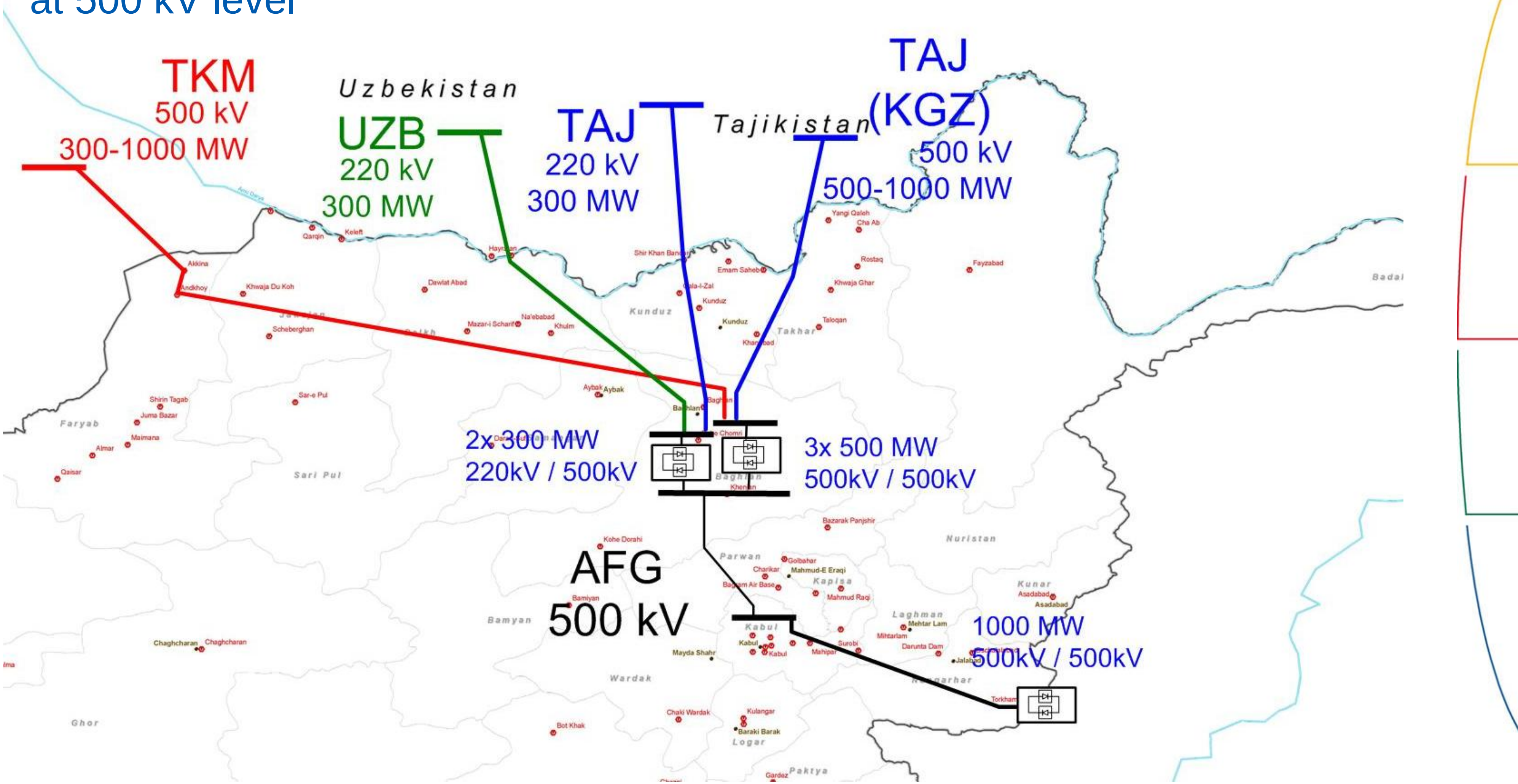
TUTAP - Project Phasing

Phase 1 to 4 – Two HVDC B2B converter at 220 kV level and two converter at 500 kV level



TUTAP - Project Phasing

Phase 1 to 5 – Two HVDC B2B converter at 220 kV level and three converter at 500 kV level



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TUTAP - Project Phasing

Phased project development is required (with energy trade as driving force)

- Phase 1
  - About 100 MW from TKM
  - Up to 300 MW from UZB
  - Up to 300 MW from TAJ, seasonal
  - Afghan generation islanded
- Phase 2
  - 300 MW from TKM (HVDC B2B at 220 kV)
  - 300 MW from UZB
  - Up to 300 MW from TAJ, seasonal
  - Afghan generation islanded
- Phase 3
  - 500 MW from TKM (HVDC B2B at 500 kV)
  - 300 MW from UZB, seasonal (HVDC B2B)
  - 300 MW from TAJ, seasonal (HVDC B2B)
  - Afghan generation feeding to national grid
- Phase 4
  - 1000 MW from TKM (HVDC B2B at 500 kV)
  - 300 MW from UZB
  - 300 MW from TAJ
  - Afghan generation feeding to national grid
  - up to 1000 MW export possibility to Pakistan
- Phase 5
  - 1000 MW from TKM (500 MW seasonal)
  - 300 MW from UZB
  - 1300 MW from TAJ and KGZ seasonal
  - Afghan generation feeding to national grid
  - up to 1000 MW export possibility to Pakistan

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Cost Estimation (1)

Cost estimation for the different phases

Phase 1 including following

- Line 500 kV Afghan border - Andkhoy* length about 40 km
- Line 500 kV Andkhoy - Sheberghan* length about 70 km
- Line 500 kV Sheberghan - Mazar-e-Sharif* length about 140 km
- Substation and substation expansion 220/100 kV Andkhoy, Sheberghan and Mazar-e-Sharif

Requires 100 $m

Phase 2 including following

- Line 500 kV line Mazar-e-Sharif - Pul-e-Chomri* length about 190 km
- HVDC Back to Back 300 MW at Pul-e-Chomri

Requires 170 $m

* Line operated on 220 kV level

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Cost Estimation (2)

Phase 3 including following

- Line 500 kV line Atamyrat - Pul-e-Chomri operation on 500 kV
- Line 220 kV line Mazar-e-Sharif - Sheberghan length about 140 km
- Line 220 kV line Sheberghan – Andkhoy length about 70 km
- HVDC Back to Back 500 MW at Pul-e-Chomri
- 500 kV line Pul-e-Chomri – Kabul
- Substation 500/220 kV Pul-e-Chomri and Kabul

Requires 380 $m

Phase 4 including following

- HVDC Back to Back 300 MW at Pul-e-Chomri
- HVDC Back to Back 500 MW at Pul-e-Chomri
- Line 500 kV line Kabul – Pakistan Border length about 200 km
- HVDC Back to Back 1000 MW at Pakistan Border
- Substation expansion 500 kV Kabul

Requires 370 $m

Cost Estimation (3)

Phase 5 including following

- Line 500 kV line Sangtuda – Pul-e-Chomri length about 250 km
- HVDC Back to Back 500 MW at Pul-e-Chomri
- Line 500 kV line Pul-e-Chomri – Kabul second circuit length about 317 km
- Substation expansions

Requires 413 $m

Investment cost summary

Construction time – 3-4 years /phase

Project timeline -12-15 years (considering partial overlapping of phases)

Benefits for CA – SA energy corridor

Installation of an HVDC B2B Hub in Afghanistan will be the backbone of the required energy corridor infrastructure

Benefits of the interconnection by HVDC B2B schemes

- Flexible integration of all energy sources in CA without operational constraints due to non-synchronous operation of the networks
- Full year power export from CA to SA
- Seasonal use of different energy carriers (winter thermal power from Turkmenistan and Uzbekistan, summer hydro power from Tajikistan and Kyrgyz Republic
- Creation of Afghan national power system, with integration of new own power generation projects
- Possibility of power wheeling even between countries in CA (seasonal support for power deficit like in winter in Tajikistan and Kyrgyz Republic from Turkmenistan)
- Modular and flexible development, correlated with the growth in trade volume