Research on International Power Network Construction in Central-Asia

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Abstract. As part of the Belt and Road Initiative, China promises to provide its abandoned renewable energies in Xinjiang for solving the power shortage problem in Central-Asia countries. This brings a great chance for energy investment and cooperation in power grid construction between China and Central-Asia countries. This paper analyses the power structure and energy institutions in 6 Central-Asia countries and predicts its energy potential and power requirement based on its GDP growth rate. A power grid connection plan is further proposed based on the predictions. This power grid construction would benefit all the countries involved and boost area economic growth for years.

1. Introduction
A green and clean electricity production method has been widely recognised as an urgent requirement internationally. However, in some inland developing countries, due to insufficient financial and technical support, their power production is still dominated by fossil fuels power plants [1]. Moreover, due to the relatively high economic growth rate in Central Asia, power shortage has become a serious problem for them. However, without financial and technical support, fossil-fuel power plants would still be their first choice in the future energy development. This would make the global carbon emission tasks much more difficult to finish and risk damaging the environment [2].

One of the typical area mentioned above is Central Asia area, including Pakistan, Kazakhstan, Tajikistan, Kyrgyzstan, Turkmenistan, Uzbekistan and Xinjiang, China.

As stated by President Xi Jinping in the 2015 New York United Nations Development Summit (UNDS), China proposes the construction of global energy network and dedicates in promoting a green and clean electricity production method. Xinjiang Province is one of the key power bases in China. The renewable energies have developed rapidly in recent years, reaching 22 MWh[1]. It also has the most advanced High-voltage Direct Current (HVDC) power transmission system and its corresponding power grid construction.

HVDC transmission is superior to AC transmission in international power transmission due to its improved stability and power capacity. By using HVDC, the reliability and transmission flexibility of the transmission system is improved.

As proposed in Belt and Road Initiative [1]–[3], China is willing to share its abundant electricity and advanced power technologies to other developing countries, seeking mutual interests and greater prosperities. The construction of a cross-country power network based on HVDC technologies can
reduce the use of fossil-fuels, optimize the unbalanced source-load distribution and promote the economic growth both in Central-Asia and China.

This paper researches the current power system status in 6 Central-Asia countries. A prediction of their future energy requirement is carried based on their economic growth rate. Based on the prediction, the construction plan of global power network is regulated.

2. Current power system status in Central-Asia
The current power structure of 6 Central-Asia countries is discussed in this section.

2.1. Kazakhstan
According to the stats from Kazakhstan energy department, there are currently 71 power plants in operation, producing 19000 MW power. 83.3% of them come from thermal power plants, 4.8% from gas-turbine, 11.9% from hydropower stations. 70% of the power generation relies on coal, 15% on natural gas and heavy oil [4]–[6].

There are lots of wind and photovoltaic resources available in South and Southwest Kazakhstan. Although renewable energies have been promoted by the government for years, only 1500kW wind farms are currently under construction.

The major problem in Kazakhstan’s power structure is concluded as:
- High industrial power consumption
- High carbon emission
- Heavy air pollution in the urban area
- Power shortage in the remote area

With the rapid economic development, the annual power demand increase in Kazakhstan is 5%-6%. If the economic growth rate kept constant over the next few years. Annual power increase rate is estimated to be 7.2% by 2020. Significant power shortage will be a major problem in South Kazakhstan.

Due to the relatively low infrastructure investment and technological support, no significant improvement can be founded in Kazakhstan’s future development plans. Kazakhstan government has declared a national law for encouraging the development of renewable energies in 2011. However, even by the goal, renewable energies will only take around 1% of Kazakhstan’s total power requirement.

2.2. Kyrgyzstan
Only 18 power plants are currently operating in Kyrgyzstan, producing 3748 MW power. 80.8% of them come from 16 hydropower plants, while the rest come from 2 thermal stations [7]–[9]. While the hydropower is a clean and green renewable energy, its dominated role in Kyrgyzstan does cause a series of the problem including: seasonal power variation, lack of resources and insufficient power regulation ability.

In opposite to Kazakhstan, Kyrgyzstan government tends to promote the development of renewable energies continuously. In the foreseeable future, the Kyrgyzstan government has proposed over 20 policies for encouraging renewable energies investment including land tax reduction.

An annual power consumption of each resident in Kyrgyzstan has exceeded 2400 kWh due to its fast industrial and agriculture development. However, due to its relatively low power supply (3746MW), continuous increase of electricity price (Resident electricity price: $0.043 to $0.1/kWh) has been conducted by the government to encourage energy-saving, significantly limiting the economic development. Estimated annual power requirement is 30 TWh, the maximum power load is 6000 MW by 2020, if the growth rate kept constant.

2.3. Uzbekistan, Turkmenistain
The power stations installed in Uzbekistan has reached more than 12400MW. There are 45 power plants in Uzbekistan, containing 13 thermal power plants (88.2%) and 32 hydropower plants (11.8%). As the largest national power company, Uzbekenergo has 16 power stations with 12040MW installed capacities. An only limited number of photovoltaic projects are declared by Uzbekistan government. 3
photovoltaic power stations are planned by 2020 in Samarkand, Namangan, and Suhan River. The total power capacities are estimated by 0.1 MWh and the ETA is around 2020[10], [11].

The install power capacities in Turkmenistan consists of 2857 MW gas-based thermal power plants, 1.2MW hydropower plants, 1592.7MW coal-based thermal power plants, and 400MW oil-based power plants. After the agreement with the Generic Electric company(USA) in 2006, the install capacities are expected to be increased by 50% in 2020[12]–[14].

The current power status in Uzbekistan and Turkmenistan are better than the previous countries. They are expected to be not only self-supported but also export energy to the other countries. By 2020, Uzbekistan is expected to have a total power requirement of 90 TWh and the maximum power load is 16000 MW. Turkmenistan, on the other hand, should have 30 TWh and 5500 MW. Itself can export 6 TWh to other countries, making it the most important power hub in Central-Asia. Pakistan should have 12.09 TWh total power requirement by 2015.

2.4. Tajikistan
Similar to Kyrgyzstan, the power structure in Tajikistan is also hydropower dominated. With over 98% of its 5400MW power from hydropower station, it shares a similar structure problem to Kyrgyzstan. 2 thermal power plants are used as the backup supply, generating only 318MW power to the grid.

Unlike Kyrgyzstan, Tajikistan doesn’t have abundant wind resources. Currently, it focuses on the development of photovoltaic power and has a 160KW experiment system in Gyakov National Hospital and Institute of Maternal Science in Dushanbe. Although a nuclear power trade agreement has been signed with Russia in 2012, no nuclear power plant has been planned in the foreseeable future[15].

The power prediction in Tajikistan is kind of unique in Central-Asia. Even its annual power production can theoretically meet its annual power requirement. Although the abundant water resources in the rainy season can not only provide enough power in summer but also have enough power for export, Tajikistan still needs to import power from other countries in winter seasons as shown in Fig.1. Therefore, Tajikistan focuses more on balancing the seasonal power variation. This makes the power network an excellent choice for Tajikistan.

![Figure 1. Power status in Tajikistan](image1.png)

![Figure 2. Centre-Asia Super Power grid](image2.png)

2.5. Pakistan
By June 2015, the total install capacities in Pakistan is 24823 MW, increased by 6.3% compared to last year. Thermal plants take more than half its total power supply (67.74%), leading hydropower (28.66%) and a small number of other energies (3.6% nuclear and wind power)[16].

With the economy develops faster and faster in Pakistan, the power shortage problem is getting worse. It has become an important factor restricting economic development. According to information from Pakistan, the largest electricity demand in Pakistan is 13490 MW, while the capacity to generate electricity is 10790 MW and the electricity gap is 2700MW. The lack of power generation capacity is the main cause of the power crisis in Pakistan.

2.6. Summary of Power connection status in Central-Asia
As stated in the previous sections, several international power transmissions lines have been constructed for years as shown in Fig.2. To conclude, the Central-Asian super grid is a North-South oriented, tree-structured, 500KV single-loop power grid. However, due to the insufficient financial and technical support, this giant Central-Asian power network is currently facing the following
challenges: fragile power structure, high transmission losses, low transmission capabilities, ageing power devices, out-of-date control strategies, and insufficient covering areas.

With the increasing power demand, the complexity and the capacities of this power grid would increase exponentially, requiring an upgrade on both the transmission hardware (power devices) and transmission software (Control system). The cooperation between China and Central-Asian countries can solve the power dilemma in Central-Asia and significantly boost the economic development in this area.

3. International power network construction plans

The average distances between the capitals of Central-Asia countries and Urumqi, China are over 1000km. By considering the development of future wind-photovoltaic and hydropower plants, a ±500KV HVDC transmission line is more appropriate from both economic and technical point of view. When the two places are adjacent, the back-to-back DC transmission mode is selected, and the advantages are more prominent. There is no mainstream line, the DC loss is small, and the investment cost is low. It cooperates well with the current HVDC transmission system and satisfies the power demand in Central-Asia for the next decades. The typical parameters for an HVDC transmission line are shown in Table 1.

### Table 1. The arrangement of channels.

| Item                      | Value       |
|---------------------------|-------------|
| Voltage Level             | ±500KV      |
| Structure                 | 4*300       |
| Phase-Phase distance      | 59.4        |
| R₀ (Resistance)           | 0.02625     |
| R₀ (Resistance unit value)| 1.052*10⁻³  |
| X₀ (Reactance)            | 0.284       |
| X₀ (Reactance unit value) | 9.775*10⁻³  |
| B₀ (Conductance)          | 3.910⁻⁶     |
| B₀ (Conductance unit value)| 9.775*10⁻³  |
| Diameter                  | 42.0        |

A prediction of Central-Asian power requirement is conducted by using import/export power data and economic growth rate as shown in Eq.1.

\[
\begin{align*}
    \text{R}_w &= K \times R \\
    \text{W}_e &= \text{W}_0 (1 + \text{R}_w)^n
\end{align*}
\]

Where \(R_w\) is the growth rate of power requirement, \(K\) is the elastic coefficient, \(R\) is the Growth rate of GDP, \(W_0\) is the predicted power requirement, \(W_e\) is the current power requirement. The import and export power anticipation are shown in Table 2 (+ represents export power, - represents imported electricity) and its supply ability is shown in Table 3.

### Table 2. Import/Export energy estimation (TWh).

| Country       | 2017  | 2020  | 2025  | 2030  |
|---------------|-------|-------|-------|-------|
| China(Xinjiang)| -43490| -54830| -80550| -90301|
| Kazakhstan    | 531   | 615.6 | 713.5 | 827.3 |
| Kyrgyzstan    | -780  | -560.8| -356.2| -124.5|
| Uzbekistan    | -2830 | -2360.3| -1896.2| -1328.2|
| Turkmenistan  | 600   | 705.6 | 825.3 | 948.5 |
| Tajikistan    | -210  | -142.6| 85.3  | 125.2 |
| Pakistan      | 880   | 2320  | 3102  | 4234  |

Based on this prediction, the cross-country power grid connecting plan is proposed as shown in Fig.3. A ±500KV will be constructed between Xinjiang and Central-Asia, preferably to Kazakhstan.
since it is the major load Central, which would enable annual power transmission capability to reach 3000 MWh. The second transmission line (back to back transmission) with 1000 MWh transmission ability should be built between Kyrgyzstan and Xinjiang. The third one being the China-Pakistan transmission line with 6000 MWh capability which would cover Pakistan’s power requirement until 2030.

![Figure 3. Power Grid construction plans](image)

**Table 3.** Power Transmission ability (Unit: TWh).

| Year | Power storage Central-Asia | Power transmission Ability Central-Asia | Power transmission Ability Pakistan |
|------|---------------------------|---------------------------------------|-----------------------------------|
| 2017 | -2464900                  | /                                     | /                                 |
| 2020 | -1742500                  | -1642                                 | 2900                              |
| 2025 | -628300                   | -1200                                 | 4140                              |
| 2030 | 448300                    | 640                                   | 5369                              |

4. Conclusion
A forthcoming power shortage can be expected in Centre-Asia due to the lack of financial and technical support in power construction. A China-Central Asian super power grid, which transfers the abandoned renewable energies internationally, would totally solve the power shortage problem in Centre-Asia, creating numerous chances in industrial and infrastructure development for both side. In this paper, the amount of power shortage is calculated based on the GDP. The construction plan of the China-Central Asian super power grid is regulated based on the calculation considering their economic benefits and technical issues. This proposed plan reduces the use of fossil-fuels and optimizes the unbalanced source-load distribution with 2 HVDC between Kazakhstan and Pakistan, and one DC back to back power grid in Tajikistan. Its detail construction plan (including connecting position and transmission control strategies) requires more information on the specific power transmission grid and will be studied in the future.

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