Analysis on DPRK Power Industry & Interconnection Options

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<Introduction>

- DPRK suffers from Energy/Electricity shortage ….
  - Power Capacity/Generation amount of 2009 is worsen than 2008
  - Strongly related to DPRK Economy crisis
  - DPRK practices proper internal & external measures …
    - → Construction of generation plants (big or medium hydro plants)
    - → Remodeling of power facilities (plants, T/L, D/L. Network …)
    - → Enhancement of T&D facilities → Reduce power loss
    - → Ultra-strong Demand side managements
    - → Wants to the co-operational policy with the ROK, RF, China
- No exact data & statistics on the DPRK Electricity Sector
  - Nobody knows the exact data on power plants, power system …
  - Only estimated data had been published …

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<Comparison of ROK/DPRK Power Industry>

Factors		ROK (Jan. 2008)		DPRK (Jan. 2008)		DPRK/ROK
Capacity (MW)	Hydro	71,687	5,430	7,242	4,042	10.1%
	Thermal		48,541		3,200	
	Nuclear		17,716		-	
Capacity Factor(%)		91.2%		Estimates 30%		
Genration (TWh)	Hydro	414.7	5.6	25.5	14.0	6.14%
	Thermal		258.1		11.5	
	Nuclear		151		-	
Frequency(Hz)		60		60		-
Trans. Voltage (kV)		765/345/154		220/110/66		-
Dist. Voltage(kV)		22.9/0.22/0.11		3.3/6.6/11/22		-
Demand Char.		Summer daytime peak		Winter night peak		-
Supply Char.		No. Shortage		Shortage		-
Operation		Island System		Island System		-

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<Comparison of ROK/DPRK Power Industry, BOK>

YEAR / DATA		2005	2006	2007	2008	2009
South KOREA	Capacity (MW)	62260	65510	68270	72490	73470
	Generation (TWh)	364.6	381.2	403.1	422.4	433.3
North KOREA	Capacity (MW)	7770	7820	7050	7500	6930
	Generation (TWh)	21.6	22.5	23.7	25.5	23.5

<Present Status, Generation>

- DPRK authority transfer their formal Data to KERI (2006)
  - **These data delivered by DPRK officers through PANMUNSEOM**
  - **Existing capacity 9500MW(Hydro 5170, Thermal 4330MW)**

    → Almost plants are decrepit, couldn't supply electricity
  - **Supply potential capacity 5970MW(Hydro 3930, Thermal 2040)**

Existing Capacity	**9500 MW**	**Hydro 5170 MW**
		Thermal 4330 MW
Potential Supply Capacity	**5970 MW**	**Hydro 3930 MW**
		Thermal 2040 MW

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<Present Status, Generation>

- **Generation amount**
  - **Min 16TWh (KERI, 2007) , 725kWh/person**
    Max 23.5TWh(BOK, 2009) ≈ 1000kWh/person
  - **Average capacity factor is about 30~35%**
  - **Max 36 TWh if free supply/demand is guaranteed …**
    → same level of 1987 per capita in ROK
- **Real Electricity Consumption**
  - **Estimates power loss 20% caused by weak system characteristics**
    → same level of 1960's (ROK, 3.99% 2008)

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<Overview of Present Status>

- DPRK Electricity Consumption per Capita ≈ 700-1000kWh/Year
  - Same Level of ROK in about 1980 …
  - At that time, ROK has no problem to supply electricity, But DPRK …
  - This is not lower than any other developing countries in about 2000

Country	Electricity Consumption per Capita
Philippines	515(kWh/year/person)
India	393(kWh/year/person)
Indonesia	390(kWh/year/person)
Pakistan	374(kWh/year/person)
Sri Lanka	283(kWh/year/person)
Bangladesh	102(kWh/year/person)
Myanmar	74(kWh/year/person)
Nepal	101(kWh/year/person)

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<DPRK plants under construction>

- Hydro Plants under Construction since 2000

[MW]

Plant Name	Install Capacity	Remarks
Guemya-gang	180	
Wonsan-chyoungnyeon	60	
Anbyeon-chyoungnyeon	200	
Uerang-choen	73	
Youngwon	135	
Tae-cheon #2	200	
Tae-cheon #4	20	
Yeseong-gang	100	
Heecheon	100	
Samsu	50	
Bankdusan-chyoungnyeon	30	

<표> 남북한 전력계통 비교 (2004년 12월 기준)

<표> 2004년 북한 전력산업 현황 추정자료

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<Present Status, Transmission>

- **Transmission System**
  - **Composed of 220, 110, 66kV system**
  - **Frequency 60Hz, same as The ROK // Russia, China 60Hz**
  - **Divided into East, West, South & Central System**
  - **Weak power system**
  - **Plan to construct 500kV Line to connect east/west system**
  - **Power transmission west → east in rainy season**
    east → west in dry season
  - **Eastern system DUMAN-river Hydro & SEONBON Thermal plants**
  - **Western system AMROK-river hydro & Thermal plants nearby PYEONGYANG**

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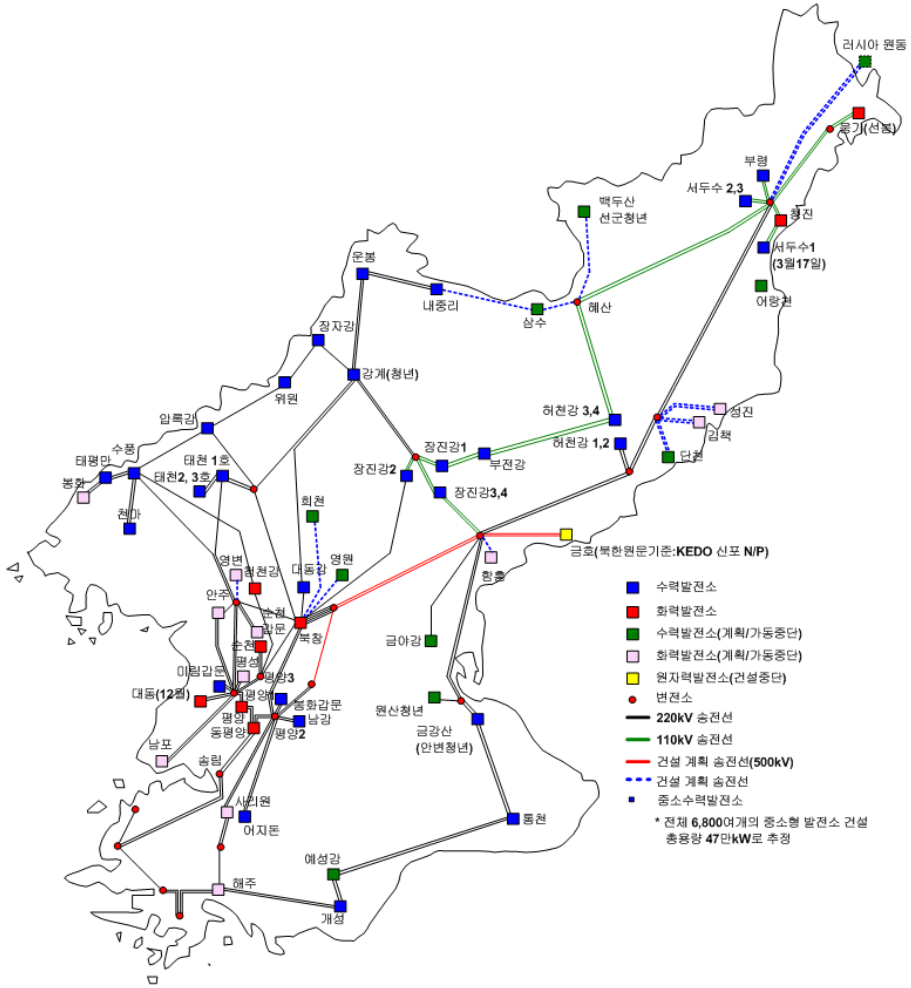
<Estimated DPRK Power Network>



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<Present Status, Distribution>

- **Distribution System**
  - **Primary Voltage → 3.3, 6.6, 11, 22kV**
  - **Secondary Voltage → 110V, 220V**
  - **Standardization to 11kV Primary Voltage**

    → KEPCO 22.9kV is more reasonable
  - **22.9kV system was already applied to supply "GAESUNG Industrial complex", 30km, 15MW x 2 circuits**

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<Present Status, Power Quality>

- **Very weak system and bad quality**
  - **Several measured data was reported**

    ① (DATA-1, measured value of 220 [V] rating) 177-209 [V]

    ② (DATA-2, measured value of 110[kV] rating) 88 -99 [kV]

    ③ (DATA-3, frequency variations, 60 [Hz] rating) 56.7 - 59.8[Hz], 51.0 - 54.0[Hz]
  - **Voltage below 0.7-0.9[pu] (ex 110kV → 80-90kV level),**
  - **Frequency 60Hz → 43-55Hz**
  - **Obstacle to practical business cooperation**

    (ex: KORES develops the DPRK coal mine, but couldn't operation because of ba power quality, seek to alternatives to solve ….)
  - **Necessity for reinforcements on overall DPRK power system**

    → Reduce power loss above 20% → below 4%, ROK level

    → Improve the industrial productivity

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<Future Prospects : Free Market Volume>

- **Demand on Free Market Volume at preset status …**
  - **Estimated by about 36TWh, more than 1,600kWh/person/year**
  - **As high as twice compared with present real consumption**
  - **Same level of ROK per capita in about 1987 ….**
- **Consumption composition ratio (KERI)**
  - **Industry over 70%**
  - **Military about 14%**
  - **House lower than 11%**

	Industry	Military	House	Transportation	Total
Consumption (TWh)	26	4.9	4.3	0.8	36
Ratio(%)	72.4	13.6	11.9	2.1	100

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<Future Prospects announced by DPRK>

Category	2010	2020
Total Capacity	11,730 [MW]	16,150 [MW]
Hydro	5,980 [MW]	6,950 [MW]
Thermal	3,750 [MW]	4,000 [MW]
Nuclear	2,000 [MW]	5,200 [MW]
Annual Average Load	9,727 [MW]	12,450 [MW]
Energy Demand	79 [TWh]	100 [TWh]

<DPRK Electricity Policy>

- **Electricity Policy for DPRK Power Supply/Demand**
  - **Divided into 5-step electricity policies**
  - **1945 - 1970 :**

    → Mainly dependent on hydro plants (90%), No shortage
  - **1970's – 1980's : Policy change hydro by coal (thermal)**

    → Construction of thermal plant supported by Russia
  - **1980's – : Policy change coal by nuclear plan**

    → Construction Plan for Nuclear plants, ex) KEDO project
  - **1990's - : Construction of medium/small hydro plants**
  - **2000's - : Conduct both internal, external policies in parallel**

<DPRK Electricity Policy>

- **Internal policy :**

→ Devise various countermeasures to overcome electricity shortage

- Construction of Large hydro plants (11 units 1180MW)
- Remodeling of overall power system

  → Generation plants, Transmission, Distribution system
- Co-operational policy with neighboring countries

  → Russia, The ROK
- Energy saving policy

  → Discriminatory power supply, replace by lighting lamp for energy saving

  → Using the Electronic metering ticket

<DPRK Electricity Policy>

- **Internal policy (continue) :**
  - **Energy 3-year's plan (03-05)**

    ① Restructuring power plants

    ② Coal production increase

    ③ Expansion for coal production machinery
  - **Science & Technology 5-year's plan (03-07)**

    ① Efficiency improve of water turbine (90%)

    ② Saving the heavy oil & Modernize the coal production tech.

    ③ Reduce the power loss (21%→16%)

    ④ Transmission systemize for NEAREST

    ⑤ Develop the renewable energy

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<Energy Policy : Practical cases>

- **Construction of large hydro plants**
  - **11 units, 1180MW**
- **Restructuring of aging thermal plants**
  - **BUKCHANG(1600MW), PYONGYANG(500MW) Thermal Plants**

    → Change Boiler, Turbine ….
  - **SUPUNG(800MW). GYANGKYE(246MW)**

    → Water Turbine change & DAM Reconstruction
- **Reinforcement of T&D Lines nearby PYONGYANG**

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<Energy Policy : Small/Medium Hydro>

- **Construction of Medium Hydro plants from 1999**
  - **Effect of small hydro was not high ….**
  - **Constructed 48 units(86MW) in 2005**

    Under construction 18개
  - **No. of units decreased (300/y →66/y),**

    Increased capacity (7-200kW/unit → 1,800kW/unit)

(Unit : kW)

	-'00	2001	2002	2003	2004	2005	Total
Planning	6,840	370	250	?	100	43	
Constructed	6,615	98	40	30	10	48(18)	6,841(18)
Capacity	292,000	24,500	30,000	30,000	20,000	86,400	470,900
kW/unit	31	250	750	1,000	800	1,800	

<DPRK Electricity Policy>

- **External policy :**
  - **DPRK requests to Electricity Aid**

    → To ROK, Short-term 500MW , Long-term 2,000MW

    → To Russia, 300-500MW
  - **Wants to build Nuclear plant through Political negotiation**
  - **Facility maintenance support from neighboring countries**
  - **ROK offers 2000MW aid if DPRK gives up atomic plan …**
  - **Electricity Aid under mutual political, economic trust should be guaranteed**
- **Nowadays, military tension happens caused by "CHEONAN …."**

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<Energy Policy : Cooperation cases>

- **External cooperation**
  - **Import used plant facilities with natural resources security**

    from RUSSIA(BUCKCHANG), CHINA (large hydro), HYDRO SWEDEN (small hydro plants)
  - **Collaboration with CHINA :**
    - **Construction of Power line & cable factory**
    - **Change of T&D power line & lighting (Compact lamp to reduce power loss by 80%)**
    - **Supply card type electronic power meter**

      → Introduction of capitalism on power consumption

<Cooperation case : GAESUNG>

- **10MW Capacity Transmission Line & "PEACE substation"**
  - **Electricity supply was started since March 2006**
  - **At first, using 22.9kV 2-circuit distribution line**
  - **Now, 154kV transmission line and 154kV substation, so called "PEACE S/S" since 2007**
  - **40,000 North Korean are now working in GAESUNG industrial complex**
  - **KEPCO had the financial damage more than 10 million dollars annually because of the high cost but low electricity price for this area**

<Cooperation case : GAESUNG>

<Interconnection Options : AC/DC >

Comparison of AC/DC options

Category	AC	DC
Transmission capacity	Disadvantage	Advantage
Reactive compensation	Disadvantage	Advantage
Fault Impacts	Disadvantage	Advantage
Fault Current	Disadvantage	Advantage
Power quality	Disadvantage	Advantage
System control	Disadvantage	Advantage
Power loss	Advantage (short distance)	Advantage (long distance)
Economic efficiency	Advantage (short distance)	Advantage (long distance)
Point of issue	Low Frequency Oscillation Unstable Phenomena	Commutation Failure caused by weak system

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<Interconnection Scenario>

- **Many scenarios for NEAREST has been published**
  - **ESI, KERI, NI report/paper etc.**
  - **Has rough concept/contents and similarities with each other**
  - **Among these scenarios, "(RU)-DPRK-ROK" is the key point**
- **Future interconnection potentials b/t ROK and DPRK**
  - **Possibility of power interconnection in future**
    - **Power supply for GAESUNG industrial complex was realized**
    - **ROK government offers 2000MW aid if DPRK gives up atomic plan**
  - **DPRK wants to build light water reactor ….**
  - **Unified power system operation will be realized**

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<Interconnection Scenario>

- **Future potentials for "RF-DPRK" power interconnection**
  - **"RU Vladivostok – DPRK Cheongjin" 375km, DC Line**
  - **Expect 220kV 50Hz AC → 500kV 50Hz AC**

    → ±500kV or ±600kV DC Operation
- **Future considerable points**
  - **Harmonization of Short and Long term Interconnection policy**
    - **GAESUNG & Cheongjin**
    - **Parallel operation of interconnection system**
  - **How to operate 50Hz AC S/S in Cheongjin after DC operation begins ?**

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<Feasible power exchange, ROK-DPRK-RF>

- **Summary for "ROK-DPRK-RF" interconnection scenarios**

Item	Scenario-1	Scenario-2	Scenario-3	Scenario-4
Interconnection Type	3 Terminal	2 Terminal	2 Terminal	BTB
Route	ROK-DPRK-RF	ROK-RF via DPRK	ROK-RF via East Sea	DPRK internal power system
Min Power	2GW	2GW	3GW	1GW
Max Power	4GW	4GW	3GW	4GW
Cost	Medium	Medium	Large	Small
HVDC Type	VSC	VSC or CSC	VSC or CSC	VSC
Energy security	Normal	Bad	Good	Bad
Reliability	Normal	Good	Good	Bad
Priority	1	2	3	4

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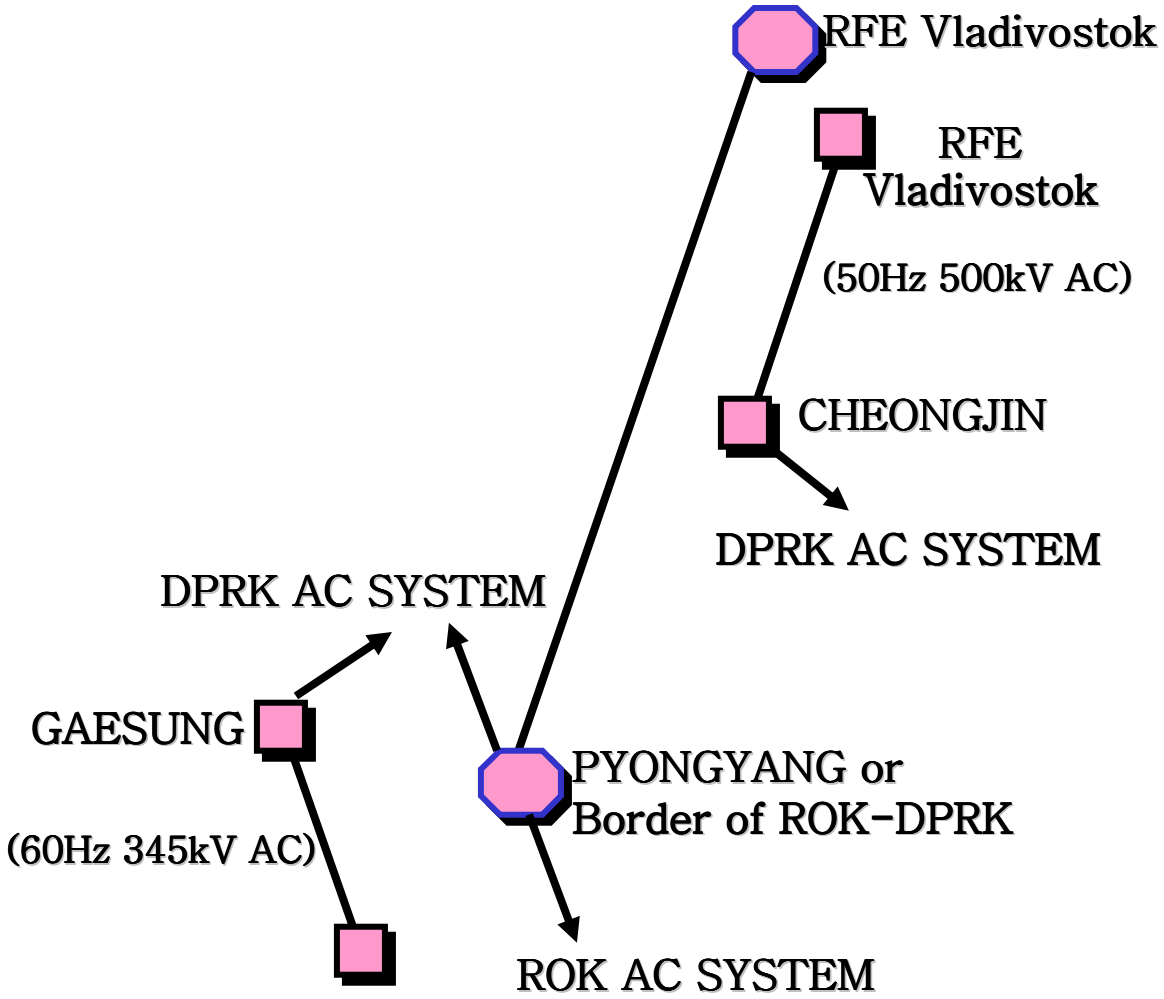
<Future Prospects : Interconnection Scenario>



<Barriers on Interconnection>

- **Structural and regulatory barriers**
  - **Political and administrative styles of regulation considering natural monopoly characteristics of transmission**
  - **Treaty and Legal barriers**
  - **Economy-wide investment conditions**
  - **Legal framework for investors including financing**

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<SCENARIOS>

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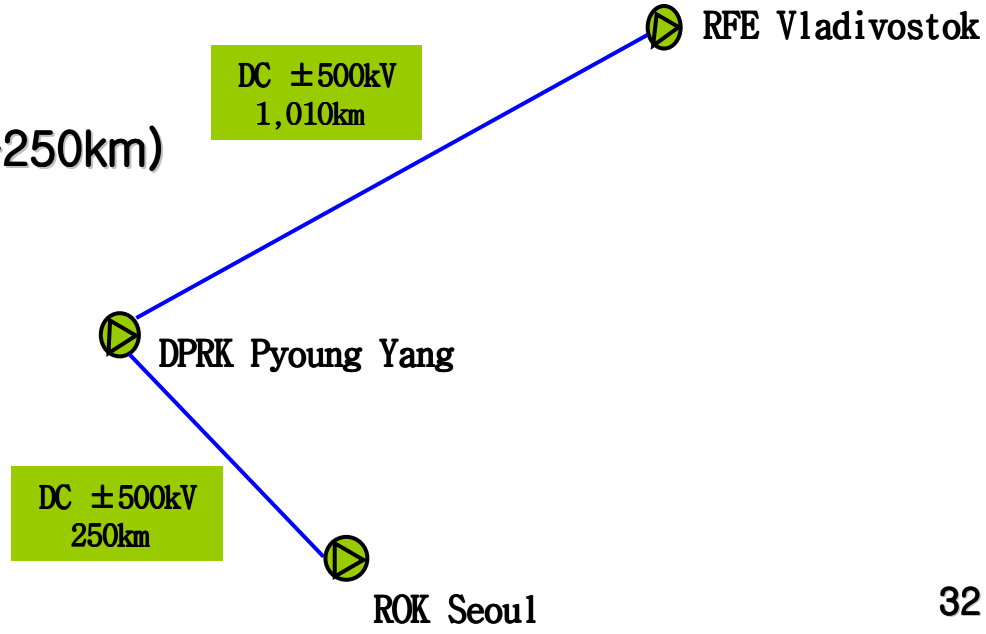
<Scenarios>

- Four Scenarios are proposed
  - ex) (Scenarios-1) is ...
    - Power System Interconnection “ROK-DPRK-RF”
    - Capacity of 2~4GW HVDC, ±500-600kV 1,260km
    - 3-C/S Terminal, Seoul, Pyongyang, Vladivostok
  - Composite system reliability analysis, HL II Level
    - NEAREL(NEAREST-RELIABILTY) Program is developed
    - Composite System Reliability Program considering Generation, Transmission and Interconnected Tie Line
    - TEAG (Tie line constrained Equivalent Assisting Generator Model) Considering Assisting System plus Tie Line

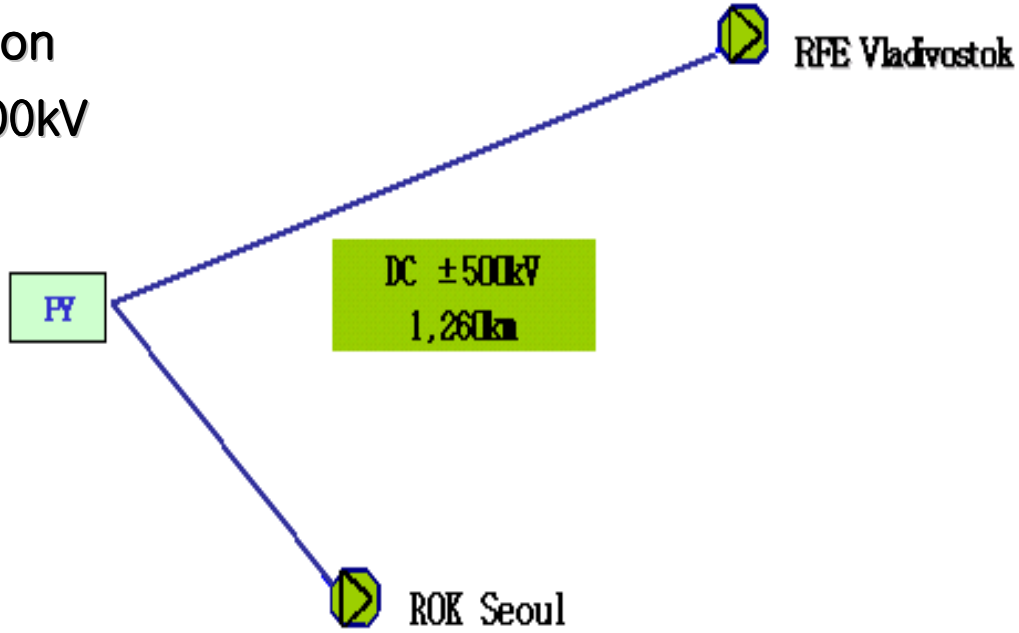
<ROK-DPRK-RF interconnection Scenario>

- (scenario-1)
  - "ROK-DPRK-RF" 3-Terminal HVDC interconnection
    - Converter stations will be located in Vladivostok, some point near Seoul and Pyoung Yang
  - HVDC system configuration
    - VSC-HVDC, DC ±500kV
    - T/L : 1,260km (1,010km+250km)



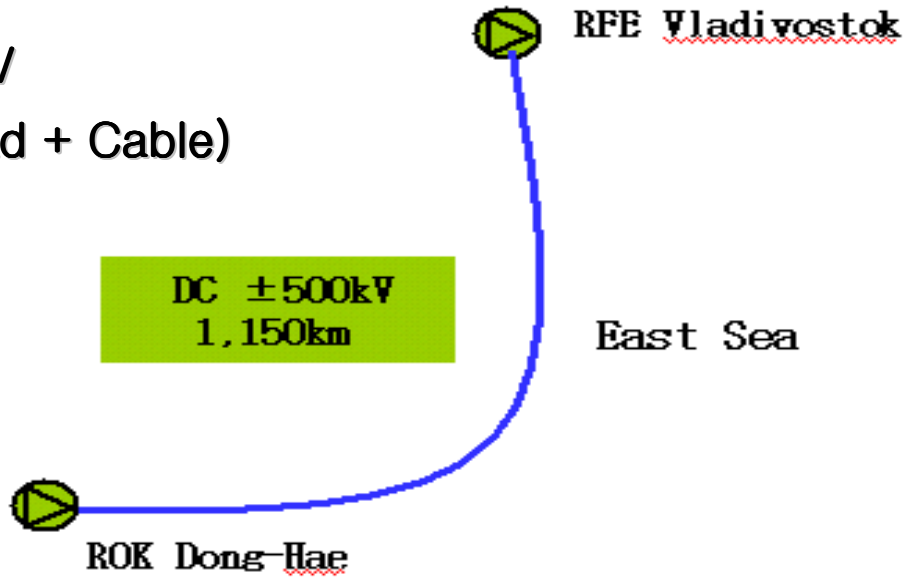
<ROK-DPRK-RF interconnection Scenario>

- (scenario-2)
  - "ROK-RF" 2-Terminal HVDC interconnection
    - DPRK provides the interconnected line route
    - Converter stations for supplying or receiving the power will be located in two places; Vladivostok and some point near Seoul
  - HVDC system configuration
    - VSC-HVDC, DC ±500kV
    - T/L : 1,260km



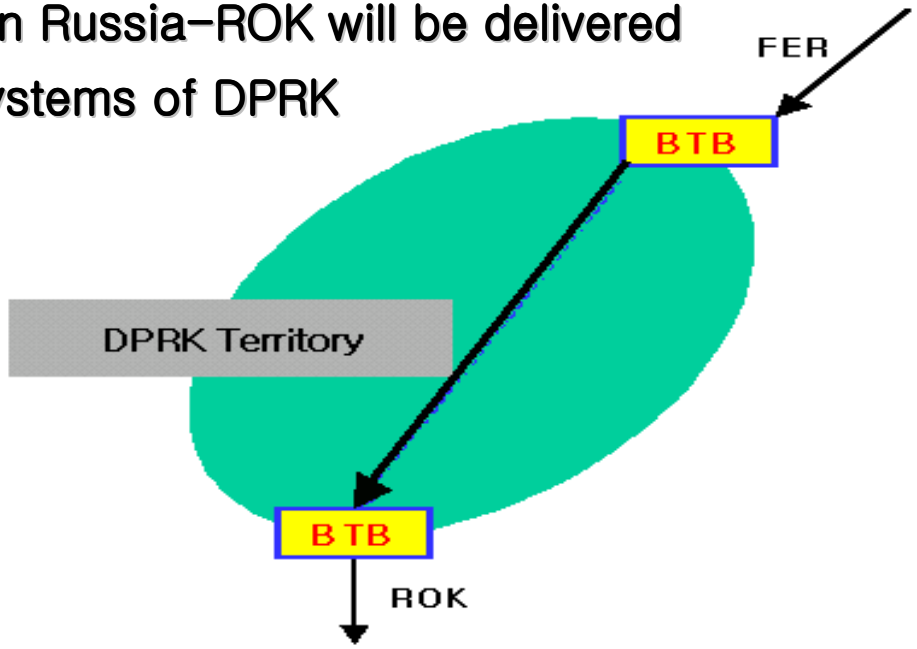
<ROK-DPRK-RF interconnection Scenario>

- (scenario-3)
  - "ROK-RF" 2-Terminal HVDC interconnection
    - Interconnected line via East Sea
    - It has the merits of energy security viewpoints when importing power from Russia without the demerits of passing through DPRK territory
  - HVDC system configuration
    - VSC-HVDC, DC ±500kV
    - T/L : 1,150km (Overhead + Cable)



<ROK-DPRK-RF interconnection Scenario>

- (scenario-4)
  - "ROK-RF" BTB interconnection
    - BTB interconnected system in border area
    - Two converter stations will be located in the border area
      : Russia-DPRK and DPRK-ROK
    - Exchange power between Russia-ROK will be delivered through the AC power systems of DPRK
  - HVDC system configuration
    - VSC-HVDC, DC ±500kV



<Conclusions for feasible power exchange>

- Proposal for "ROK-DPRK-RF" interconnection
  - Overview of interconnection
    - 3 Terminal PTP-HVDC system is suitable for interconnection
    - Converter stations are located at Vladivostok, Pyung Yang and Seoul
    - BTB-HVDC is not available due to weak power system of DPRK
  - System configuration
    - DC ±500kV, Multi-Terminal HVDC system
    - VSC type HVDC system is more appropriate for interconnection
    - Two-Bipole DC transmission
  - Feasible exchange power
    - Feasible exchange power taking account of technical and economic constraints is 3GW to 4GW
    - 3GW to 4GW is allowable from the viewpoint of energy security (About 5% of power demand in 2017)

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<Conclusions for feasible power exchange>

- NEAREST Scenarios for NEA 6-countries : 3 alternatives
  - (Main Land) // (East Sea) // (Large New Interconnection)
  - Multi-Terminal HVDC Interconnection, DC ±500-±600kV
  - Possible for CBT caused by base and seasonal load difference
- Generation capacity is reduced and Capacity factor is increased for all interconnection scenarios.
- (Initially) CBT with contract base → (Finally) Market base is reasonable
- Deregulation has positive effect on CBT, Uncertainty of DPRK, Pos./Neg. points of Energy security, Cooperate financing with government guarantee

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<Study results with basic premise>

- Reliability study :
  - Average reliability index of all countries is greatly increased
  - But, ROK is slightly decreased in case of unidirectional supply from ROK to DPRK because of the severe electricity deficiency_of DPRK
  - Of course, after DPRK status is stabilized, reliability index of ROK will also be increased.
- Different premises for each economic assessment :
  - (Economic) : max/min import/export tariffs lower than (50-α)Won/kWh
  - (Marketability) : About (40) Won/kWh for CBT
  - Similar results with unidirectional solution, but have small difference caused by different premise

<Conclusions for feasible power exchange>

- Proposal for NEAREST region interconnection
  - Overview of interconnection
    - (Main Land Circle) 5 Countries : ROK, DPRK, RF, China, Mongolia
    - (East Sea Circle) 4 Countries : ROK, DPRK, RF, Japan
    - (Large New Circle) 6 Countries : ROK, DPRK, RF, China, Mongolia, Japan
  - System configuration
    - DC ±500kV, Multi-Terminal HVDC system
    - VSC type HVDC system
    - Two-Bipole DC transmission (Overhead + Cable)
  - Power exchange pattern
    - Seasonal power exchange between interconnected countries
    - (Summer Season) RF, DPRK → ROK, Japan, China
    - (Winter Season) ROK, Japan, China → RF, DPRK, Mongolia