6.3 Study of System Reliability

6.3.1 Method of Study of System Reliability

The 500 kV network system will be reinforced by 2010 as shown in Table 6-3-1. A double-circuit line from the north to south will be completed around 2010. A 500 kV power grid will be constructed northward from Nho Quang substation and southward from Di Linh and Phu Lam substation by 2020. Figure 6-3-1 shows the 500 kV network system in 2020 as planned by EVN.

"The north-south transmission lines" indicate transmission lines connecting Nho Quang substation to Phu Lam and Di Linh substations. "The north-central region" indicates the region between Ha Tinh substation in the northern and the central area, and "the central-southern region" indicates the region between the Plei Ku substation in the central and southern region.

Moreover, the 500 kV power grid expanding northward from Nho Quang substation is called "the north grid".

The goals of the study are as follows.

- Optimum reinforcement of the north-south transmission lines
  - Calculating possible power flow from the north to central regions by changing the scale of reinforcement of the north-south transmission lines and estimating the optimum reinforcement of north-south transmission lines
- Method of power transmission of PSPP

The studies were carried out in the normal state of the system without any contingencies (the N-0 criterion) as well as in the state of the system where the N-1 criterion can be met. Power supply is still possible without any special influences on the system; even if a unit of facilities is dropped. The reason for selecting both criteria is that the existing 500 kV transmission lines of Vietnam consist of one circuit which the applied reliability criterion is the N-0 criterion. However in the future, additional general criterion such as the N-1 criterion should be applied as well.

The general requirements for the N-1 criterion are as follows. Dropping a circuit of lines must not cause an increase in the power flow which is greater than the thermal capacity of facilities and must leave the system stable without causing any remote generator shedding[1]. Dropping a generator

[1] Generator shedding with the protection relay system that controls remote circuit breakers through telecommunication circuits from a location detecting contingency

by a single circuit fault must not cause frequency-changes to reach unacceptable levels. The power supply must not be interrupted in the case of dropping a single circuit of lines.

Acceptable levels of frequency-changes are to be set so as to prevent the expansion of outages that are caused by the dropping of a cascading generator due to the extraordinary rise and fall of the frequency. 1 Hz is usually set as the criterion of frequency changes regarding system planning.

6.3.2 Main Study Conditions

- PSS/E was used for the study. The 500 kV network system in 2020 was based on the data collected during the first site survey.
- The loads on the 500 kV system were assumed to be able to fill the total capacity of transformers in order to study severe cases.
- The amount of shunt reactors compensating charges of 500 kV lines was assumed to be the same amount that EVN had planned for. Generator terminal voltages were assumed to be less than 110% and power factors of generators were assumed to be greater than 85%. Reactive power was compensated so as to keep the voltages of 500 kV bus bars as flat as possible.
- The standard conductors of 500 kV lines of Vietnam consist of four ACSR 330 conductors. The capacity of the 500 kV line was assumed to be about 2,200 MW.
- For the study on system stability, a general evaluation method was applied that “The System remains stable even if a fault section is removed by main protection relays of 70 ms after a three-phase short circuit, and differences in phase angles of each 500 kV generator are converged in about 10 seconds.”
- The north-south transmission lines have two circuits according to EVN’s plan. If series capacitors were not used, there would be a few hundreds MW of the power transmission ability of a few hundred MW from the viewpoint of stability, which would be considered insufficient. Therefore, installation of series capacitors was expected among Nho Quang substation in the north and Phu Lam substation in the south. In the north and south grids it is thought that there should be no problems with stability even if the series capacitors are not installed, thus the installation of series capacitors in the north and south grids were not expected. Because there is a possibility of stopping generators due to the shaft-twist vibration caused by series capacitors, it will be necessary for EVN to carry out interactive studies between series capacitors and generators, regarding generator-shafts, modeling, and a selection of tools for analysis and determine what to measure.
- The 500 kV and 220 kV network systems in 2020 will be composed of loop systems at

different voltages. Therefore, there will be some cases that 220 kV lines or 500 / 220 kV transformers are overloaded in situations of loads or generator output. Moreover, fault currents are expected to exceed 45 kW. As in the vicinity of the Phu My power plant, Hoc Man substation and Cai Lai substation, etc. The 220kV system to the south has a possibility of exceeding standard capacities of circuit breakers in Vietnam. More detailed studies should be carried out to come up with countermeasures to prevent unnecessary power flow and increasing fault current in 220 kV network systems. Local splitting of the system and application of large capacity circuit breakers such as 50 kA or 63 kA can be given as measures to prevent increases in fault currents of the 220 kV network systems.

- In such a situation, 220kV connections between 500 kV substations may have the possibility of splitting operations. Moreover, power flow and stability in the 500kV network system can be appreciated for safety in the case that 220kV connections are split. Therefore, the reliability of the 500kV network system was evaluated on the condition that 220kV connections between 500 kV substations were split.

6.3.3 Optimization Study of 500 kV System in 2020

(1) Evaluation of the 500 kV System Planning in 2020 of EVN

It is thought that the power flow from the south to north in 2020 will be several hundreds of MW at most, from the viewpoint of balancing supply and demand, and there are no expected problems regarding power flow and stability.

On the other hand, power flow from the north and central area to the southern area tends to grow by an uneven distribution of hydropower and coal-fired power plants. Therefore, studies on the possible power flow from the north were carried out. In order to conduct a safe evaluation, power flow between the northern and central area, that is, power flow from Ha Tinh substation to the central region, was assumed to come exclusively from the Nho Quang substation. Moreover, the possible power flow from the north to the south is influenced by power from the central region. Therefore, it was assumed to be a paradigm. If power flow between the south and north is roughly fixed, the distribution of generation and loads in the north and the south do not largely affect the stability of the north-south transmission lines. This fact was confirmed by using the plain model that summarizes the systems of the north and south.

Table 6-3-1 Reinforcement steps in the 500kV system up to 2010 planned by EVN

No	Construction subject	The number of line × distance /Number × capacity	Year
1	Plei Ku - Phu Lam (Another circuit)	1×547 km	2003
2	Phu My	2×450 MVA	2003
3	Phu My - Nha Be	2×49 km	2003
4	Nha Be - Phu Lam	1×16 km	2003
5	Nha Be	2×600 MVA	2004
6	Da Nang (Another transformer)	1×450 MVA	2004
7	Plei Ku- Doc Soi – Da Nang	1×300 km	2004
8	Nha Be- O Mon	1×180 km	2005
9	Da Nang - Ha Tinh	1×390 km	2005 2nd Quarter
10	O Mon	1×450 MVA	2005-2006
11	Tan Dinh	1×450 MVA	2005-2006
12	Thuong Tin	1×450 MVA	2005-2006
13	Nho Quan	1×450 MVA	2005-2006
14	Ha Tinh - Thuong Tin	1×335 km	2005 – 2006
15	Branch to Nho Quan	2×30 km	2005
16	Phu Lam - O Mon	1×170 km	2006 – 2007
17	Quang Ninh – Thuong Tin	1×110 km	2007 – 2008
18	Thuong Tin (Another transformer)	1×450 MVA	2007 – 2008
19	Tan Dinh (Another transformer)	1×450 MVA	NA
20	Doc Soi	2×450 MVA	2006 – 2008
21	Di Linh	1×450 MVA	Dai Ninh TEL place and simultaneous period
22	Nhon Trach	1×450 MVA	2008
23	Quang Ninh	1×450 MVA	2007 – 2009
24	Divergence to Dong Nai 3&4 power plant	2×20 km	2008 – 2009
25	Phu My - Nhon Trach	1×300 km	2008 – 2009
26	Song May	1×600 MVA	2008 – 2009
27	Song May - Nhon Trach	1×20 km	2009
28	Song May - Tan Dinh	1×30 km	2009 – 2010
29	O Mon (Another transformer)	1×450 MVA	NA

Source: Power network projects in 2002-2010 (Attached to Decision No.40/2003/QD-TTg dated March 21, 2003 by the Prime Minister)

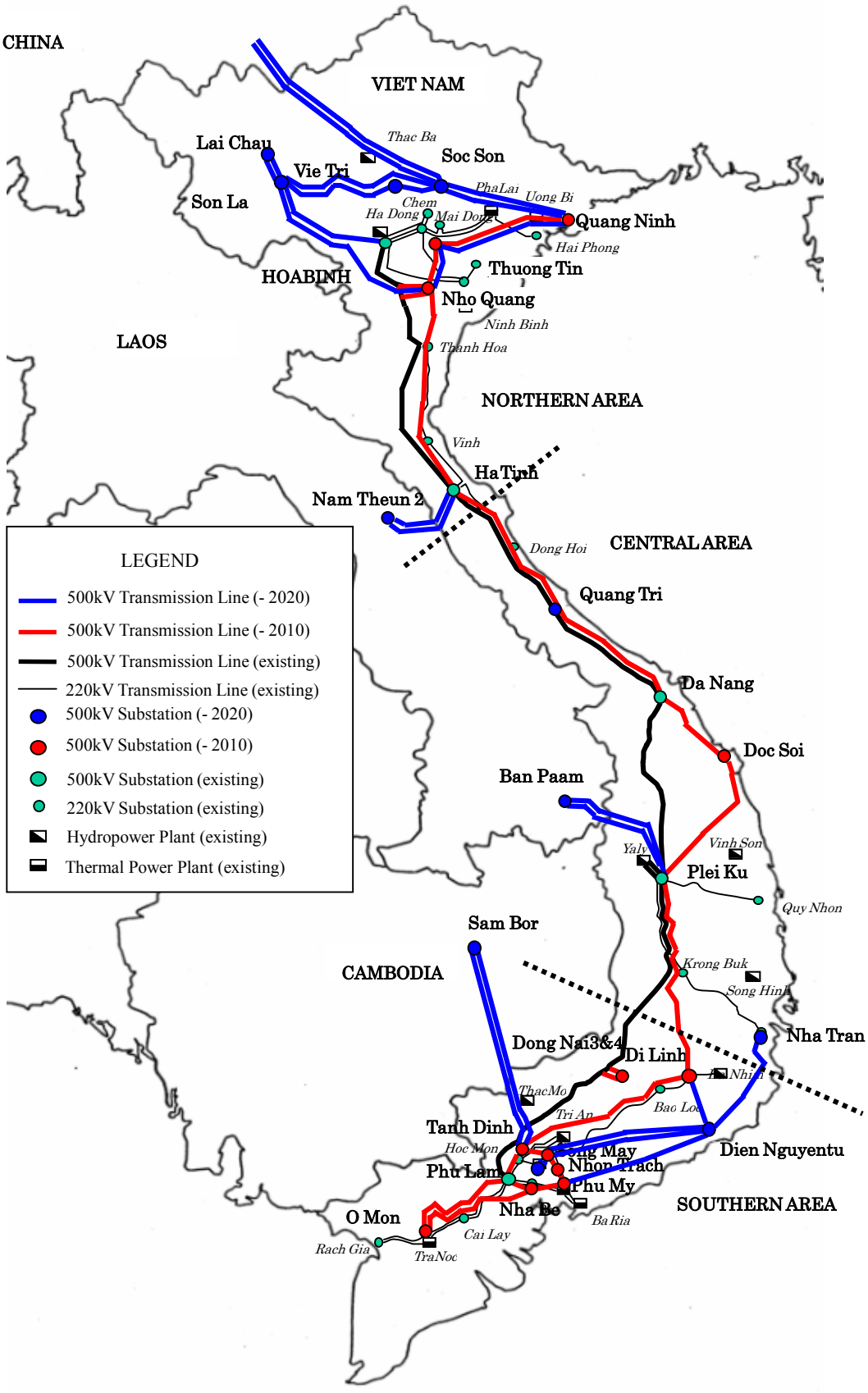


Figure 6-3-1 500kV network system in 2020 according to EVN's plan
(Double circuits between north and south)

a. The Permissible Power Flow of north – south transmission lines in case of N-0 criterion

Power produced in 500kV system in the central region and at Dong Nai power station near the south influences the limit of power flow between the north and the central region. When power is at the maximum level, the limit of power flow between the north and the central region is minimized. The minimum limit of the power flow is about 1,300MW. Power flow between Plei Ku substation and Di Linh substation reaches the limit of thermal capacity at this time.

The limit was confirmed by the result that power flow of 2,200 MW of the section between Plei Ku- Di Linhh under the following conditions reaches the thermal capacity of the section.

Table 6-3-2 The conditions for the confirmation of the limit of the power flow of 500 kV system in 2020 by the plan of EVN in case of adopting N-0 criterion.

Power flow of the section between north - south		1,300 MW
Generated power in central region	Yaly power station	720 MW
	Generated power from Laos	940 MW
	Generated power from 220 kV system of Plei Ku	200MW
Condition of the power flow in south region	Nuclear power stations in south region are stopped	

There are no problems with the power flow in the northern and southern grids. The system remains stable in case of slight disturbances such as small load changes. Therefore, it is possible to transmit power from the north to the central region up to 1,300 MW without depending on output from power plants. Power loss on the north-south transmission lines is about 90 MW, or approximately 7%, in the case that 1,300MW is transmitted from Nho Quang substation in the north to the Phu Lam and Di Linh substations in the south.

b. The permissible Power Flow of North – South Transmission Lines in case of N-1 Criterion

Figure 6-3-2 shows the allowed power flow between the north and the south in case that the N-1 criterion is applied and the Dong Nai power station is not operated.. The limit from the thermal capacity side is shown as a blue line on the following map. The limit of stability is shown as a red line, and is smaller than the allotted power flow from the thermal capacity side. The most severe fault from the stability side is the fault that occurs between the Plei Ku substation and the Di Linh

substation. Consequently, the range of operation to meet the N-1 criterion when Dong Nai power station is not operated becomes a red net area as seen in the figure below. The range of operation when Dong Nai power station is operated is reduced only by output from Dong Nai power station. The limit of power flow from the north to the central region in case of applying the N-1 criterion is about 1,400 or 1,500 MW when the power produced in the central region which is a small amount; however, only a small amount of power flow is allowed when a large amount of power is produced in the central region. Because the power that is produced in the central region and at Dong Nai power station exceeds 2,000MW which is larger than the limit of the power flow between the central region and the south. The limit is 2,000 MW or less when applying the N-1 criterion in comparison.

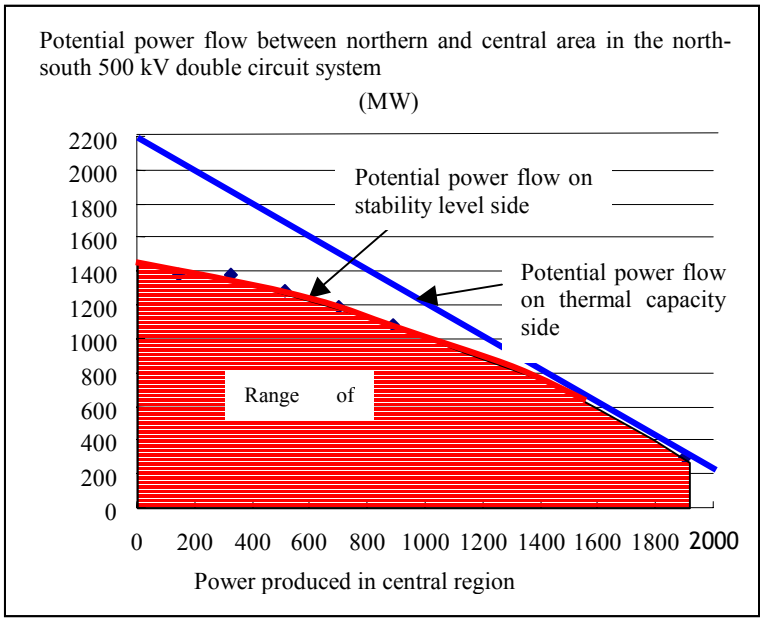


Figure 6-3-2 Potential power flow between north and central region in the north – south 500 kV double circuit system

The maximum amount of power flow between the north and the south is about 1,400-1,500 MW when the N-1 criterion is applied as mentioned above. Because the capacity of the Nho Quang substation is 900 MVA, the maximum amount of power flow from Nho Qunag substation meeting the N-1 criterion between the north and the south is 2,400 MW (Fig.6-3-3)

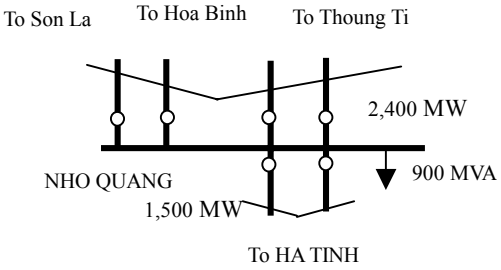


Fig.6-3-3 Maximum power flow from Nho Quang substation which meets the N-1 criterion applied to the north-south transmission lines

c. Evaluations and a Summary

Evaluations of the 500 kV system planned by EVN are summarized as shown in Table 6-3-3. Figure 6-3-4 graphically shows the limit of power flow in case that the power produced in the central is of a significant amount.

As mentioned above, the installation of a series capacitors on the north-south transmission lines was assumed, but not the installation of series capacitors for the 500 kV north and south grid.

Table 6-3-3 Evaluation of the 500kV system in 2020 planned by EVN

N-0 standard	When a large amount of power is produced in the central region, the power flow can increase to 1,300MW between the north and the central region.
N-1 standard	When a large amount of power is produced in the central region, the power flow is not permitted from the north to the central region. (When a small amount of power is produced in the central region, the power flow can increase to about 1,400 - 1500 MW between the north and the central region.)

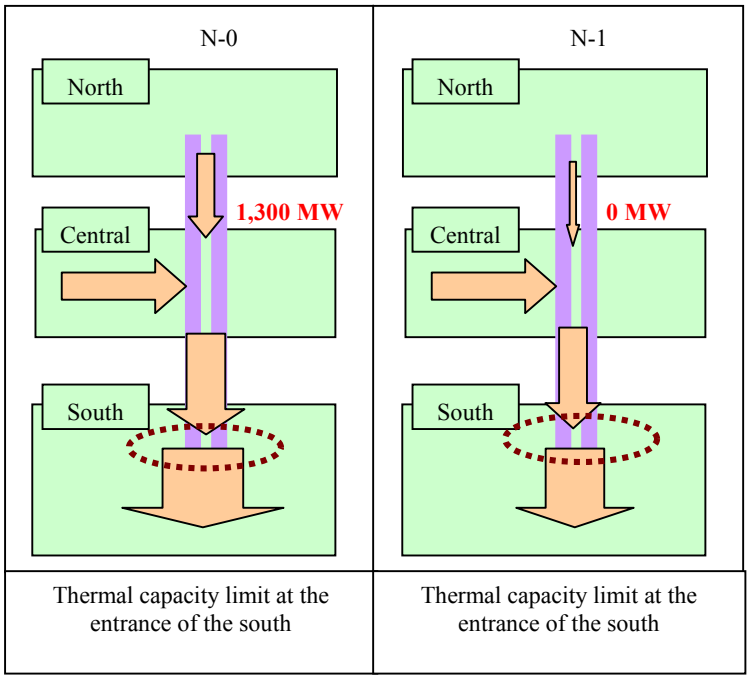


Figure 6-3-4 Limit of the power flow from the north – south 500kV lines with double circuits planned by EVN
(Series capacitor installed on the north-south lines when the maximum amount of power is produced in the central region)

(2) The Study of the Optimization of Reinforcements of 500 kV System in 2020

From the viewpoint of the supply and demand of power, there is a large economical effect on operation costs of thermal power plants by power transmission of hydropower stations in the north and the central region to the south. Therefore, we carried out brief studies of increasing the limit of power flow from the north to the south by putting further reinforcements on the 500 kV network in 2020 as planned by EVN.

a. Northern-Central area: 2 Circuits and –Central-Southern area: 3 Circuits

A case of construction of a 500 kV circuit between Plei Ku and Nha Trang was studied for the following two reasons.

- According to a basic plan by EVN, a 500 kV circuit will be constructed from the south to Nha Trang substation in the central region by 2020. As the distance between Plei Ku and Nha Trang is about 300 km, a connection of this section can make another central-south interconnection easy and cost-effective.
- Strictly speaking, the section between the southern area and Nha Trang does not meet the N-1 criterion because a single circuit fault would cause a supply interruption of Nha Tang. The

connection of Nha Trang to Plei Ku can fulfill both ends of the power supply and the section meets the N-1 criteria.

The study results are shown in the following.

Table 6-3-4 Results of the studies of north-central 2 circuits and central – south 3 circuits

Projects added to 500 kV system in 2020 planned by EVN	Plei Ku - Nha Trang 300 km × 1 cct
Construction cost	82 mil USD
The limit of power flow from north to central region N-0 criteria	In case the maximum output produced in central region and Dong Nai P/S, the limit is about 1,600 MW between north and central region from the static stability side (Tendency to be converged of oscillation due to slight demand changes such as 100 MW)
The limit of power flow from north to central region N-1 criteria	In case the maximum output produced in central region and Dong Nai P/S, the power flow about 1,100 MW between north and central region becomes the limit from the thermal capacity side at a single circuit fault of the central region to the south. This power flow can cause a stable condition in case of a single circuit fault of each section. Thus, the limit of power flow from north to the central region is about 1,100 MW.

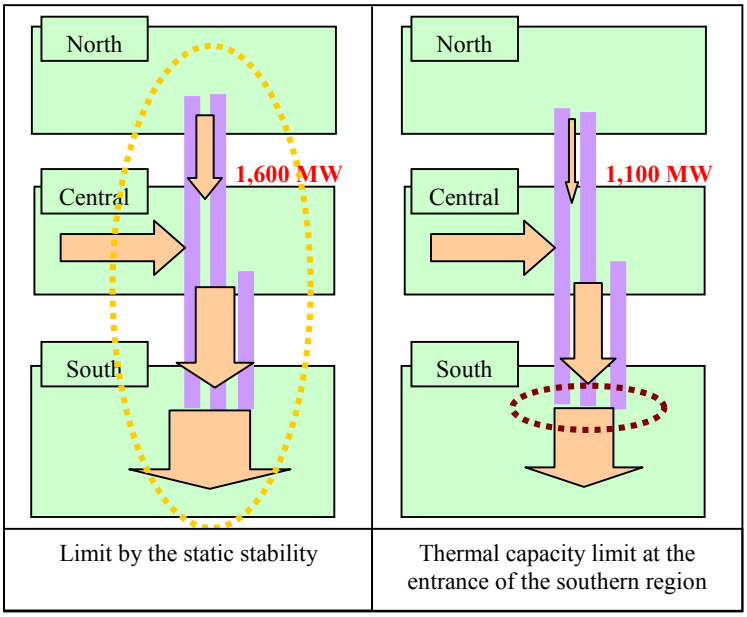


Figure 6-3-5 Limit of power flow in the Northern-Central area with 2 circuits in the Northern-Central area and 3 circuits in the Central-Southern area
(Series capacitors are installed in north-south transmission lines. In case that power output from the central region is at the maximum limit)

b. North-central area: 3 circuits and –central-south area: 3 circuits

A case study was conducted where the 3rd circuit was added to the north-central transmission lines is described in a.. Construction of the 3rd circuit can improve the static stability of whole

system, however, capacity of the transmission lines at the north-central area is the same as the system shown in Table 6-3-5. Therefore, the transmission capability in case of applying the N-1 criterion will not be improved.

Table 6-3-5 The result of the study of north – central 3 circuits and central-south 3 circuits

Projects added to 500 kV system in 2020 planned by EVN	Plei Ku - Nha Trang 300 km × 1 cct Nho Quang - Ha Tinh 290 km × 1 cct Ha Tinh – Da Nang 390 km × 1 cct Da Nang – Plei Ku 300 km × 1 cct
Construction cost	350 mil USD
The limit of power flow from north to central region N-0 criteria	In case the maximum output produced in central region and Dong Nai P/S, the limit is about 2,200 MW between north and central region from the static stability side (Tendency to be converged of oscillation due to slight demand changes such as 100 MW)
The limit of power flow from north to central N-1 criteria	In case the maximum output produced in central region and Dong Nai P/S, the power flow about 1,100 MW between north and central region becomes the limit from the thermal capacity side at a single circuit fault of central to south region. This power flow can give a stable condition in case of a single circuit fault of each section. Thus, the limit of power flow from north to central region is about 1,100 MW.

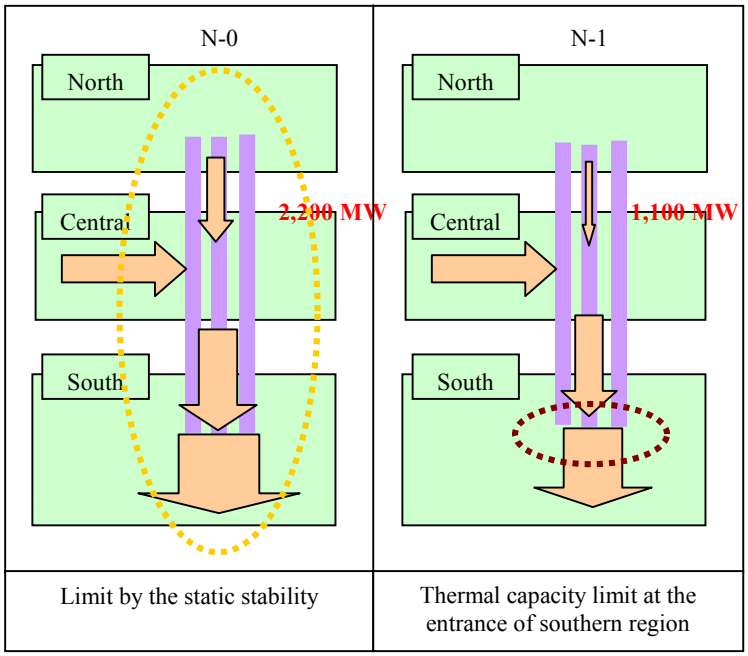


Figure 6-3-6 The limit of power flow at the Northern-Central Region with 3 circuits in the Northern-Central Region and 3 circuits in the Central-Southern Region
(Series capacitors are installed in north-south transmission lines. The case of power output from the central region is the maximum)

c. North-central 3 Circuits and Central - South 4 Circuits

The case when the 4th circuit is added to the central-south lines of the system described in b. The construction of another circuit from north to south in the north system will be required for maintaining the power flow capacity and stability of the north system.

Table 6-3-6 The result of the study of north-central 3 circuits and central-south 4 circuits and another circuit in the north system

Projects added to 500 kV system in 2020 planned by EVN	Plei Ku - Nha Trang 300 km × 1 cct Nho Quang - Ha Tinh 290 km × 1 cct Ha Tinh – Da Nang 390 km × 1 cct Da Nang – Plei Ku 300 km × 1 cct Plei Ku – Di Linh 320 km × 1 cct Soc Son – Thuong Ti 100 km × 1 cct
Construction cost	467 mil USD
The limit of power flow from north to central region N-0 criteria	In case the maximum output produced in central region and Dong Nai P/S, the limit is about 2,200 MW between north and central region from the static stability side (Tendency to be converged of oscillation due to slight demand changes such as 100 MW)
The limit of power flow from north to central region N-1 criteria	In the above case, if N-0 is applied, the system has allowable power flow and stable. Therefore the limit of power flow can be determined by the N-0 criterion.

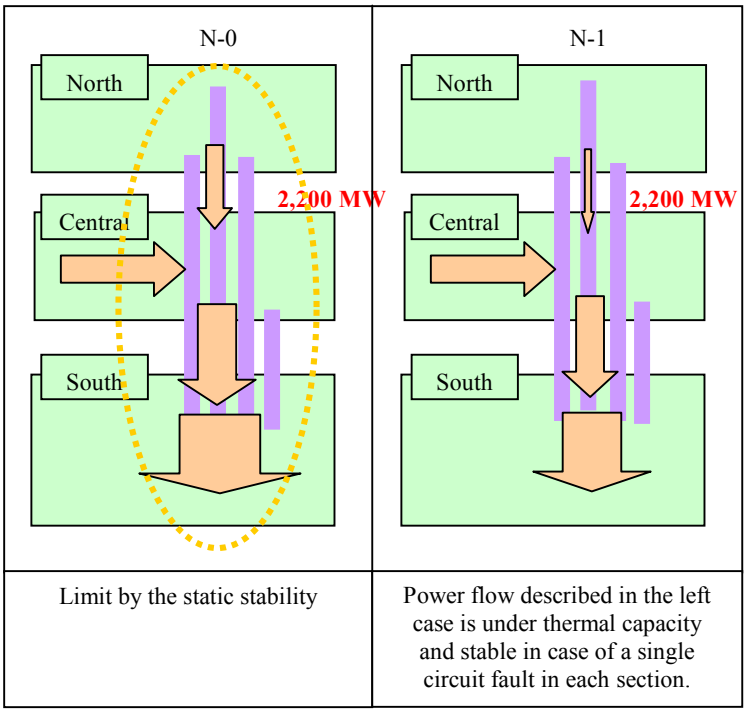


Figure 6-3-7 The limit of power flow at north - central with 3 circuits of north-central and 4 circuits of central-south
(Series capacitors are installed in north-south transmission lines. In case that power output from the central region is at maximum)

(3) Summary of the Study of Reinforcements of the 500 kV System until 2020

The results of the study of the reinforcements of 500 kV system until 2020 in comparison with the construction costs and power flow limit are summarized in Table 6-3-7.

Table 6-3-7 Summary of the results of the reinforcement scenarios study up to 2020

	Case with 500kV system reinforcement until 2020	Increment construction cost from base case (mil USD)	Limit power flow between north and central region in case of N-0 criterion (MW)	Limit power flow between north and central region in case of N-1 criterion (MW)
1	EVN 2020 year's plan (base case) With 2 circuits of north – central region and 2 circuits of central – south	-	1,300	0
2	With 2 circuits of north – central region and 3 circuits of central – south	82	1,600	1,100
3	With 3 circuits of north – central and 3 circuits of central – south	350	2,200	1,100
4	With 3 circuits of north – central region and 4 circuits of central – south and another circuit in the north system	467	2,200	2,200

If the N-0 criterion is applied, the power transmission ability of 1,300MW will result between the north and the central region in 2020 according to the plan of EVN. This ability is considered to be economical in regards to the capital investment control side, because the power supply effect from the north to the south on saving investments in power stations is full with about 1,000MW.

However, the effect of economic operation on saving fuel costs is estimated to be about 10 million USD a year when the power transmission ability increases from 1,300MW to 1,600 MW as explained in chapter 6-2. Because an increase in the investment of the transmission lines is 82 million USD in case of Table 6-3-5 “with 2 circuits of north - central and 3 circuits of central – south”, it can be converted to about 10 million USD a year. Therefore, the addition of transmission lines between Plei Ku and Nha Trang in the 2020 plan of EVN, and the result of saving fuel costs is estimated to be almost same as the effect in terms of an increase in the investment of transmission lines. Furthermore, the connection of Nha Trang to Plei Ku will result in the all connections of respective 500 kV substations to neighboring substations being able to connect both ends of the power supply. System reliability of the transmission lines from the center region to the south region can be improved. On the other hand, in case of Table 6-3-4 “with 3 circuits of north - central and 3 circuits of central – south”, the effect of economic operations on saving fuel costs is estimated to be about 20 million USD. The investment of the transmission lines is about 350 million USD, which is equivalent to about 50 million USD a year, and significant economical merit cannot be expected. Therefore, the superior case in this study is shown in Table 6-3-4, “2 circuits of north - central and

3 circuits of central – south". However, the economical merit could not be clearly estimated so as to conclude the implementation of this case. Therefore, it will be necessary for EVN to carry out a study of detailed estimation of the effect of economic operations on saving fuel costs including the methods of power generators, and careful examination about the effect of improvement in system reliability.

It is also important to study the operation method when unexpected accidents happen that are not set in the criteria. For example of countermeasures from an operation side, the installation of the relays that transfer the signal designating the specified generator shedding of the north system or installation of the protection system maintaining the isolated system in case that the route fault of north-south interconnection by any chance.

6.3.4 Methods of Power Transmission of PSPP in the North

The PSPP is located over 100 km or more from the center of demand. If 220 kV is applied for the voltage of the transmission lines to the center of demand, three to four lines are needed. Great reinforcement of the existing 220kV system is also needed for the power transmission for both the generation and pumping operations, which is not economically feasible at the time. The voltage of the transmission lines is assumed to be 500kV. The influence of the PSPP on the 500 kV network system in 2020 was also studied.

(1) PSPP in the North

Table 6-3-8 shows the candidates of PSPP in the north. Both candidates are located about 10 km from the Hoa Binh power station. However, there is no room for installation of new bays in Hoa Binh power station for the PSPP transmission lines. Therefore, the methods of T-off branches from the 500 kV network for the transmission lines of PSPP were examined.

Table 6-3-8 Candidates of pumped storage hydro power plants in the north

PSPP site	Distance to Hoa Binh substation
Phu Yen East (JN3) 1,000 MW	70 km
Phu Yen West (JN5) 1,000 MW	80 km

There are two routes of transmission lines passing near the PSPP sites. One is the northern route that will be constructed from Son La power station to Vie Tri substation and Soc Son substation with one circuit each. Another is the southern route that will be constructed from Son La

power station to Hoa Binh substation and from Son La power station to Nho Quang substation by one circuit each.

(2) Main Specifications and Study Conditions of Transmission lLnes of PSPP

- The transmission voltage of PSPP is 500kV.
- In general, it is required to select an economic conductor of power source transmission lines in comparison with the loss and construction cost of the lines. However in Vietnam, ACSR 330mm^2 ×4 was selected as the standard conductor for the 500 kV network, which does not have enough data to show slight differences in costs by using other conductors. The average operating factor of the optimum conductor is generally in the range of about 40 % - 60 %, of which ACSR 330mm^2 ×4 seems adequate for power transmission of 1,000 MW. In this study, ACSR 330mm^2 ×4 was set as the conductor for the transmission lines of PSPP. A more precise study regarding these data will be needed.
- Concerning the number of circuits of transmission lines from power stations, it becomes a problem as to whether or not there are any certain effects on the system in the case that a single circuit fault occurs, and whether or not the frequency changes due to a drop in capacity of a generator or a pumping motor which are in acceptable range. The demand at an off-peak period in 2020 is expected to be about 13,000 MW. Therefore, it cannot be clearly determined whether a drop in 1,000 MW is acceptable or not because a frequency change is expected to be 1 Hz when 1,000 MW is dropped. On the other hand, the drop of 500 MW is acceptable because a drop of 500 MW will make an expected frequency change when less than 1 Hz.
- Study cases were set in the most severe situations including cases of fully loaded transformers or fully output generators.
- There are not any problems in respective cases of the transmission lines towards the PSPP that branches off from the network system, on the condition that a single circuit fault does not occur. The results are shown below from the study cases of the N-1 criterion. The condition of the maximum power flow of 1,500 MW to Ha Tinh substation was set so as to make the power flow of the north-south transmission lines meet the N-1 criterion as mentioned above.
- Remote generator shedding by a telecommunication system for the stability maintenance at a circuit fault is not allowed, however dropouts of units at a circuit fault is allowed if they lead the frequency change at only about 1Hz or less.
- When the power flow exceeds the thermal capacity of the remaining circuits in the case of a circuit fault, the power generation control of the pumped storage power plant is allowed.

- The costs of transmission facilities used for the study are shown in Table 6-3-9.

Table 6-3-9 Costs of transmission facilities

500kV facilities	Cost
Transmission line (single circuit)	263,160 US$/km
Bay	1,570,000 USD

Source: Son La PMB and IE

- Power loss calculation was carried out on the following conditions.
  - Power loss calculation during the operation of PSPP was carried out on the condition that PSPP was assumed to operate as a generator during the peak-demand period from October to May, that is 7 hours a day, and operate as a pumping motor 10 hours a day during the 6 months.
  - The large hydropower stations such as Son La and Hoa Binh were assumed to operate during the peak period of time at full output from October to December and at 80 % output from January to May.
  - The study was carried out for the two operating patterns of the northern power stations that are classified as the low output and high output case of transmitting power to the southern area of Vietnam.
  - The 500 kV transmission lines on the northern route and the transmission lines in the southern route will be commissioned in accordance with the operation of Son La power station; therefore precise routes of the transmission lines have not yet been determined in detail even in the km ranges. Therefore, the distances from a T-off branch point to PSPP are assumed to be the same for both the northern route and the southern route.

(3) Results of the Studies

a. Cases of the Southern Route Connection

Cases of the connections of PSPP to the section between Hoa Binh and Son La power station do not meet the N-1 criterion because the Hoa Binh power station load is as large as 900 MW at the maximum stage. Cases of the PSPP connections to the transmission lines between Hoa Binh and Son La meet this condition. In consideration with the system reliability of transmission lines between Hoa Binh and Nho Quang substation, PSPP cannot be connected to the circuit between Son La and Hoa Binh. The connection to the point between Son La and Nho Quang is allowed. (Appendix 6-2) Therefore, the methods of connecting to the southern route can be determined as follows.

Cases of the connection to the southern route with a single circuit: Connection to the line between Son La power station and Nho Quang substation with a single circuit

Cases of connecting to the southern route with double circuits: Connection to the line between Son La power station and Nho Quang substation with double circuits

b. Cases of the Northern Route Connection

All cases of the northern route connections do not have any problems with stability if a single circuit fault occurs during generation and pumping operations of PSPP both for a case of connection to the section between Son La and Vie Tri and a case of connection to the section between Son La and Soc Son. There are not any problems with power flow in the case of a circuit fault during both generation and pumping operations of PSPP, because power flow can fall within thermal capacities for both cases of the connections. Therefore, both cases of the connection to the section between Son La and Vie Tri and to the section between Son La and Soc Son are possible. The construction cost of transmission lines is the almost same in both cases. Therefore, superiority was determined in comparison of power losses between respective cases.

1) Cases of Connection with a Single Circuit

Both the case of connection to the section between Son La and Vie Tri by a single circuit and the case of a connection to the section between Son La and Soc Son with a single circuit can be considered. The results of the comparison of both cases are shown in Table 6-3-10.

Table 6-3-10 Comparison of power losses in cases of connection with a circuit to the respective T-off points on northern route
(PSPP operating from October to May) (Unit: GWh)

	Low output case of power stations in the north area	High output case of power stations in the north area
Son La – Vie Tri	133.8	135.7
Son La – Soc Son	134.7	136.8

The least power loss is produced in case of the connection to the section between Son La and Vie Tri for both operation patterns of power stations. Because the construction costs of the transmission lines are the same, the case of the connection of Son La and Vie Tri is superior to other cases.

2) Cases of a Connection with Double Circuits

It is possible to connect both to the section between Son La and Vie Tri and to the section between Son La and Soc Son in the northern route. There are three ways of making connections. The results of the power loss calculations are shown in Table 6-3-11.

Table 6-3-11 Comparison of power losses in cases of connection with a circuit to the respective T-off points on northern route

(PSPP operating from October to May) (Unit: GWh)

	Low output case of power stations in the north area	High output case of power stations in the north area
North Son La - Vie Tri Double circuits	130.3	132.4
North Son La - Soc Son Double circuits	131.4	133.5
North Son La - Vie Tri Single circuit	123.6	125.8
North Son La - Soc Son Single circuit		

The least power loss is produced in case of the connection to the section between Son La and Vie Tri and between Son La and Soc Son with each single circuit available for operation patterns of both power stations. Because the construction costs of the transmission lines are the same for respective cases, the case of the connection to the section between Son La and Vie Tri with a single circuit and the connection to the section between Son La and Soc Son with a single circuit is superior to other cases.

c. Comparison of Cases of the North Route Connection and the South Route Connection

As mentioned before, the connecting point on the southern route is restricted to in the section between Son La and Nho Quang from the viewpoint of system reliability, therefore, there are two cases of connecting to the northern route and to the southern route with each single circuit as shown in the following. Table 6-3-12 shows the result of the power loss calculation.

Table 6-3-12 Comparison of power losses in cases of connection with double circuits

(PSPP operating from October to May) (Unit: GWh)

	Low output case of power stations in the north area	High output case of power stations in the north area
South Son La - Nho Quang North Son La – Vie Tri double circuits	116.6	127.1
South Son La - Nho Quang North Son La – Soc Son double circuits	117.3	127.5

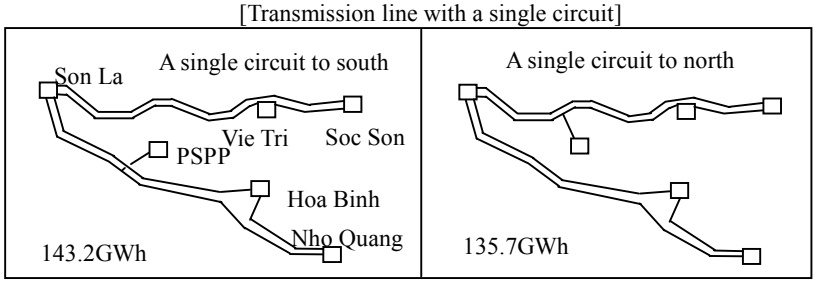
In spite of several operation patterns of generators, the case of the connection both to the section between Son La and Nho Quang and to the section between Son La and Vie Tri with each single circuit produces the least amount of loss. The construction costs of the transmission lines in both cases are the same; therefore the case of connection both to the section between Son La and Nho Quang and to the section between Son La and Vie Tri with each single circuit is superior to other cases.

(4) Optimum Method of the Connection

The above studies are narrowed down the cases in comparison of power losses that have possible connections from the viewpoint of system reliability and that have the same branch point. Figure 6-3-8 shows the system configurations of the respective cases.

Power losses in the Figures represent the losses produced in the case of full outputs of generators in the north area and the generating/pumping operation of PSPP.

Cases of a drop in generating/pumping power of 1,000 MW is allowed in the case of a single line fault
[Transmission line with a single circuit]



Cases of a drop in generating/pumping power of 1,000 MW is allowed in the case of a single line fault
[Transmission line with a single circuit]

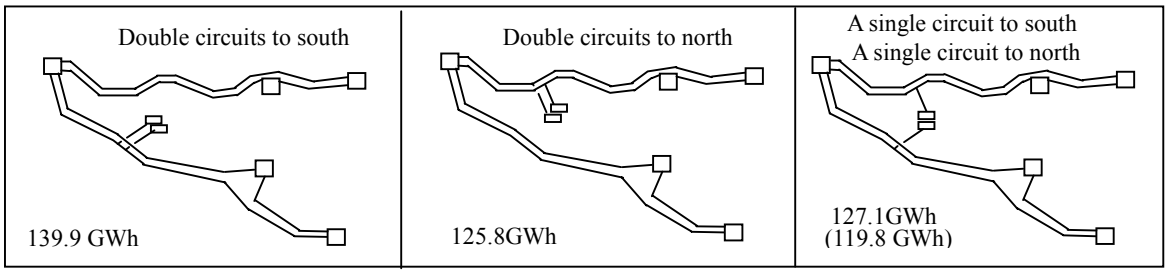


Figure 6-3-8 Cases of PSPP connections

In order to seek the optimum case, comparison of the cost of power loss and construction costs between the cases of respective patterns of the connections is needed. However, construction costs of the transmission lines and the passes of the northern and southern route and operation patterns of other generators largely affect power losses. Therefore, it is difficult to determine the optimum connection at the present time for the following reasons.

- In case of frequent operations of suppressing output of generators in the south area and utilizing power generators in the north area, the power flow from north to south at the off-peak period of time becomes too large and the loss at the pumping operation of PSPP occupies a main portion of the total loss. Therefore, cases of north connection are superior in such operations. On the contrary, in case of operations of suppressing output of generators in the north area, the loss at the peak period occupies a main portion of the total loss. Therefore, cases of the south connections are superior in such operations. The case producing the least amount of loss depends on the patterns of operation of generators in the off-peak period.

- Assuming the condition of high output of north generators for power-transmission to the south area, the difference of power loss between the case of south connection and the north connection with a single circuit is about 10 GWh a year. The difference of power loss between

the cases of the connections with double circuits is about 10GWh a year.

- On the other hand, a 10km longer transmission line from PSPP increases the power loss by 4 GWh a year and construction costs by 0.28 mil USD a year. These are equivalent to the loss of about 16 GWh a year as calculated by the cost of power loss. Therefore, lengthening the transmission lines of PSPP 10 km is equivalent to an increase in costs by about 20 GWh a year.

- Therefore, the differences of the cost of power loss between the case of connection to the south route and the case of connection to cost of a 10 km transmission line. Because of the non-specific plans of the transmission line route, it is impossible to say which case is superior; the case of connection to south route or the case of the north route.

- On the contrary, it can be considered that the route is set out so as to pass through near the PSPP which is connected to the T-off branch on the route. The route of the 500 kV transmission lines from the Son La power station will pass within the range of about 20 or 30 km whose center is PSPP. Because it is 100 km from Son La power station to PSPP, an increase in the length of the route is considered to be about 10 km at maximum by changing the route of the 500 kV transmission lines from Son La power station to the route selected to pass very near to the PSPP. The cost of the lengthening the route is equivalent to a loss of 20 GWh a year as in the same manner mentioned before. Therefore, according to this estimation, the increase in the costs of changing the route so as to pass through the nearest point from PSPP, the north route or the south route, does not counterbalance the cost saving of the power loss by changing the connecting point.

Therefore, more detailed studies are needed for implementation of the transmission lines of PSPP in comparison of:

- Cost of power losses
- Construction cost of the transmission lines among the five cases,

in consideration with:

- A permissible drop in generators or pumping power of PSPP in case of a single circuit fault (The permissible range of the variations in system frequency within 1Hz)
- The direction of the transmission lines from Son La
- The patterns of operations of generators in the northern grid.