Formation of options construction and structuring power network of the Republic of Sakha (Yakutia), taking into account the development of electric power centres of Eastern Siberia and the Far East

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Abstract - Reviewed by forecasts of consumption of electrical energy and power by progressive and maximum, inertial options on the Republic of Sakha (Yakutia). Recommended half-wave technologies.

Index Terms - energysystem, generating sources of Yakutia, half-wave, selection of capacity.

It's not the new question about foundation of United energy systems of Yakutia and it's merging with energy systems of Siberia and Far East, and also creation of superpower high voltage lines for energy transition from hydroelectric station of Lensk pond to united energy systems of Siberia. Solving of this questions took place since day one of electro power lab of power division of north physic-technology problems institute. Still in the 60's of past century were introduced main development variants of generating sources, intersystem connections and technical solutions of increasing capacity and reliability of electrical equipment working in extreme conditions of the north [4,6]. There were introduced, and after realized sources: first in the world HYDRO POWER PLANT (HPP) operating in conditions of permafrost – Viluyskya HPP, Yakutskya HPP (gas fueled), Nerungrinskya HPP, THERMO POWER PLANT (TPP) gas fueled in Mirniy and Udachniy and others.

Long-year field research of hydropower and water management laboratory of divison (H.E. Chistyakov, D.D. Nogovicin and others) allowed to prove building of HPP in South Yakutia. These results took place now a days.

Focused on intersystem connections, for realizing step by step development of UPS of Yakutia and it's connection with border regions. On first phase of development, discussed options of constructing power lines in: Mirniy – Lensk – Syhoi Log; Yakutsk – Aldan; Yakutsk – Perevoz; Yakutsk – Ohotsk; Viluyskay HPP – Aihal – Ydachniy; Mirniy – Nuyrba – Verhne-Viluysk – Viluysk and others.

Choosing of voltage perspective power lines and backbone network was based on existing and perspective connections with power systems of Siberia and Far East. According to voltage standards in Yakutia was introduced voltage scale: for distributive networks – 35, 110 and 220 kV and fro backbone AIR LINE (AL) 220 kV, 500 kV in perspective.

Was calculated intersystem connections between East, Central and South powersystems of Yakutia on voltages 220, 330 and 500 kV.

Based on the analysis of prolonged and long distance transmission lines and transmitting power limit was introduced and after realized in metal tiristor stabilization and control system with mission to expand power transmit limit on prolonged lines of power transmission (LPT), it's first task only for AL-110 kV from Mirniy – Villuyisk [1,3,4,6]; was developed and recommended methods and tools for increasing reliability of main powersystem equipment, which is been operating in conditions of cold environment; was defined bandwidth capacity of intersystem and backbone LPT, according with static and dynamic stability limits, based on mathematic modeling and programming.

Calculations were made in cooperation with scientist from Siberian Power Institute SB of AS USSR (now ESI SB of RAS). Solving of

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this tasks allowed to optimize modes of East powersystem with significant economy impact. Since power line Mirniy – Viluyisk, length 587 km, was designed to work on voltage 110 kV, and RPC "YakutskEnergo" ignored our warnings about 30% power loss, then as a solution, we proposed calculated bypass 220 kV voltage power line Mirniy – Nurba, which nowadays implementing on the current track AL-110 kV. By the director of division and power laboratory Chudinov G.M., in the same years were proposed construction of HEPS, founded on Djebariki-Haiskya coals and connecting Yansk powersystem, which was planned to base on Adichanskya HEPS or nuclear plant.

Today, Yakutian power system is the most important part of the Russian Far East region power complex. OAO AK "YakutskEnergo" holds dominating position on internal republic power market. In the period 2002 -2004 power flowcurrent to FOREM overestimated 1,5 milliard kV·h/year. But in the following years power supplement to FOREM decreased on almost 10%, as a result of launching Bureyskya HPP. Backbone of republic power supplement consist of power plants with setup power 2056 MW and power networks "YakutskEnergo", it's AL length is 0,4 -220 kV, chain length is 21032 km. Main generating sources nowadays are: Viluyiskaya HPP 1, 2 with setup power 680 MW; 2 engines of Svetlinskya HPP (VHPP-3) – 180 MW; Mirninskya HPP – 120 MW; Yakutskya HPP – 320 MW; Yakutskya WPP – 12 MW; Nerungrinskya HPP – 570 MW and Chylmanskya HPP – 48 MW (Fig. 1).

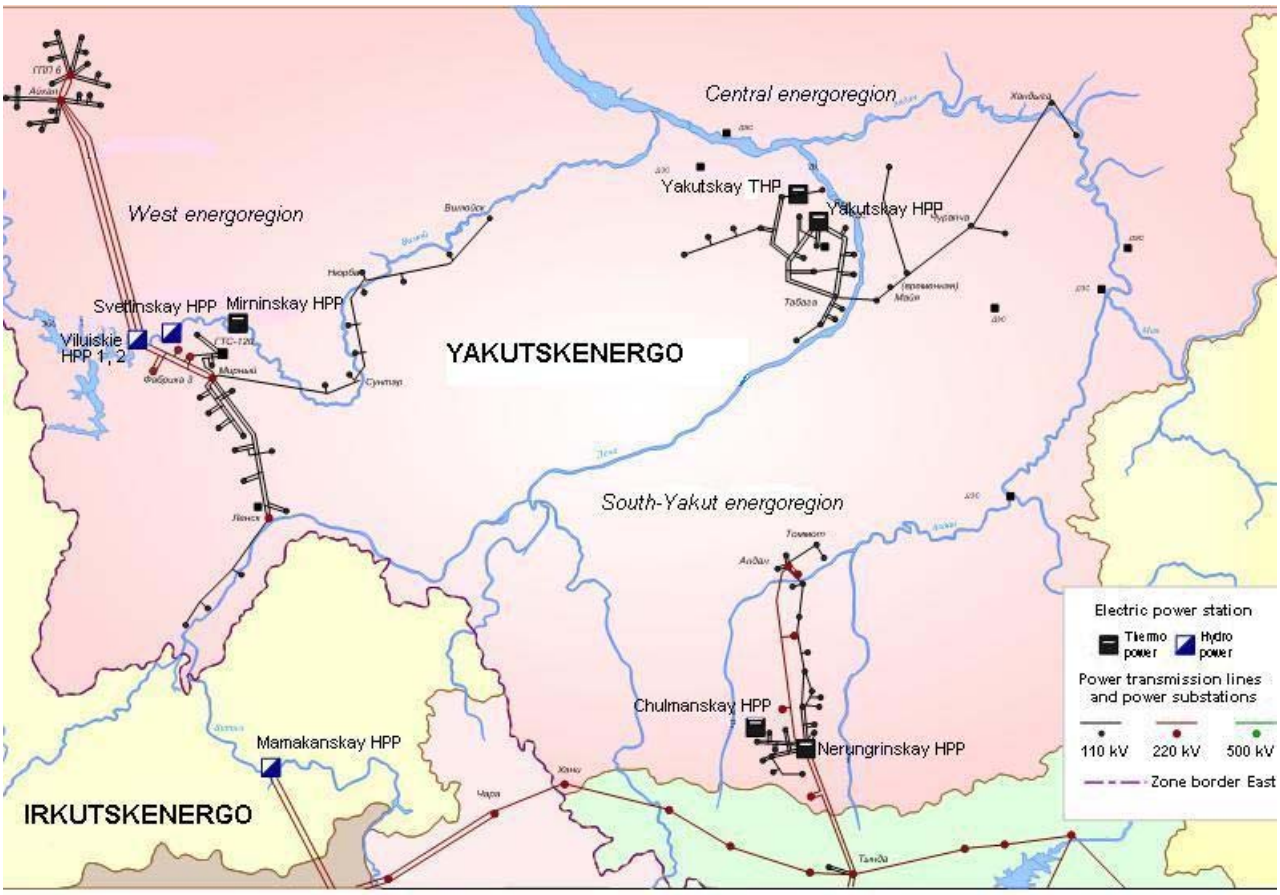


Fig. 1. Existing power networks scheme of Republic of Sakha (Yakutia).

In the last years, in republic centralized power supply was launched:

- AL-110 kV "Handiga – Djebariki-Haya" it's length 67 km, for supplement coal mines "Djebariki-Haya" and miners settlement.

- Two queues of launching complex AL-220 kV "Mirniy – Syntar – Nuyrba", it's length is 131,2 km, including 1,2 km of Viluy river trespassing, it's summary length is 374 km;
- was completed reconstruction of Yakutskya HPP first queue, including replacement of gas-turbine engines from GTU-35 to modern GTU-45;
- completed building of AL-110 kV "Sylgachi – Eldikan".

It's expecting significant increase of power consuming and capacity, in middle and long-term in Republic of Sakha (Yakutia). The reason of growth is active investment of government and private companies, focused on aggregation of natural resources and creation of required producing, transport and power infrastructure.

Expectation of power consuming and power include inertial and progressive, maximum variants. Differences between them are defining by possibility of new investment projects realization.

According to inertial variant, power consummation in Republic of Sakha (Yakutia) will increase to 1,5 times, from 6,2 milliards of kW·h in 2005 to 9,3 milliards of kW·h per hour in 2030, consuming of electrical power to 1,5 times from 1,2 thousands MW in 2005 to 1,8 thousands MW in 2030.

According to maximum variant, power consummation will increase to 4,9 times, from 6,2 milliards of kW·h in 2005 to 29,9 milliards of kW·h per hour in 2030, consuming of electrical power to 4,5 times from 1,2 thousands MW in 2005 to 5,4 thousands MW in 2030 [7-9,15].

In case of not enough development of power infrastructure, inertial development is most possible. Leading development of power infrastructure, creation of effective and reliable power system in Yakutia will lead to realization of most existing investment projects and appearing of new ones. Maximum power consuming and power is most possible expectation scenario.

Exposed power is obviously not enough for covering increasing loads of republic and border territories. Without entering new generating powers, in current time existing power deficit in Central energyregion, in 2012 expecting in South-Yakutskya, in 2015 – in West [10,11].

Also Yakutia is one of the biggest regions by number of hydro potential (72352 MW, 64 perspective rifts). On the rivers of Lena pool (Aldan, Timpton, Uchyr, Olekma), construction of South-Yakutian hydro power complex (SYHPC) is possible, with output power more than 8 000 MW. Construction of SYHPC is a key direction in development of generating in republic.

The most important strategic question is to launch generating powers of South-Yakutia hydropower complex (SYHPC). The first option suppose launching two plants of first queue SYHPC - Kankynskya and Nijne-Timptonskya with summary setup power 2100 MVt, the second option is to build SYHPC in full volume, defined by promising plans of "HydroOGK" (7 plants with summary setup power 8495 MW) [7-9].

So, the first variant of development united power system is directed to cover perspective loads of republic, including flowcurrent from UES East, the second option suppose possible power outputting of SYHPC to UES East, UES Siberia and to export in Chine, a Korea.

Launch of second queue SYHPC is planning on period 2016-2030. According to time limit, decision about building of HPP was planned to accept before 2010. Main affecting the decision factors are:

- scales and implementing dead lines of investment projects, which define demand on power in republic;
- speed of social-economy development of border territories;
- demand in power by countries of Asian-Pacific region (first of all, KNR and KNDR) and the opportunity to export electric energy in these countries [8,9,16];
- economy indicators of efficiency projects of buildings HPP and alternative generating sources;
- cost policy on Far East market of power.

Main course of power infrastructure development depends on volume and vintage of launching generating powers.

Development of generating sources in Yakutia should comply with following:

- increasing in generating powers should be more than demand;
- usage of current hydro-potential of South Yakutian rivers;
- technical level, reliability and ecology should be on level of world standards.

According to SYHPK, sequence of building HPP, define conditions of:

- availability of a real consumer at the time of launching powers of plant period;
- possibilities of usage HPP, which is being build, for creating powerbridge and uniting following HPP;
- rift availability, as from point of view proximity to powernetwork infrastructure, and also by availability of railroad-transport system.

In addition to launching of SYHPK in republic, it is required to increase generating power on heat power plants, which will increase system reliability of Yakutian powersystem and will provide demand in power before the moment of launching hydrocomplex. Lage development projects of TPP are:

- launching of three 215 MW blocks on Nerungrinskya HPP, accordingly in 2010, 2012 and 2015;
- reconstructing of four blocks GT-35 Yakutian HPP of second queue, with increasing unit setup power of blocks to 60 MW, launching it in 2012, 2013 and 2016;
- building of HPP with summary power capacity 96 MW in isolated power regions;
- Building of Talakanskya TPP at 2020, with power capacity 192 MW.

"ALROSA" is the largest consumer of power in Yakutia, it provides launch of Svetlinskya HPP on two engines with power capacity 180 MW.

The first option of hydropower complex development suppose building of two HPP – Kankynskya and Nijne-Timptonskya [12,13]. These plants included in General locations scheme of power objects on period to 2020. It's planned to acquire funds on building Kankunskya HPP from Investment fond of RF, as part of the application on project "Complex development of South Yakutia". Building of Nigne-Timptonskya HPP is planned to achieve on funds from "HydroOGK"

It's planned to launch 400 MW by Kankunskya HPP before 2015, on a period 2015-2020 planned completion of Kankuskya HPP, it's summary power is 1300 MW and planned launching of 600 MW on Nijne-Timptonskya HPP. Finishing of construction Nijne-Timptonskya HPP is planed on period 2021-2030.

In case of building only two HPP Timptonskya Cascade in 2030, Yakutian power-system will be deficit on 868 MW. That's why power load will be covered from powers of HPP East [8,9].

Launching power of HPP, according to second option can be divided on three phases:

- Before 2015: launching first engines of first queue SYHPC Kankynskya (Idjekskya) HPP (400 MW).
- 2016-2020 – completion of the Kankunskya HPP with power capacity increase to 1300 MW and construction Nigne-Timptonskay HPP – counterregulater of Kankunskya HPP with capacity of 800 MW. Full-scale building of the second queue hydropower complex – Verhne-Aldanskya HPP – 1000 MW, Olekminskya HPP – 1500 MW, the first queue of which is 115 MW, and cascade of Uchyrskya HPP – with summary power 7138 MW.
- 2021-2030 – completion of cascade Uchyrskya HPPs (Sredne-Ychyrskya - to 3300 MW, Uchyrskya – to 365 MW) and Nigne-Olekminskya HPP to 230 MW.

Construction of generating sources on south Yakutia will ensure not only internal needs of Republic, but also flowcurrent to UES East and Siberia and export electricity to China, Korea, Japan. With the full implementation of the considered project variant a surplus of electrical power in the Republic will make

over the years: 2015 - 573 MW, 2020 – 6517 MW, 2030 – 5733 MW [12,13].

Moreover, the Central and West energyregions will be deficit to 2015. Deficit of Central energyregion at 2015 will be 66 MW, at 2030 – 952 MW, and West at 2030 approximately will be 316 MW. One way to cover deficit is uniting of Yakutian energoregions. At present the balance sheet of "Yakutskenergo" located 5402 km of power lines with voltage 110-220 kV, including 3512 km of AL 110 kV and 1890 km of AL 220 kV. The main priorities of power network development with voltage 220 kV and above in the period till 2030 are:

- outputting power of large power plants, including members of the South Yakutsk hydroelectric complex;
- uniting of Central, Southern and Western energyregions among themselves and with the UES Siberia and UES East ;
- reducing zone of decentralized power supply by replacing diesel power plants with power lines from the Yakutsk power system, which will significantly reduce the cost of electricity production;

Thus, implementation of power grid construction proposals in the Republic of Sakha (Yakutia) as by the first and the second option for the period until 2030 will not only unite isolated working Southern, Central and West energyregions, but also will realize the connection between the UES Siberian and UES East through a Yakutian power grid.

In the period up to 2030, it's assumes the development of distribution grids with voltage 110 kV and below, as well as reinforcing the 220 kV grids, which will also carry the distribution function.

In the development of grid infrastructure in the period to 2030 at the option maximum of the socio-economic development there are three phases:

The period before 2015: Construction of AL 220 kV (in size of 500 kV) "Kankunskya HPP - Nigniy Kuranah (Aldan)"and 220 kV (in size of 500 kV)" Kankunskya HPP - Neryungrinskay HPP" for the output power of Kankunskya HPP into the grid of Yakutia to supply the Southern and Central regions and for supplying petroleum pipeline system VSTO by the Aldan – Lensk line.

- Construction of double-line AL 220 kV in the direction of "Tommot – Yakutsk", linking Southern and Central energyregions to improve the reliability of the Center and supplying customers in the area of action of this transit. It is worth to note that to improve effectiveness of usage AL 220 kV for power transition over long distances, it's required to use the splitting of the wire by phase in a compact design for increasing the bandwidth capacity to 2 ... 3 times. The proposal is confirmed by calculations.

- Construction of the second line AL 220 kV "Neryungri - Aldan – Tommot", providing demand of Taegnogo and Desovskogo iron ore and Seligdarskogo appatit deposits, golden ore deposits of Kuranahskya field and the gold-uranium deposits of Elkonskoy group, as well as the construction of Kankunskya and Nigne-Timtonskay hydropower plants.

- Construction of AL 500 kV "Neryungriskya HPP - Aldan" to increase the power capacity bandwidth of "Nerungri – Tommot" and supply of new customers in the area "Nerungri-Tommot".

- Reinforcing and construction of power lines 220 kV in the direction of "Maya - Khandyga - Razvilka - Nezhdaninskoe" 600 km long for power supply of Nezhdaninskoye gold deposit.

- Constructing of AL 220 kV "Mirniy-Suntar-Nyurba-Viluysk" 600 km long for transferring on power heat consumers of Suntar and Nyurba uluses.

- Constructing of AL 220 kV "Suntar-Olerminsk" to connect consumers of Olerminsk ulus and NPS VSTO to centralized power supply.

- Reinforcing transition of 220 kV along BAM in direction to "Tinda – Hani – Chara".

The first phase of power infrastructure development (till 2015) does not depend on the options of input power in South Yakutia hydropower complex. Infrastructure development on second and third phases depends on launch-

ing powers of SYHPC. The scheme of Yakutian power grid till 2015 is shown on Fig. 2. The following are options of power grid infrastructure development till 2020 and 2030. On that exact period planned the maximum amount of power grid construction in Republic.

In the period until 2020 is planned:

- Switching of AL “Kankunskya HPP – N. Kuranahsk (Aldan)” and “Kankunskya HPP – "Neryungriskya HPP” to voltage 500 kV and constructing the second chain 500kW “Kankunskya HPP – N. Kuranahsk” for transferring power of Kankunskya HPP to Yakutian power grid.

- Constructing of second chain AL 500 kV "Neryungriskya HPP – Aldan”.

- Constructing of two-chain AL 500 kV “N. Kuranahsk (Aldan) - Nigne-Timptonskay HPP” for power transfer of Nigne-Timptonskay HPP to power grid.

- Construction of grid DC ± 200 kV for power transfer to plant of SYEPC with total capacity power more than 6.7 GW to directions “Southern energyregion – West energyregion – UES Siberia”; “Uchurskya HPP – Neryungri – Olekminskya HPP – Lensk – Kirengi”; “Neryungri – China” and “Olekminskya HPP – China”.

- Constructing of two-chain AL 500 kV “Olekminskya HPP – Verhne-Aldanskya HPP” and two-chain AL 220 kV “Olekminskya HPP - Hani”.

- Constructing of two-chain AL 220 kV “Olekminsk – Nigne-Olekminskya HPP”.

- Constructing of two-chain AL 500 kV “Sredne-Uchurskya HPP – Uchurskya HPP” for transferring power from Uchurskya HPP.

- Constructing of two-chain AL 220 kV “Talakan – PPPT Lensk – Mirniy” for supplying full-scale development of petroleum pipeline system VSTO, of West Yakutian petroleum-gas deposits and transferring power of Talakanskya HPP [5,13].

- Constructing of one-chain AL 220 kV “PPPT Lensk – Olekminsk – Aldan” for power supplying of full-scale development petroleum pipeline system of VSTO.

- Constructing of AL 500 kV “Skovorodino – Zeiskya HPP” and AL 500 kV "Neryungriskya HPP – ss Tinda – Skovoroidino”. for reinforcing connection of Yakutian power system with UES East and transferring capacity abroad.

In the period until 2030 .

- Constructing of two-chain AL 500 kV “Yakutsk - Aldan” to supply growing loads and to cover deficit in power and power of Central energyregion;

- Constructing of second AL 500 kV “Skovorodino – Zeiskya HPP” for reinforcing connection of Yakutian power system with UES East.

The implementation of the planned Yakutian power grid development program require construction of more than 8 thousand km (by route) of DC and AC power lines with 220 kV and above voltage, including DC - about 1,3 thousand km, AC - about 4 thousand kilometers at 220 kV and about 2.5 km at 500 kV and also 14 substations of 220 kV AC and 500 kV and 4 substations DC.

The above measures for the establishment of generating sources and the grid infrastructure require significant investment. Despite the slight difference between the options of power grid infrastructure development, the implementation cost of the period 2030 is much higher. This is due to high capital capacity of full-scale building of South Yakutsk HPP of hydropower complex and transport systems of AC electricity, which are 2.5 times more expensive than AC systems at the same distance.

It is known that for the output power over long distances, three-phase AC system took international recognition as the most simple and reliable in terms of transferring, distribution and capacity selection.

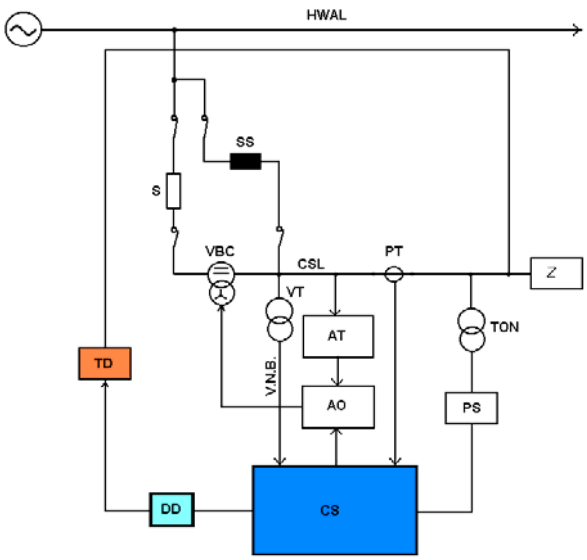
New developments [2,14,17-20] in three-phase overhead line allows to increase it’s natural capacity in two or more times, comparing to natural power of a traditional three-phase AL. The high cost of converting DC transmission substations, which is more than 3 times

the cost of substations AC, cast doubt on the path of the network, despite some gains in the value of the line. The advantage of three-phase electricity especially when using them for transmission at distances of between 2000 and 4000 km on the basis of a balanced technology. Half-wave lines and lines that are configured on half-wave have two important properties: exceptionally static sustainability and need no additional installations of reactive power compensation of reactive power line. The disadvantages of half-wave AL (HWAL) should include the complexity of smart power take-off.

Developments of the recent years in the field of mode issues of long transmission lines and system forming AL allow us to recommend an improved device for capacity selection from the HWAL (Fig. 6) and stabilization the voltage mode at the consumer on the basis of the developed at the Institute FTPS regulator-stabilizator voltage tiristor system device (RSVT) [3].

It has sufficient depth of voltage regulation (40%) and high performance (0,25 T). In emergency situations, it contributes to instant limiting of overload power and short circuit due to an artificial keys switching. In principle, the stabilization half-wave line parameters and load device consists of reactive parameters of the line and voltage stabilization devices controlled by one system.

Thus, during formation and implementation options of construction and structuring of the power grids of the Republic of Sakha (Yakutia) taking into account development of power centers of Eastern Siberia and the Far East, it's appropriate, along with a DC, to recommend to add to the development strategy of the power system of the Republic of Sakha (Yakutia) until 2030 the usege of half-wave technology. Moreover, the additional expenses are practically not necessary, and in case of necessary it can always be turned on the traditional three-phase line. Some possible directions are shown on Table 1.



TD - tuning device
AT - regulating transformer
AO –regulating organ
VBC - voltage booster channel
PS – power supply
TON -transformer of own needs
SS – shunting switch
PSL - capacity selection line
PT - power transformer
VT - voltage transformer
CS – control system
VNB – voltage negative feedback
DD - regulating angle defining device
S - switcher

Fig. 2. The principle of capacity selection in the half-wave line and stabilization of the selection line parameters.

Table 1
Combinations include electricity to implement half-wave technology

Вариант №	Наименование линии	Протяженность линии, км	Примечание
1	2	3	4
1a.	Ust-Kut – New – Lensk Lensk – Olekminsk – Aldan Aldan-Maya-Maya Churapcha – Khandyga – Razvilka	1100 830 500 600	
	Total:	3030	
1b.	Ust-Kut-Aldan-Maya-Nezhdaninskoye	3100	
2.	Ust-Ilimskay HPP – Ust-Kut Ust-Kut - Aldan Aldan-Nerûngrinskay HPP Nerungrinskay HPP - Uchurskie HPPs	270 1930 325 500	
	Total:	3025	
3.	Ust-Kut - Lensk Lensk – Olekminskay HPP Olekminskay HPP-Cancunskay HPP Cancunskay HPP - Nerungrinskay HPP Nerungrinskay HPP -Yakutsk	1100 560 400 240 825	
	Total:	3125	
4.	South-Yakutskay HPC - North China hydroelectric	3000	in North China
	Total:	3000	
5.	Boguchanskay HPP – Ust-Kut Ust-Kut - Lensk Lensk – Mirniy Mirniy – Nyurba - Yakutsk	525 1100 274 975	
	Total:	2874	
6a.	Mirniy – Vilyuisk – Yakutsk - Nezhdaninskoye Nezhdaninskoye – Ust-Kut Ust-Nera - Ust-Srednekanskay HPP (Kolymskay) Ust-Srednekanskay HPP - Magadan	1990 312 238 275 325	
	Total:	3140	
6b.	Mirniy – Vilyuisk – Yakutsk - Ust-Nera - Ust-Srednekanskay HPP - Magadan	3140	
7.	Viluiskay HPP - Yakutsk Yakutsk-Nerungrinskay HPP – Zeyaskay HPP	1425 1385	UES East
	Total:	2810	
8.	Uchurskie HPPs – South Korea	2500	Installation on Uchurskie HPPs generators with an operating frequency 60 Hz given frequency 60 Hz South Korea

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BIOGRAPHIES

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Graduated from Leningrad Polytechnic Institute in 1966. In 1974, he defended his dissertation, in 1990- the Doctor of Technical Sciences, 1993 was awarded the title of Professor, in 2000 elected member-correspondent of RAS. Main research interests: development, validation and control the behavior of electric power systems m interconnections. He is a fellow of the Academy of Sciences of the RF, International electrical energy Academy, Member of the CHAIR, a senior member of IEEE.

Vitaly P. Kobylin has ended Tomsk polytechnical institute in 1969 on a speciality "Power plants". He received the degrees of Candidate of Technical Sciences in 1989 and Doctor of Technical Sciences in 2003, managing laboratory within 17 years, now the head of department of electric power industry IPTPN the Siberian Branch of the Russian Academy of Science. Main research interests: elaboration of scientific bases for reliability, durability and efficiency in the transport of electricity, sensitive issues long routes using conversion technology in cold climates.

German I. Samorodov has ended Novosibirsk State Technical University in 1963. Since 1963 he has been working in Siberian Research Institute of Power Engineering. He received the degrees of Candidate of Technical Sciences in 1968 and Doctor of Technical Sciences in 1990. He is a professor of electrical engineering. His research interests include EHV and UHV power transmission over long and very-long distances, economics and reliability of power systems.

Vitaly A. Sedalishev graduated from Yakutsk State University in 1972 with a degree in physics. Since 1972 on present time – scientific employee of department of

electric power industry IPTPN RAS. Main research interests include reliability of electrical equipment, polymeric insulation, earthing devices.

Rose P. Li-Fir-Su has ended Novosibirsk electrotechnical institute in 1978 on a speciality "Electronic devices". Since 1981 for 1995 - the engineer-designer of design department IPTPN the Siberian Branch of the Russian Academy of Science. Since 1995 on present time - the scientific employee of a department of electric power industry IPTPN. Main research interests include reliability of electrical equipment, converting equipment.

Andrey V. Kobylin has ended the Yakut state university in 2007 on a speciality "Electrosupply of industrial plants". Since 2006 on present time - the engineer-elektronic of a department of electric power industry IPTPN the Siberian Branch of the Russian Academy of Science. Main research interests include reliability of electrical equipment, industrial electronics.