

**Power flow control in circular grid of intersystem links
of Russia and Finland power system**

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1. INTRODUCTION

Analysis of "Nordel" amalgamation operational conditions in the low water years and in the periods of rapid temperature reduction determines the task of the intersystem power transmission lines' development in order to ensure the possibility of the electric energy receiving from the adjacent amalgamations, including the transmission from Russia. Actual power balance of "Nordel" amalgamation is determined by existing natural conditions, considering that with the total installed capacity of about 78 GW for the power systems of the Scandinavian countries the total installed capacity of the hydraulic power plants is equal to 48 GW, i.e. more than 60%. In the last ten years the electric energy balance of the Scandinavian countries varied over a wide range and was from +8 to –8 TWh per year.

The "Nordel" Balance Group evaluates (in analysis for a time period up to 2004) the possible reduction within 17 TWh for the electric energy generation in dry years. In so doing the main importers of the electric energy shall be the power systems of Norway and Sweden. In 2001 the "Nordel" balance was negative and was equal to –5 TWh, including more than –10 TWh for Finland.

An electric energy export from Russia to the Scandinavian countries is accomplished for more than 20 years and reached 8 TWh in 2002. Further increase of the electric energy export from Russia to Finland may be only from the northern regions of Russia. The creation of the transmission lines from Kola region to the northern regions of Finland and Norway is considered as real one. This direction is determined by the export possibilities of the region as well as by the availability of convenient passages for the location of the routes of new transmission lines.

2. STRUCTURE OF "NORDEL" SYSTEM-FORMING GRID

The amalgamation of the power systems of the Scandinavian countries, which was formed nearly 40 years ago as the “Nordel” amalgamation, consists in the long, backbone transmission lines of 300 and 400 kV. The creation of the transverse ties between the grids of the national power systems, including ac lines between the power systems of Sweden and Norway (400 kV “Borgvik –Hasle” aerial line and “Skogssäter – Halden” line in the south and “Narsprånget – Ofoten” line in the north) and between the power systems of Finland and Sweden (Fenno-Skan “Rauma – Forsmark” dc cable line in the south and 400 kV “Petäjäskoski - Letsi” aerial line and “Keminmaa – Svartbyn line in the north) has determined the shaping of the circular intersystem lines in the “Nordel” amalgamation composition.

The mode parameter control principles, adopted in "Nordel" amalgamation, are as a rule orientated on the "soft" control of the frequency and power flows. The real control means for the power flows in operating circular circuits is so far the Fenno-Skan dc transmission line. The variation of the value and direction of the power flow, transmitted via Fenno-Skan line, gives an opportunity to execute the control of the power flows in Finland - Sweden circular grid. The full control range is up to 1000 MW. The power flow control is executed as per the condition of the Finnish power system running mode as well as per the loading condition of 400 kV backbone lines of Sweden. The total length of this ring is about 2000 km.

3. ELECTRIC ENERGY TRANSMISSION FROM RUSSIA TO FINLAND

The value of the electric energy transmitted from Russia to Finland is continuously increasing. In the beginning of 2000 the power flow of up to 700 MW capacity has been transmitted via Vyborg Converting Complex (VCC). The value of the transmitted power was raised up to 1000 MW after the enhancement of the VCC throughput capacity in 2001. The next stage was the creation of the complex circuit of Russia-Finland power transmission in order to add the AC power transmission line to the HVDC back-to-back and that made it possible to increase the power flow via the VCC up to 1400 MW. The annual value of the electric energy export from Russia in this direction (in case of the following the interstate power transmission line norms and operational conditions that were coordinated with the Finnish side) may reach 10 TWh.

It is proposed to accomplish the transmission of additional electric energy flow from Russia to the Scandinavian countries. An additional transmission of the power flows may be done from the Kola region of Russia in accordance with the condition of stable, guaranteed, positive balance of the power and electric energy as well as per the condition of the possibility organization for the passages to route the new power transmission lines.

In order to solve this problem, the technical solutions have been developed to ensure the electric energy transmission from the Kola region (of UES of the North-West of Russia) to Finland in amount up to 3.5 TWh with the capacity of no less than 500 MW. The Pre-Feasibility Study of the controlled, interstate, "Kola Power Bridge", that connects the Kola region grids and the grids of the northern part of the power system of Finland, has been done. The "Power Bridge" composition has a provision for the construction of the "Kniazhegubskaya HPP (the Kola region of Russia) – Pirttikoski (Finland)", interstate ac transmission line. The technical aspects of the controlled power transmission application have been jointly studied by the experts of Russia (ENERGOSETPROJECT" Institute") and Finland (FINGRID OYJ).

In order to create the conditions for the power and electric energy transmission from the Kola power system to the power systems of the Scandinavian countries and the Central European countries the construction of the network projects has been considered for the territory of the Kola power system and the Finnish territory, including the required reinforcement of the backbone power transmission lines in the national power systems.

4. POWER FLOW CONTROL IN CIRCULAR GRID

The shaping of the circular grids, that envelop backbone grids of adjacent national power systems of Russia and Finland, will require significant modification of running principles of the operational mode in each power system with the aim of coordinated power flow control within this grid. An alternative is independent control of power flows in each circular circuit via creation of corresponding controlled links. The development of the designs of such links has gained wide acceptance. Among other things, the possibility is under consideration in UCTE for utilization of the FACTS (Flexible AC Transmission System) for the prevention of the overloading of the system-forming links and maximum usage of the throughput capacity of existing grids [1].

The creation of “Kola Power Bridge”, that has a provision for the construction of the lines from Kola region to the northern regions of Finland and Norway, will form the circular grid, that envelop the backbone power transmission lines of the Russian and Nordel amalgamations. An additional ring will be created with total length of about 2500 km, including up to 1000 km at the territory of Finland and approximately 1500 km at the territory of Russia. The power flow control within such a ring will require an application of special means to ensure re-distribution of power flows for the effective utilization of throughput capabilities of existing and newly constructed power transmission lines. The creation of the controlled interstate power transmission line has been proposed at the feasibility study stage.

Preliminary analysis of the effectiveness of the “Kola Power Bridge” creation as controlled power transmission will make it possible to eliminate power balance influence in the nodes, that are directly adjacent with a “ring”, but in the adjacent regions as well. Power balance redistribution between individual regions of the Finnish power system only will create the balancing power flow in the ring (of Russia-Finland amalgamation) in amount of approximately 20% of the realized variation. The controlled transmission eliminates in full scope the influence of the operational mode and flow oscillations in Sweden - Finland ring (redistribution of the power flows between 400 kV AC transmission lines and Fenno-Skan DC transmission) on the operational mode of “Kola Power Bridge”. The balance variation in practically any node in Finland is taken up by the Northern and the Southern direction with the factor of 0.3 and 0.7 respectively. This phenomenon is determined by the fact, that the grids of the Northern-Eastern region of Finland are significantly less developed than the grids of the Southern and the Southern-Eastern directions. The design total resistance of equivalent link between the frontier points of the Northern and the Southern link via the territory of Russia and Finland is approximately the same and equal to approx. 200 Ohms (set for 330 kV voltage). The balance variation even within the border regions of Russia does not practically change the flow distribution between the Northern and the Southern directions (links).

Hereinafter it is planned to create new circular ring, that will include the grids of the northern Kola power system and power system of Norway. One will also require an application of effective power control within such a ring in order to optimize the power flow distribution in this circular link..

The experience of the creation and operation of the interstate transmission lines, that contain the controlled links and AC transmission lines, may be utilized as a basis for the design of new links, including the processes at the forming of BALTREL.

5. CONCLUSION

Forming of circular arrangements of the backbone grid will require the organization of the power flow control within this ring. The main control tasks are:

- elimination of mutual influence of adjacent amalgamations on the mode parameters;
- full utilization of the throughput capabilities of the existing grids, including the version at the expense of necessity elimination for the creation and keeping of the reserve;
- elimination of additional requirements for the development of grid and its configuration;
- opportunity of full realization of the advantages of liberalized electricity trade in competitive European market.

REFERENCES

- [1] U. Bachmann et al.: "Possibilities of Multifunctional FACTS Application in the European Electric Power System under the Changing Conditions of the Liberalized Electricity Market" 14-112, CIGRE Session, 2002