Problems of Nuclear Power Plant Integration into Belarusian Power System

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***Abstract*—The article characterizes the Belarusian power system, the typical loads and the capacities balance in 2013 during the heating and interheating periods taking into account putting the NPP into operation. The expected capacities balance of the Belarusian power system for 2020 is calculated as well. The comparative analysis of the main characteristics for the typical loads in 2013 and 2020 revealed a number of problems connected with the integration of the NPP into the Belarusian power system. The proposals to improve the flexibility of the power system and increase its response to power demand changes under the conditions of the NPP operation are offered.**

***Index Terms*—Cogeneration, energy consumption, load management, power distribution, power system reliability.**

The Belarusian power system includes 3 condensation power plants with capacity of 4140.6 MW , 37 combined heat and power plants (CHP) with capacity of 4337.8 MW, 24 wind and hydroelectric power stations with capacity of 27.8 MW and 183 industrial generating plants (decentralized) with capacity of 636 MW. The general capacity of the Belarusian power system consists of 9142.2 MW (the data are provided for 01.01.2014).The Belarusian power system has two features which distinguish it from the majority of other power systems:

1. High unevenness of power and heat consumption. The coefficient of unevenness for the daily load (the relation of the minimum power consumption to the maximum one) is about 0.64. The coefficient of filling for the daily load distribution reaches 0.86. Within a year the heat load changes considerably, so, in the winter of 2013 the maximum heat consumption of CHPs is 2750 MW, and in the summer - only 1220 MW, i.e. it decreased twice.

2. The high share of CHPs in the structure of the generating capacities (47.0%). Producing at the same time heat and power, CHPs have the best indicators of fuel use efficiency. However, at the decrease of the heat consumption the power generation also is decreased. CHPs can work in the condensation mode, however, under this condition their performance coefficient is lower than the one that condensation power plants have.

Due to the high share of CHPs in the structure of the generating capacities getting over a night load minima in the heating period is the considerable problem for the Belarusian power system. The daily load has the coefficient of unevenness about 0.64.

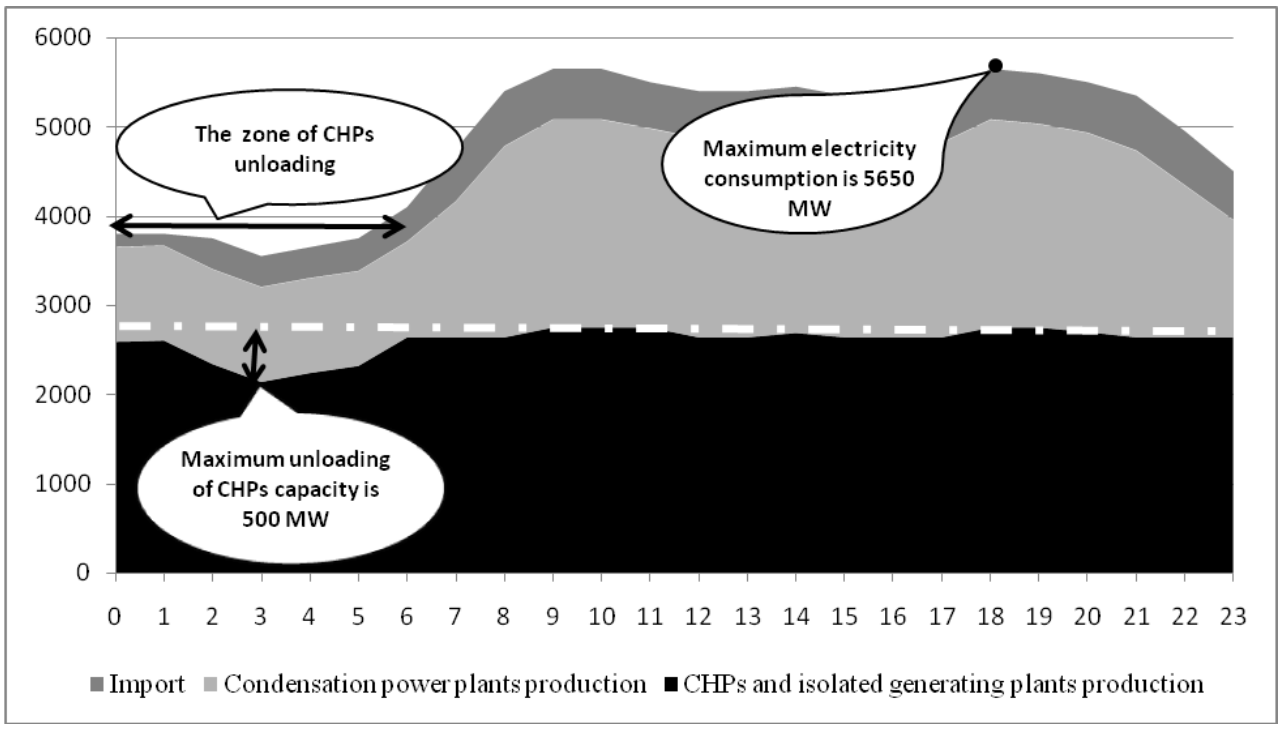
Fig. 1 shows the daily load distribution during the heating period in the working day of 2013.

During the heating period in the working day the night load minimum is 62.8% of the maximum load. It means that power plants are compelled to unload approximately from 5650 MW in the period of the load maximum to about 3550 MW at night that is by 2100 MW.

During the interheating period in the working day the night load minimum makes 63.5% of the maximum load. It means that power plants are compelled to unload approximately from 4800 MW in the period of the load maximum to about 3050 MW at night that is by 1750 MW.

During the interheating period the maximum electricity load in the working day decreases approximately by 15.05% in comparison with the heating period. The heat load and respectively the generated by CHPs electricity load in the working day during the interheatig period decrease 2.25 times in comparison with the heating period. During this period part of the CHPs is under repair. The condensation power plants play the main role in electricity supply during the interheating period. In essence summer daily load curve determines the amount of installed capacity of the condensation power plants in the Belarusian power system. Therefore the getting over the night minimum on summer days is easier, than in the winter.

The on-line capacity of the condensation power plants is changed from 1091 MW at night to 2647 MW in the daytime during the working day in the interheating period.



Unevenness of the daily load distribution and law sufficiency of the condensation power plants are the main reasons for involvement of the CHPs in the regulation of the load. Now the problem of unevenness of the load is solved also with the help of electricity import from Russia.

The capacities balance of the Belarusian power system in the winter and summer maximum of 2013 presented in table I.

TABLE I. The Capacities Balance of the Belarusian Power System in the Winter and Summer Maxima of 2013, MW

Parameter	Winter maximum 2013	Summer maximum 2013
Maximum of electricity consumption	5650	4800
Hot reserve capacity	633	633
Cold reserve capacity	430	430
Capacity limitations connected with s technology processes	446.28	1785
Capacity decrease because of repairs	925	1290
Power import	565	932.8
Equals: necessary installed capacity (1 + 2 + 3 + 4 + 5 – 6)	7519.28	8005.32
Installed capacity	8925.6	8925.6
Deficit (–) or reserve (+) of installed capacity (8 – 7)	1406.32	920.28

In case of a long emergency stop of several large generating blocks of 250-320 MW and reduction of power import volumes it is necessary to use practically all the generating equipment of the Belarusian power system being in the cold reserve for ensuring the capacities balance. During the interheating period there is a considerable reserve of the installed capacity (920.28 MW). However in case of refusal from power import (932.8 MW) there will be a deficit in power supply (920.28 MVT-932.8 MW=12.52 MW).

The construction of the NPP in Belarus first of all is caused by an urgent need to increase energy security of the country and by that to create reliable power supply sources for its development in the future. The Belarusian NPP will consist of two power units with the total capacity up to 2400 (2x1194) MW. The NPP is located at the Ostrovetskaya platform of the Grodno region.

For the Belarusian NPP the Russian "NPP-2006" design with the water-to-water nuclear reactors (WWR) of the "three +" generation is chosen. It is characterized by the increased safety parameters, technical and economic indicators and completely meets the international standards and recommendations of IAEA on the nuclear and radiation safety.

The main technical and economic parameters of the NPP-2006:

- installed capacity of the each power unit is 1194 MW;
- design life-time of the power unit operation is 60 years;
- electrical efficiency is 36.56% (gross);
- power expense on the own needs of the plant is no more than 7.15% of the rated capacity;
- capacity factor is 92%.

The first power unit of the Belarusian NPP will be put into operation in 2018, the second one – in 2020.
According to the power consumption forecast of the Republic of Belarus by 2020 the demand on electricity will achieve 44.62 billion kWh under the conditions of economy intensive development and energy saving measures implementation

Taking into account this demand on power and operation of the two power units of the NPP in 2020 load distribution s during the heating and interheating periods in the working day of 2020 (Fig. 2 and 3) were simulated.

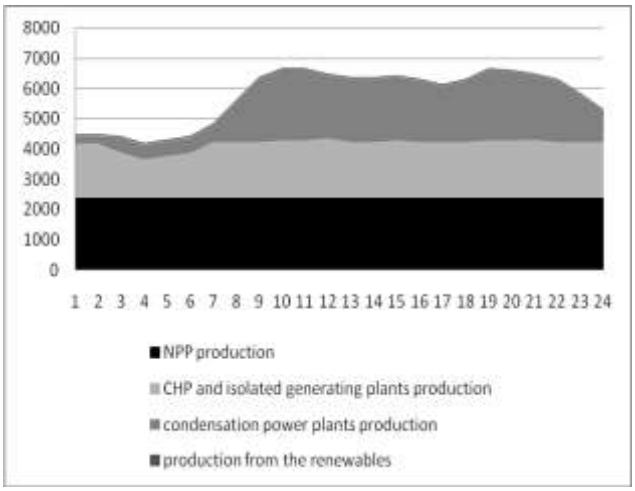


Figure 2. The daily load during the heating period in the working day of 2020, MW

During the heating period in the working day in 2020 the power plants will be compelled to unload from 6674 MW in the period of the load maximum to 4193 MW at night that is by 2480 MW, which means that the load minimum makes 62.83% of its maximum. In this case the maximum unloading of the CHP below the heat load has to make 573 MW.

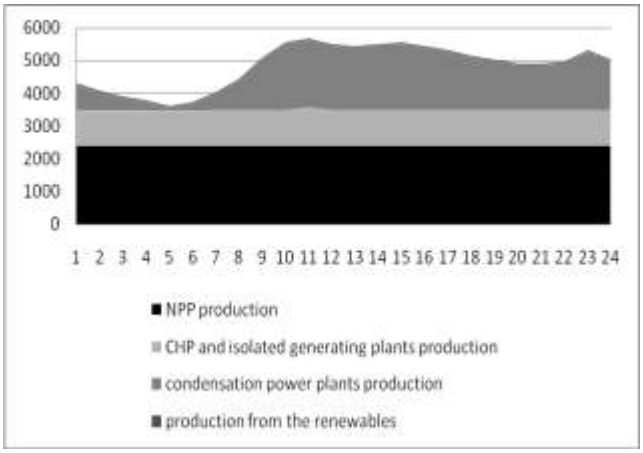


Figure 3. The daily load during the interheating period in the working day of 2020, MW

During the interheating period in the working day of 2020 the power plants will be compelled to unload from 5670 MW in the period of the load maximum to 3603 MW at night that is by 2067 MW. It means that the load minimum makes 63.54% of the maximum loading. In this case the condensation power plants will have to unload from 2044 MW to 79 MW that is by 1966 MW.

Thus, if to compare load during the heating period in the working day in 2013 and in 2020, it should be noted that unloading of the power plants has to be increased by 380 MW at night, the maximum unloading of the CHPs has to be increased by 73 MW. It shows that the introduction of the NPP will aggravate the problem of getting over night load minima during the heating period. When comparing loads during the interheating period in the working day in 2013 and in 2020, it should be noted that in 2020 the power plants will have to unload by 216 MW more than in 2013.

The characteristics of standard daily loads of the Belarusian power system in 2013 and in 2020 are presented in table II.

TABLE II. The Characteristics of Standard Daily Loads of the Belarusian Power System in 2013 and in 2020 **(**Capacity P in MW, Energy E in GWh)

Load	**α**	**β**	**P min**	**P max**	**ΔP max**	**E daily**
Heating period-working day 2013	0.62832	0.86320	3550	5650	2100	117.050
Interheating period-working day 2013	0.63542	0.85330	3050	4800	1750	98.300
Heating period-working day 2020	0.62824	0.86318	3880	6176	2296	127.942
Interheating period-working day 2020	0.63541	0.85325	3334	5247	1913	107.447

As follows as from table II, the daily load curve during the interheating period in the working day of 2013 has the lowest unevenness (α= 0.63542),the daily load curve during the heating period in the working day of 2020 has the highest unevenness (α = 0.62824). The greatest load maximum will be characteristic for the working day of the heating period of 2020 (6176 MW), the greatest load minimum was characteristic for the working day of the interheating period of 2013. The greatest daily consumption will be observed in the working day during the heating period in 2020 (127,942 GWh). The load maximum in 2020 in the standard working day will increase in comparison with 2013 by 526 MW, however owing to the introduction of the NPP the power balance during both the heating and the interheating period of 2020 will be carried out.

The capacities balance of the Belarusian power system in the winter and summer maximum of 2020 is presented in table III.

TABLE III. The Capacities Balance of the Belarusian Power System in the Winter and Summer Maximum of 2020, MW

Parameter	Winter maximum 2013	Summer maximum 2013
Maximum of energy consumption	6674	5670
Hot reserve capacity	1392.5	1367.6
Cold reserve capacity	1200	1200
Capacity limitations connected with technology processes	635.1	2540.5
Capacity decrease because of repairs	1000	0
Power import	0	0
Equals: necessary installed capacity (1 + 2 + 3 + 4 + 5 – 6)	10901.6	10778.1
Installed capacity	12702.5	12702.5
Deficit (–) or reserve (+) of installed capacity (8 – 7)	1800.9	1924.4

As follows from table 3 there is a considerable reserve of the installed capacity (1800.9 MW) in the heating period of 2020. The need for power import isn't observed. In the interheating period of 2020 the reserve of the installed capacity is by 123.5 MW more, than during the heating period of the same year.

When comparing the capacities balances in the winter maximum of 2013 and 2020 it should be noted that the power consumption maximum in 2020 will increase in comparison with 2013 by 1024 MW, however owing to the growth of the installed capacity in 2020 by 3776.9 MW in comparison with 2013 the need for power import won't be observed, and the reserve of the installed capacity will increase by 394.58 MW. The power consumption maximum during the summer period in 2020 will increase by 870 MW in comparison with 2013, the reserve of the installed capacity in 2020 will increase in comparison with 2013 by 1004.12 MW, thus in 2020 during the summer period there will be also no need for power import.

Thus, it is possible to draw a conclusion that the introduction of the NPP, on the one hand, will aggravate the problem of getting over the night load minima during the heating period, on the other hand, will increase the energy security of the Republic of Belarus thanks to creating the considerable reserve of the installed capacity and absence of the need for import.

For improving the economical operation of the Belarusian power system and increasing the flexibility of its response to power demand changes it is theoretically possible to consider the following actions:

- construction of a hydro pumped storage unit;
- installation of peak gas turbines;
- application the power tariff differentiated by zones of days for consumers decentralized generating plants;
- application of electric boilers which assume the heating capacity of the Belarusian power system at night and give out the heat in the rest of the time, reducing power generation in the power system in the heating mode;
- use of energy storage units of large capacity. Now in the leading countries of the world scientific research in this sphere is intensively developed;
- creation of the central automatic frequency and active capacity regulator (CAFACR) that will allow providing automatic control power plants production and minimizing power balances deviations;
- increase in electricity consumption and load alignment in the industries of the economy and in the social sphere of the country.

Before putting the NPP into operation it is necessary to choose the optimum configuration of these actions.

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