Increasing the reliability of the united power systems of central Asia in conditions of energy transition

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Abstract. The issues of increasing the reliability of the United Power System of Central Asia in the current conditions of operation and energy transition are analyzed. The issues of integrating renewable energy sources into the energy system are addressed, taking into account the forecasted volumes of their input until 2030.

Main objectives of UPS CA

Since 1960, the United Power System of Central Asia (UPS CA) and South Kazakhstan has been the basis of the electric power industry of the four Central Asian republics and adjacent regions of South Kazakhstan. The effects of interconnecting energy systems are known and are depended on the degree of their integration.

In the conditions created after 1991, the strategically justified desire of independent states for self-balance led to the loss of advantages from the unification, while until recently only the mutual exchange of electricity under intergovernmental agreements was preserved. Under the new conditions, the principles of joint operation of energy systems in the CA's UPS, the functions of coordinating bodies and the Unified Dispatch Control (UDC), have changed.

It was not possible to preserve all the advantages of parallel operation of power systems that existed under tight dispatch control, since each power system has its own criteria. The desire of each energy system to obtain maximum profit, without taking into account the interests of its partners, leads to the deterioration of its own criterion [1].

One of the main tasks of the UPS remains the reservation of energy systems in normal and emergency regimes and the implementation of contractual interstate exchanges of electricity under Intergovernmental Agreements (IGA) and the rational consumption of energy resources.

The energy systems of the states must meet the needs for base, peak and reserve power, reactive power sources, and the development of projects for the development of the electric power industry for the UPS as a whole. In this regard, alternative options for commissioning generating capacities, building new power plants with the efficient use of various energy resources should be considered, taking into account the promotion of the inclusion of Renewable energy sources (RES) and energy-saving technologies.

Integration of renewable energy sources in UPS CA

According to the Energy Industry Development Concept [3], in Uzbekistan, by 2024, it is planned to launch RES with a total capacity of 4000 MW (including SPP–2400 MW and WPP–1600 MW), and by 2030 – to increase the capacity of RES to 9000 MW.

To understand these scales, we note that the installed capacity of the Uzbekistan energy system is just over 16 GW. If the influence of RES variability can be solved by maintaining hot reserves at power units and using storage devices, then the problem of discontinuity inherent in solar stations has its own characteristics for Uzbekistan.

It is not possible to solve this problem with mobile gas stations such as gas turbines or gas-piston ones, even in such a gas-rich country as Uzbekistan. The problem with replacing the solar power that disappears in the evening is not due to a lack of generating capacities in the energy system, but with restrictions on the rate of power gain at gas stations due to existing restrictions in the country's gas transmission system (GTS) [4].

Problems with the speed of lifting the load at the stations can be solved as follows:

a) reorganize the operation of gas transmission facilities so that they operate on a flexible daily schedule of power plants, and not on an almost flat schedule as it is today – an undertaking associated

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with high financial and time costs;

b) switch to the mode of daily mazut burning during the hours of load rise in the evening maximum, when there are restrictions on load increase due to lack of gas. To do this, it will be necessary to keep in working condition a part of the existing traditional power units that can operate on both gas and mazut. This is a very costly operation: mazut is currently burned under extreme circumstances in the winter and a transition to year-round daily fuel oil combustion is unlikely;

c) installing energy storage devices at SPP and/or in the energy system. It is also an expensive operation, which countries that massively introduce renewable energy have to take.

If the problem noted above is not addressed, a situation with large uncompensated surges of power will be created almost daily on the transit North-South of Kazakhstan loaded to the limit and, accordingly, on the interface of the UPS of Kazakhstan - UPS of Russia.

Now the allowable surge of power towards Russia is 500 MW, and from Russia towards the UPS CA – 300 MW. Taking into account the latter factor and preventing the violation of stability in the energy system of Uzbekistan, automatic shutdown of power units with a capacity of over 300 MW was introduced. Thus, when an 800 MW unit is switched off at the Talimarjan TPP, emergency automatics are activated at SALS (Special Automatic Load Shedding) in the amount of 800–300 = 500 MW, while the Control of the previous mode (CPM) is provided, which determines the required amount of SALS depending on the load, carried by the emergency shutdown unit.

Note that the problem is not only in the shortage of power reserves. Today, the UPS CA does not have enough power reserves. Thus, in the Kyrgyz energy system there are reserves of about 150–200 MW, and after the connection of the Tajik energy system, reserves of the order of 700–1000 MW will appear.

An increase in mobile reserves is possible through the joint construction of new HPPs by the countries of the region in water-rich Tajikistan and Kyrgyzstan in order to create peak capacities to compensate for the impact of renewable energy.

Taking into account the decrease in the region's water resources, attention should be focused on Pumped storage stations (PSSs), using for this purpose the existing reservoirs of daily and weekly regulation [7, 8]. These activities will help reduce imbalances from renewable energy, but this is a very long-term process.

The existing surges towards the UPS of Russia are due to the fact that with the existing centralized frequency regulation system, the regulators in the national energy systems of the UPS CA do not have time to respond to disturbances earlier than the stations of primary and secondary regulation in Russia. Large unbalances, leading to a breakdown in stability, currently occur infrequently, mainly during emergency shutdowns, in which, for one reason or another, the compensating effects of emergency automatics were not enough.

With the introduction of RES, as will be shown below, such imbalances in the UPS CA will occur every day, which casts doubt on the possibility of fully ensuring the sustainability of the parallel operation of energy systems.

On the sustainability of UPS CA with the introduction of renewable energy.

Given the high pace of RES integration in UPS CA and the duration or high cost of measures to overcome the associated problems, it should be expected that surges in power imbalances from RES will occur every day and the probability of accidents in UPS CA will, accordingly, increase, which was confirmed by systemic accidents in power systems UPS CA in 2020-2022 years.

Besides, the transit capacity of the North-South UPS of Kazakhstan is used up to the maximum load and, as a result, it will be necessary to disconnect consumers in the UPS CA from emergency automatics on a daily basis in order to maintain the stability of parallel operation.

Let's show this problem on the following example of the launching of a solar power plant with a total capacity of 3000 MW. In the current regimes in the Uzbek energy system, to cover the load during the hours of the evening maximum, it is necessary to increase the generation at thermal stations by about 1500 MW, which the existing GTS can hardly accomplishes, especially in winter (Fig. 1).

With the launch of solar power plants in Uzbekistan, with which, agreements between parties will be concluded on the basis of the “Take or pay” principle, the energy system will be forced to additionally unload up to 3,000 MW at TPPs during the day and, as a result, raise 4,500 MW in the evening, considering the replacement of the disappearing capacity at SPP.

Taking into account the regimes of “Uztransgaz” JSC do not allow changing gas consumption at thermal power plants by more than 250-300 thousand m3 per hour, it is clear that problems in the GTS will occur both during daytime unloading of thermal power plants and during evening load sets at thermal power plants, which will lead to power imbalances.

The danger of large uncompensated power imbalances was shown by the events in the UPS CA on January 25, 2022 with the full breakdown of the power interconnection [2].

The Commission of UPS CA, under the leadership of the Coordinating Dispatch Center “Energy”, conducted an investigation with the involvement of independent experts, including SO UPS, identified the causes of the incident and developed a number of measures to prevent similar accidents in the future.

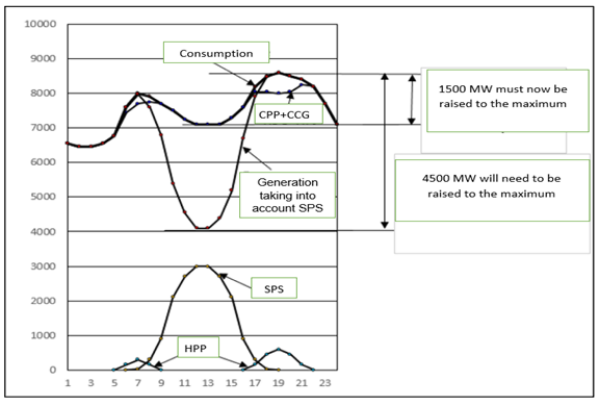

Fig. 1. Change in the daily generation of TPPs and HPPs of the Uzbek energy system before ad after the commissioning of a 3000 MW solar power plant

During the investigation of the accident, it was revealed that at the Syrdarya TPP (SDTPP) there was a long-term arc burning between the fixed and moving contacts of the lead-in disconnector of the suspended type of the 500 kV L-502 line (SDTPP – Tashkent Substation), which, due to air ionization, switched into phase-to-phase short circuit with disconnection of L-502 from High-speed protections (HSP) on both sides with successful three-phase automatic reclosing.

At the same time, the second busbar system of 500 kV was disconnected at the SDTPP from the excessive operation of the main and backup sets of differential protection of the 2nd busbar system 500 kV. After 2 minutes, because of a repeated two-phase short circuit, L-502 again disconnected from the Phase differential protection (DFZ) on both sides. The short circuit happened for the same reason. The first busbar system of 500 kV was disconnected at SDTPP from the excessive operation of the main and backup sets of differential protection of the 2nd busbar system.

A local accident with the down of the first 500 kV busbar systems at the SDTPP, with the loss of generation at it and the division of the power system created imbalance of more than 2000 MW, seven times

higher than the calculated imbalance, that fell on the North-South transit of Kazakhstan, which caused a breakdown of the dynamic stability of this transit, loaded almost to the limit.

Transit separation almost doubled the power imbalance in UPS CA, which led to the development of an emergency with a decrease in frequency to 47.1 Hz, with the operation of automatic under-frequency load hedding system at individual stations in South Kazakhstan and the shutdown of two CCGTs in the Uzbek power system and, ultimately, a frequency avalanche.

The Commission has developed a number of measures aimed at pre-venting the recurrence of such accidents in the future, the implementation of which will eliminate the occurrence of uncompensated power surges in the future. However, it seems that they are not enough to avoid the recurrence of such systemic accidents in the implementation of plans for the construction of renewable energy sources in the UPS CA.

The advanced introduction of RES in Uzbekistan and Kazakhstan can lead to:

- a sharp increase in the problems with the regulation of imbalances and the necessary power reserves for this during the entire time of the day, not only during peak hours as it is now;
- the urgent need to solve the problem with excess gas during the daytime, when solar stations will operate at full capacity, and thermal power plants - at a technological minimum;
- the problem with the increasing the speed of load at thermal power plants.

Considering previously noted acute shortage of power reserves in the UPS CA, it can be concluded that with the large-scale introduction of RES, power surges for the North-South transit of Kazakhstan will be inevitable and daily failures of the stability of this transit will become the main problem that may turn out to be the key obstacle to the integration of RES.

Increasing the transit capacity of the North-South of Kazakhstan to maintain stability during power surges, as experience shows, is an expensive and, at the same time, a temporary and quickly exhausted measure. To solve the problem of ensuring the stability of the parallel operation of the power systems of Central Asia with the UPS of Kazakhstan and the UPS of Russia, in [2] the authors proposed the idea of using back-to-back HVDC converter station (HVDC-Scheme) in the UPS CA in the problem area (Fig. 2).

Fig. 2. Suggestion for DC insertion

Conclusion

As noted above, in the accident on January 25, 2022, the shutdown of the North-South transit of Kazakhstan led to almost a doubling of the power imbalance and the development of the breakdown in the system.

If the injection of power supplied through this transit for the southern regions of Kazakhstan is maintained in an emergency, this would contribute to obtaining a regime in the UPS CA with a smaller deficit and, accordingly, at lower costs for its normalization. It is proposed to separate the UPS CA and the Southern regions of Kazakhstan from the UPS of Kazakhstan by a HVDC-Scheme installed in the L-514 (Shu - Frunze) cut-off, and by transferring the shunting 220 kV overhead lines to dead-end modes [2].

The capacity of the HVDC-Scheme must be chosen sufficient to supply the Shymkent and Dzhambyl regions from the UPS of Kazakhstan, estimated at about 1000 MW. The analysis shows that if such HVDC-Scheme would be in the UPS CA, then in the accident on January 25, the frequency would decrease after the busbar systems at the Syrdarya TPP were extinguished only to 48.5 Hz and there would be no development of the breakdown in the system with the operation of the automatic under-frequency load

shedding system at the stations and the subsequent frequency avalanche in the power system.

This approach will allow to address of several current problems:

- with centralized frequency regulation by Russian stations, all power imbalances in the UPS CA fall on cross-border communications towards the UPS of Russia and overload them, while operating through a direct current insertion, the imbalances will remain in the UPS itself;
- taking into account the preservation of supplies through the HVDC-Scheme and the frequency effect of the load, frequency regulation will be much easier than with the preservation of parallel operation with the UPS of Russia and the UPS of Kazakhstan;
- the structure of the Automatic Control of Frequency and Power flows (ACFP), which is planned to be developed and implemented in the CA UPS, will be simplified; the task of regulating deviations in the balance of flows at the border of the UPS CA with the UPS of Kazakhstan will disappear and the ACFP will focus on regulating the frequency and flows within the energy association.

1. Analysis of the accident on January 25 in UPS CA shows the presence of problems with power balancing in case of violation of the stability of the North-South transit of Kazakhstan.
2. The large-scale introduction of variable and intermittent RES, combined with the existing and expected problems in the gas transmission system of Uzbekistan, greatly increases the likelihood of uncompensated surges in the North-South transit of Kazakhstan. The RES implementation program should be linked to a large-scale reorganization of the gas transmission system with the creation of interaction between the operators of the electric and gas networks in the region to ensure the operation of the GTS in accordance with the schedule of the energy system.
3. In order to efficiently use water and create peak capacities to compensate for the impact of RES, it is proposed to increase efforts in the region for the joint construction of hydroelectric power plants, as well as pumped storage power plants, using for this purpose the existing reservoirs of daily and weekly regulation.

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