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The Impact of Renewable Energy Sources on Power Flows in the Electric Power System of Uzbekistan

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Abstract. This paper analyzes the variations in power flows along the main power transmission lines of the electric power system of Uzbekistan, taking into account the power generation by large PV power plants (PVP), which will be commissioned by 2024. The paper concludes with recommendations on the modernization of the electric power economy.

INTRODUCTION

There is a worldwide trend towards a new concept of global energy development due to the need to answer several economic, demographic, and environmental issues. Nowadays, it has become clear that solar, wind and nuclear energy, as well as energy efficiency, are the development pillars of global energy development for the long-term supply of "clean" energy to the population and industry. This is due to the depletion of economically viable oil, coal and gas fields, as well as the problems of climate change. The period of the dominance of fossil fuels in the global energy mix is coming to an end. Analysts are optimistic that by 2050 the share of solar and wind energy in the total global energy mix will exceed 50% [1-3].

In the face of excessive usage of fossil fuels, rapid growth in global industry and business has resulted in a serious lack of available energy. Environmental considerations, in addition to concerns about supply security, have made investment in low-carbon power generation technology a top priority on the energy agendas of many governments across the world. As a result, generating power from renewable energy sources is a viable option that will not only meet rising energy demand but also protect the environment.

Because RES are intermittent and their locations are geographically spread, integrating them has added extra uncertainties and obstacles to power networks. The fast rise in energy generation caused by RES necessitates a variety of studies to assess the effects of RES integration on the power system.

Several governmental resolutions were adopted to expand the use of renewable energy sources in Uzbekistan. These resolutions aim to increase the share of renewable energy in the total volume of electricity production to 20% and 25% by 2025 and 2030, correspondingly [4-6].

METHODOLOGY

The main components of renewable energy in Uzbekistan are: solar, hydraulic and wind energy. According to the results, the technical potential of renewable energy sources in Uzbekistan is 270 million tons of fuel equivalent, which is more than three times higher than the annual demand for energy resources (Table 1) [1, 2, 7].

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TABLE 1. Potential of renewable energy sources of the Republic of Uzbekistan

Type of renewable energy sources	Potential in million tons of fuel equivalent per year		
	Uzbekistan		Worldwide
	Gross	Technical	Gross
Solar energy	76459	265	$131 \cdot 10^6$
Wind energy	3.33	0.64	$2 \cdot 10^6$
Hydraulic energy	3.43	0,39	$7 \cdot 10^6$
Biomass energy	13.8	2.92	$0{,}1 \cdot 10^6$
Total	76480.0	269.05	$140.1 \cdot 10^6$

Table 2 presents the results of processing actinometrical data based on long-term observations to determine the annual amount of direct solar radiation reaching the surface normal to the sunrays - $\sum q_\perp$ in actual weather conditions (i.e., taking into account clouds) and the actual annual number of sunshine hours -n, which are the key indicators of the availability of solar energy for specific regions of the country (Table .2) [2, 7].

TABLE 2. The annual amount of direct solar radiation reaching the surface normal to the sunrays

Regions	$\sum q_\perp$, kW hour/m^2	n, hours
The north of the Republic (the Republic of Karakalpakstan, the Khorezm region and the north of the Navoi region)	1900-2100	2900-3000
The south of the Republic (the Kashkadarya and Surkhandarya regions)	1900-1960	2950-3050
The Ferghana Valley (the Ferghana, Andijan and Namangan regions)	1500-1550	2650-2700
The Zerafshan Valley (the Samarkand, Jizzakh, Bukhara regions and the south of the Navoi region)	1910-1980	2930-3000
Tashkent city	1943	2852

As can be seen from the above data, the indicators of renewable energy resources of the Republic of Uzbekistan fully meet the conditions for the construction and operation of large photovoltaic and wind power plants (WPP).

RESULTS

Large-scale work on the practical use of renewable energy sources has begun in the Republic of Uzbekistan. The country has already installed its first PV power plant with a capacity of 100 MW on the territory of the Navoi region. The installation was integrated into the power grid of the Republic of Uzbekistan. It is also planned to build and commission six large PV power plants with a total capacity of 1,297 MW in the Navoi, Samarkand, Jizzakh, and Surkhandarya regions by the end of 2023. These are the regions chosen since the total annual value of solar radiation exceeds 1900 kWh per square meter [8-12].

Figure 1 shows the network diagram of the South-Western part of the power system of the Republic of Uzbekistan. The PV power plants mentioned above will be connected by its nodes.

Let us consider the impact of the commissioning of these PV power plants and their integration into the electric power system of the Republic of Uzbekistan on the power flows.

Table 3 demonstrates the results of estimating the established regime of the electric power system to date, while taking into account the peak capacities of these six PV power plants after their integration into the electric power system. The substations located nearest to the construction site of PV power plants, namely, "Samarkand", "SS Besopan", "Kattakurgan", "Sherobod" and "Zhizzakh", were chosen as the proposed nodes for connecting PV power plants.

Only the already built PV power plant with a capacity of 100 MW in the Karmana village is connected directly to the L-17-km-1 high-voltage line connecting the “Navoi thermal power plant” and “Kuyumozor” substations.

Estimations show that when PV power plants generate their peak capacity, the active power flows along the lines L-501, L-502, L-513 and L-550 increased by 14%, 8%, 3% and 13%, respectively. The largest increase of 24% could be observed on line L-525. At the same time, the reactive power flows along these lines decreased from 1 to 17 MVAr. The maximum decrease was recorded for line L-525. Production of active power flows directly near the major consumers explains the reduction of reactive power flows and hence related losses in the grid.

It is important to note that the active power flows along some lines, namely L-17-A and L-17-D, decreased by 20% and 23%, respectively. It will provide an additional reduction in the losses of active and reactive power flows in the grid and reduce the payback period of the PV power plant. The analysis shows that the installation of large PV power plants next to the main consumers does not add to the burden on existing transmission lines. In this case, the maximum level of overflows does not exceed 54% of their capacity.

The ability of existing grids to redistribute additional capacity generated by new PVPs and WPPs without any problems does not guarantee the stable operation of the electric power system after their integration. A large number of calculations are required to determine the dynamic, static and resultant stability before commissioning large renewable power plants.

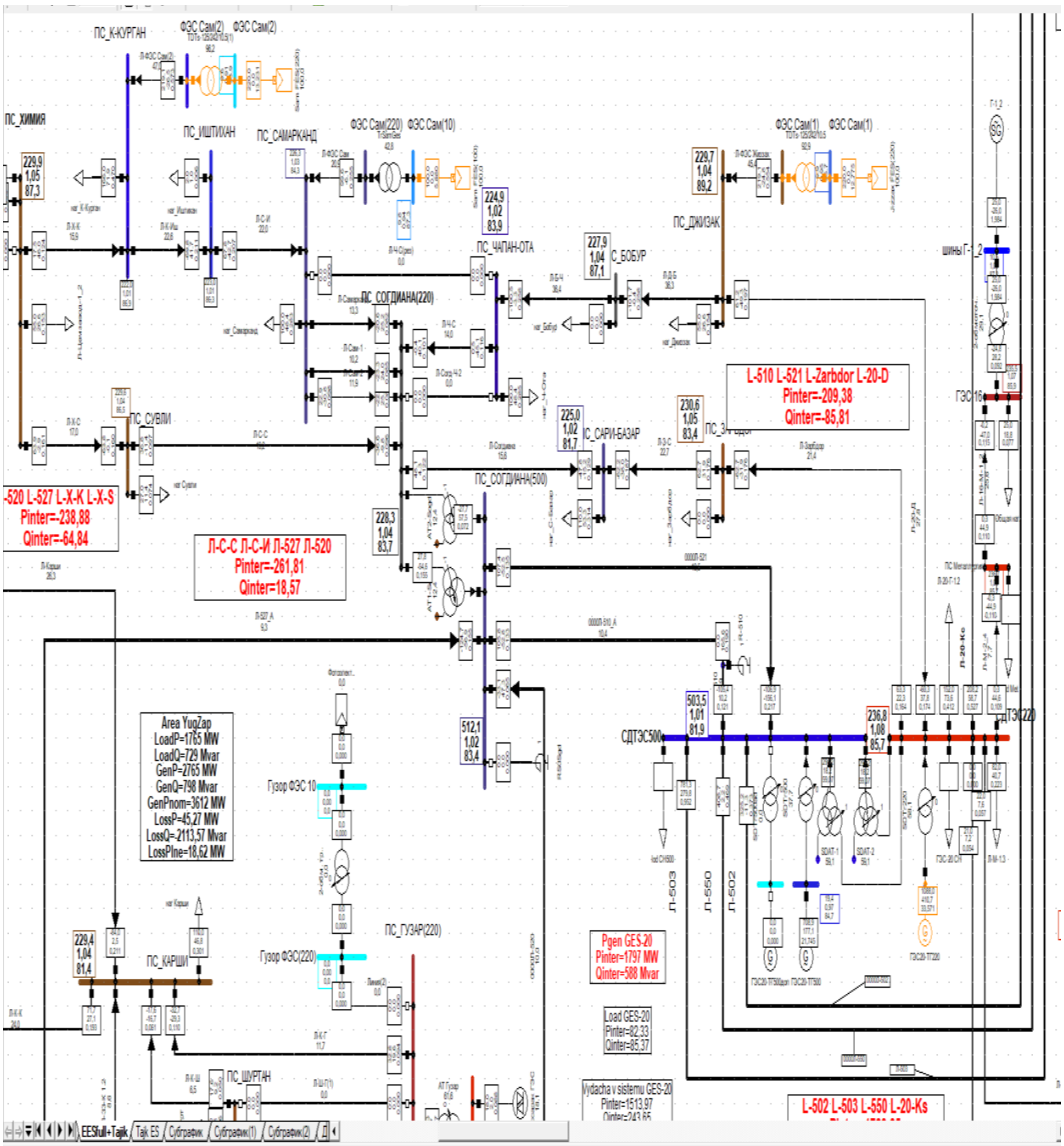

FIGURE 1. A fragment of the electric power system of Uzbekistan

TABLE 3. Power flows before and after the installation of the PV power plants

Name	Line Type	Length. km	Loading-(%)		Capacitive Loading-(MVAr)	
			The first case	1297 MW PVP	The first case	1297 MW PVP
L-17-km-1	AC 500-64(220)	71.1	22.94712	23.84292	10.00465	5.077958
L-17-km-1_a	AC 500-64(220)	35.55	-	49.78991	-	4.959059
L-17-A	AC 300-39(220)	68.	55.54933	35.65469	9.093464	9.27546
L-17-D	AC 240-32(220)	159.	50.56466	27.87995	20.44588	21.12191
L-501	AC 3x400(500)-TK	104.8	26.79925	40.98718	92.93673	71.94276
L-502	AC 3x400(500)-TK	156.294	6.849065	14.83054	156.1881	148.7257
L-508	AC 3x400/93	162.3	13.32875	5.816772	170.3963	173.5114
L-510_A	AC 3x300	217.8	12.82521	10.40029	218.2023	211.8426
L-513	AC 3x330(500)-TK	82.	10.44638	13.4514	80.01757	79.30197
L-520	AC 3x300-TK	134.74	11.64825	9.964044	133.5631	131.5865
L-521	AC 3x300-TK	216.43	12.96534	10.47955	219.3368	212.98
L-525	AC 3x300	142.	29.4766	53.58898	122.9723	105.6421
L-526	AC 3x330(500)-TK	198.	17.39074	13.31964	188.7027	187.7935
L-550	AC 3x300	123.196	10.67355	23.39143	121.7403	116.1843
L-Besopan	AC 300-39(220)	183.6	51.7553	32.19472	23.41248	24.24114
L-P-D	AC 300-39(220)	43.3	34.3517	4.503544	6.602445	6.720559
L-P-Sh	AC 300-39(220)	49.5	31.9577	4.302546	7.542249	7.678185

A significant disadvantage of PVP and WPP is the intermittent (IRES) and variable (VRES) pattern of generation, depending on the time of day and year, weather conditions [13-15]. Today, this shortcoming can be compensated by creating modern high-speed energy storage systems based on lithium-ion batteries of comparable capacity. However, the relatively high cost, environmental harmfulness, and notably short service life of the batteries require the development of more reliable and cheaper energy storage systems. To date, the most promising are gravitational storage devices and hydrogen energy.

Along with the increase of the share of renewable energy sources in the energy balance, it is necessary to construct new power transmission lines, additional reserve capacities, energy storage systems, high-speed compensating and regulating devices [6, 17, 18, 19].

In our opinion, it is necessary to develop nuclear energy along with renewable energy sources, modernize existing thermal power plants, and popularize the ideas of energy saving and energy efficiency.

CONCLUSIONS

Based on the analysis of the calculations carried out, it can be stated that the existing power grids can withstand possible variations in power flows associated with the commissioning of large PVP and WPP with a total capacity of 2797 MW. However, additional research is required to analyze their impact on static and dynamic stability, to develop a concept for the development of network equipment, system automation and electric power dispatching complexes. Along with the large power plants, it is recommended to build medium and low-power power plants near the main consumers.

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