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Comprehensive analysis of the change of pop solar power station output parameters in relation to ambient temperature

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Abstract. This article examines a 128kW solar photovoltaic plant (SPP) connected to a 0.4kV distribution network in Pop district, Namangan region. The research revealed the effect of ambient temperature on the quality indicators of electricity generated by SPP. Ambient temperature affects not only the SPP production capacity, but also the inverter performance, which is the most basic device for SPP. The results were obtained on July 21-22, 2019 year when the air temperature was 350-450 C.

1. Introduction

The Republic of Uzbekistan is carrying out large-scale reforms aimed at accelerating the development of all sectors of the economy, increasing investment attractiveness and business activity, expanding production and services. Diversification of energy balance through integrated development of the country's energy, introduction of high-efficiency energy-saving technologies, increasing energy efficiency in energy-intensive sectors of the economy, large-scale introduction of energy-saving technologies, non-conventional and renewable energy sources is an important task [1-17].

The Decree of the President of the Republic of Uzbekistan dated August 22, 2019 No RP-422 "On operational measures to increase energy efficiency in the economy and social sphere, the introduction of energy-saving technologies and the development of renewable energy sources" is of particular importance in this regard [18].

Electricity from SPP is an important source of renewable energy. Today, the amount of electricity generated from SPP is significantly increasing compared to energy from other types of renewable energy sources [19-27].

The main part of SPP consists of solar photovoltaic stations, which operate in parallel with the power grid, namely integrated into the power grid. The main device that connects the power supply to the grid by the SPP integrated into the grid is the inverter. The function of the inverter is to convert the direct current coming from the solar panels into alternating current and synchronize this alternating current with the parameters of the electrical network [11-13, 22, 28- 30].

It is important to maintain the output parameters of the grid-connected SPP. In this regard, scientific research has been conducted to provide the power grid with quality electricity when the ambient temperature reaches low or very high levels.

2. Method

The Pop solar power plant (PSPP) has a capacity of 129.6 kW and was commissioned in 2015 as a pilot project on 0.32 hectares of land in “Yangi Kishlok” mahalla, Pop district, Namangan region (Figure1). The project was implemented by “Uzbekenergo” in cooperation with the South Korean Association of Photoelectric Industry (KOPIA). The PSPP is equipped with equipment from Hanhwa, JS PV, S-Energy and TopSun. It is being tested in the natural conditions of Uzbekistan. The project will also help ensure the sustainability of electricity supply in the “Yangi Kishlok” mahalla of Pop district and will serve as an expert for the implementation of promising and large-scale projects for the development of solar energy in Uzbekistan [31-34].

Figure 1. Pop solar power plant

The PSPP consists of four different photoelectric arrays (PVA), the names of which are given in Table 1 below.

Table 1. The structure of PQEC arrays

№	PVA set line	PVA manufacturing enterprise	Inverter models
№1	3	HANWHA (HSL60P6-PB-5-250)	KACO (60.0 TL3)
№2	3	JS PV (JSMP2504)	KACO (60.0 TL3)
№3	1	S-ENERGY (SM-250PC8)	DASS TECH (DSP-3320KT)
№4	1	TOPSUN (TS-M400NA1)	DASS TECH (DSP-3310KT)

This solar power plant has generated 666,021 thousand kWh (average 146.2 thousand kWh per year) from the date of commissioning, from January 2015 to July 20, 2019.

On the left side of the PSPP, where the garden is located, there are houses on the other side and fenced with iron bars to ensure safety. Solar panels from 4 companies are installed in 8 rows of PSPP. The area where the panels are installed in the PSPP area is paved with small stones, and there is a sewer

well due to the proximity of the waterway. In PSPP, the grounding cables are laid for all, taking into account the safety of the equipment, the panels are placed on the rail.
However, it can be seen that the frame of some solar panels is tilted under the influence of hot temperatures from the same plane, which in turn affects the efficiency of the panel by changing the angle of incidence of the light. In addition, the location of the parts has changed due to poor quality and subsidence. The PSPP network is designed to be on-grid and the electricity generated is transmitted directly to the public grid via inverters. Two meters installed in the assembly cabinet determine the amount of input and output electricity, respectively. These values are monitored by a personal computer and, if necessary, recorded in memory.
In addition, the room with 3-phase KACO and DASS inverters is not temperate. The room temperature was 5900 C during the monitoring, when the air conditioner was not installed in the room, the air intakes inside the inverter were out of order and the ventilation system was out of order. However, PSPP modules and inverters are still working. Each company was measured to determine the parameters of the solar panels. We used the Sol metric SunEye-210 to determine the installed angle of the solar photovoltaic modules, the wind speed was determined on a Smart-Sensor digital anemometer, and we used the Elitech GSP-6 digital device to determine the humidity value and temperature magnitude.

3. Results and Discussions

The parameters obtained when the surface of some solar panels was dusty (Table 2) and cleaned (Table 3) were considered.

Table 2. For the uncleaned state

№	T_{front}	T_{back}	$T_{amb\ temp}$
		TOPSUN 400W	
1	57.2	60.8	42
2	56.2	61.4	
3	56.9	61	
		S ENERGY 250W	
1	57.6	60.9	
2	58.5	61.5	44
3	58.01	60.9	
		JSPV 250W	
1	59.1	61.3	45
2	59.7	62.3	
3	59	61.9	
		HANWA 250W	
1	59	61.8	39.5
2	59.2	62.9	
3	59.3	61	

The Type 1 photovoltaic system consists of three rows of HANWHA 250 W photovoltaic modules. The characteristics of HANWHA (HSL60P6-PB-5-250) photovoltaic modules and the data obtained in real conditions are given in Table 4. The system consists of 198 photovoltaic modules consisting of 9 rows connected in series with 22 modules.
Type 2 photovoltaic system consists of 3 rows of photoelectric modules from JS PV with a power of 250 W. The characteristics of JS PV (JSMP2504) photoelectric modules and the data obtained in real conditions are given in Table 5. The system consists of 198 photovoltaic modules consisting of 9 rows connected in series with 22 modules.

Table 3. Clear mode

№	T_{front}	T_{back}	$T_{amb\ temp}$
		TOPSUN 400W	
1	31.2	32	35
2	30.8	31.7	
3	30.6	32	
		S ENERGY 250W	
1	30.2	31	35
2	29.8	30.7	
3	29.2	30	
		JSPV 250W	
1	32.8	34	35
2	31.6	33.7	
3	32.6	33	
		HANWA 250W	
1	30.8	32	35
2	31.6	33.4	
3	31.5	32	

Table 4. Hanhwa array

№	Time	Solar radiation [Вт/м^2]	Ambient temperature [^{o}C]	PV temperature [^{o}C]	Generation [Вт]	FF [%]	Efficiency [%]
1	13:43	970	41	59.2	161.2	68	64.48
2	14:26	950	42	59.3	147.75	64	59.10
3	15:08	800	45	55	141.52	62	56.50
4	19:05	570	35	31.6	133.7	60	53.48

Table 5. JS PV array

№	Time	Solar radiation [Вт/м^2]	Ambient temperature [^{o}C]	PV temperature [^{o}C]	Generation [Вт]	FF [%]	Efficiency [%]
1	13:47	970	45	58	147.95	64	59.18
2	14:30	950	46	59.7	138.6	61	55.44
3	15:12	800	44	56.8	130	63	52.02
4	19:09	570	35	32.6	120	60	48.06

Type 3 photovoltaic system consists of 3 rows of photoelectric modules from S-ENERGY with a power of 250 W. The characteristics of the S-ENERGY (SM-250PC8) photovoltaic modules and the data obtained in real conditions are given in Table 6. The system consists of 72 photoelectric modules consisting of 6 rows connected in series with 12 modules.

Type 4 photovoltaic system consists of 3 rows of photovoltaic modules from TOPSUN with a power of 400 W. The characteristics of the TOPSUN (TS-M400NA1) photovoltaic modules and the data obtained in real conditions are given in Table 7. The system consists of 24 photoelectric modules consisting of 6 rows connected in series with 8 modules.

The graph shown in Figure 2 shows that the active and reactive capacities produced by SPP vary with solar radiation. As the ambient temperature increased, the efficiency of the SPP decreased, while the results showed an increase in the reactive power produced by the SPP.

Table 6. S-Energy array

№	Time	Solar radiation [Вт/м^2]	Ambient temperature [^{o}C]	PV temperature [^{o}C]	Generation [Вт]	FF [%]	Efficiency [%]
1	13:47	970	41	57.6	161.5	70	64.62
2	14:30	950	42	58.5	157.9	70	63.19
3	15:12	800	45	56.3	158.6	65	63.45
4	19:09	570	35	34.4	153.9	64	61.58

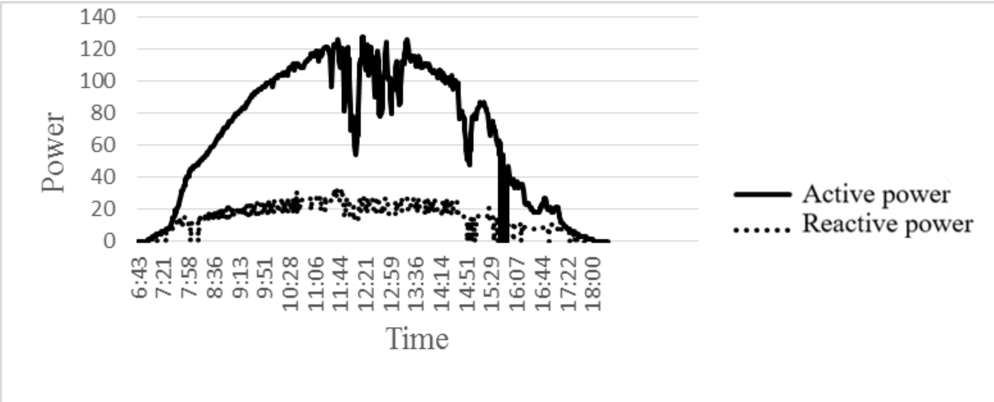

Figure 2. SPP daily generation capacity

Through the FLUKE 190-104 Scope meter, it was observed that the average voltage at the point where the PSPP and the transmission line were connected was 400V. Although this value is satisfactory, it has been observed that inverters are often disconnected from the mains. The main reason for the inverter failure was not the loads on the power line, but the lack of cooling in the room.
According to the FLUKE 190-104 Scope meter, no adverse effects of the solar power plant on the transmission network were observed; the value of the voltage was 380 + 5%.
There are two 3-phase electricity meters for electricity metering. One electricity meter records the electricity transmitted to the grid of the solar power plant, and second electricity meter records the electricity received from the grid of the solar power plant for its own needs at night.

4. Conclusions

The connection diagrams of the solar power plant have been studied. The PSPP network is designed to be on-grid and the electricity generated is transmitted directly to the public grid via inverters. Two power meters installed in the assembly cabinet determine the amount of input and output electricity, respectively. It is equipped with 4 inverters with a capacity of 49.5; 49.5; 9.6; 18 kW. Even though the quality of electricity at the output of the inverter is satisfactory, it was observed that the inverters are often disconnected from the grid. The main reason for the inverter failure was not the loads on the power line, but the lack of cooling in the room.
The active and reactive capacities produced by SPP vary depending on the solar radiation. As the ambient temperature increased, the efficiency of the SPP decreased, while the results showed an increase in the reactive power produced by the SPP.

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