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Study of reactive power of the PV system connected to the distribution network

Turaev A.I, Muratov Kh.M.

Senior scientific researcher, Scientific and Technical Center of the Academy of Sciences of the Republic of Uzbekistan, 100074, Tashkent, Uzbekistan

DSc, Professor, Scientific and Technical Center of the Academy of Sciences of the Republic of Uzbekistan, 100074, Tashkent, Uzbekistan

ABSTRACT: This article presents the results from a 9kW solar photovoltaic (PV) station located on the roof of the International Solar Energy Institute (ISEI) in Tashkent. This solar PV station operates in parallel with the power grid at the point of common coupling (PCC) to the 3-phase distribution power grid. According to the obtained results, the PV station had a positive impact on the power quality of electricity in the power grid. However, it was observed that the power quality indicators of electricity in the power grid deteriorated during periods of low solar radiation. The fact that the power quality of electricity depends on solar radiation can lead to difficult situations as the capacity of PV stations increases. It was also found that the reactive power emanating from the inverter was dependent on solar radiation. In this study, the possibility of reducing the impact on the power grid by changing the reactive power output from the inverter was considered.

KEYWORDS: Photovoltaic system, voltage variation, variation frequency, power quality**.**

1. INTRODUCTION

Despite the increased penetration of power supply systems, distributed pumping systems based on photovoltaic equipment have not received a significant share in the network voltage regulation. At the same time, these inverters have the ability to deliver reactive power as well as active power to power transmission lines. The reactive power transmitted through the inverter can be used to control the distribution grid voltage. So far, various methods of reactive power control have been studied, among which the control of reactive power to change the voltage is of particular importance. However, scientific research on the above issues is insufficient [1-3]. The capacity of grid-connected PV stations is increasing, this may affect adversely the electrical distribution network. The integration of low-power PV stations in the distribution network is not so important, because the impact of low-power PV stations is not noticeable [4, 5]. But due to the dramatic decrease in the PV module price and environmental considerations, the number of installed PV systems is increasing. This will have negative impacts on the grid that must be considered. The presence of a large number of small PV systems induces problems related to power quality, grid safety and relay protection [6]. As the capacity of PV stations increases, the probability of reverse current in low and medium voltage feeders increases. This causes excessive voltage issues across low and medium voltage feeders [7]. To solve these issues, various methods have been suggested by changing the reactive power transmitted through the PV station [6, 8, 9]. Distributed power supplies require centralized digital control systems. In turn, centralized digital management systems require large investments. In addition, one more factor to consider when finding solution for arrange reactive power injections at the amount of locally distributed generation is the reduction of nutrient losses [3, 5, 10].

II. LITERATURE SURVEY

Distribution voltage management through distributed generating capacities in power grids is less convenient in a common power system, in addition, this system creates constraints for the overall management center. The difficulty of proceeding localized distributed monitoring scheme means that Distribution Network Operators do not use distributed generation inverters like a voltage normalizer. The use of centralized management can be found in a variety of control methods [5, 6], but it is normally assumed that they are ready for data exchange, and the location of the PV station, the cloud coverage does not affect the distributed control system. Distributed non centralized management method is

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occasionally put forward to reduce confidence in communications and take priority of the ability to quickly respond to changes in the environment [2, 4, 9, 11].
The PV station is located on the roof of the International Solar Energy Institute (ISEI) in Tashkent, Uzbekistan (latitude 41.18°N, longitude 69.14°E). It started operating on February 21, 2018; the electricity generated by the PV station is transmitted to the national electricity grid without any batteries. The wiring diagram of this PV station located in ISEI is shown in Fig 1. All measurement results were obtained by several electrical measurement equipment, bidirectional electric meter calculates PV station's electricity which transmitted and received from the grid.

III. MATERIAL AND METHODS

The 9kW PV station connected to the grid consists of 56 solar modules and occupies an area of 58m2. The PV station consists of 2 parallel sub-arrays, of 18 modules, including Solar link PV-C310M three-phase commercial, industrial, utility PV inverter. Two lines were connected to the inverter with a rated power of 10 kW (Hex power). The specification of the PV module and installed inverter are summarized in tables 1 and 2.

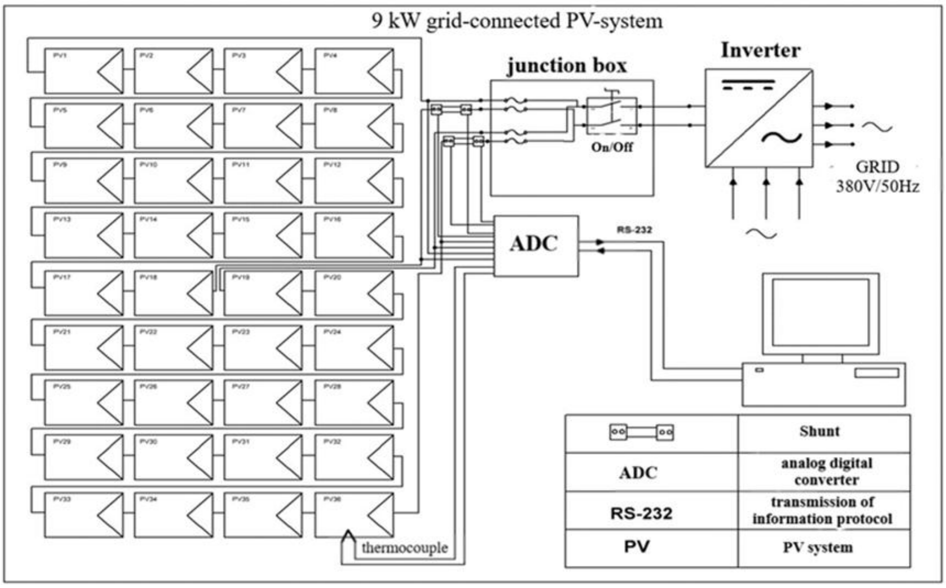

Fig.1. Diagram of PV station located in ISEI

Table 1: Characteristics of PV module (under normal conditions)

Type	Polycrystalline
Manufacturer	Luxco(Korea)
Model	LXP-3J250WA1
Peak power, [W]	250
Element power, [W]	4.1
Array power, [kW]	9.0
Voltage at maximum power V_{mp}, [V]	30.2
Current at maximum power I_{mp}, [A]	8.28
Voltage of idling Voc, [V]	37.7
Short circuit current Isc, [A]	8.73
Maximum system voltage, [V]	1000
Fuse rated current, [A]	15
Maximum mechanical load, [Pa]	5400
Dimensions, [mm]	1645x983x35

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Table 2: Inverter Specification (At Rate Conditions)

Type	Polycrystalline
Manufacturer	Luxco(Korea)
Model	LXP-3J250WA1
Peak power, [W]	250
Elementpower, [W]	4.1
Array power, [kW]	9.0
Voltage at maximum power V_{mp}, [V]	30.2
Current at maximum power I_{mp}, [A]	8.28
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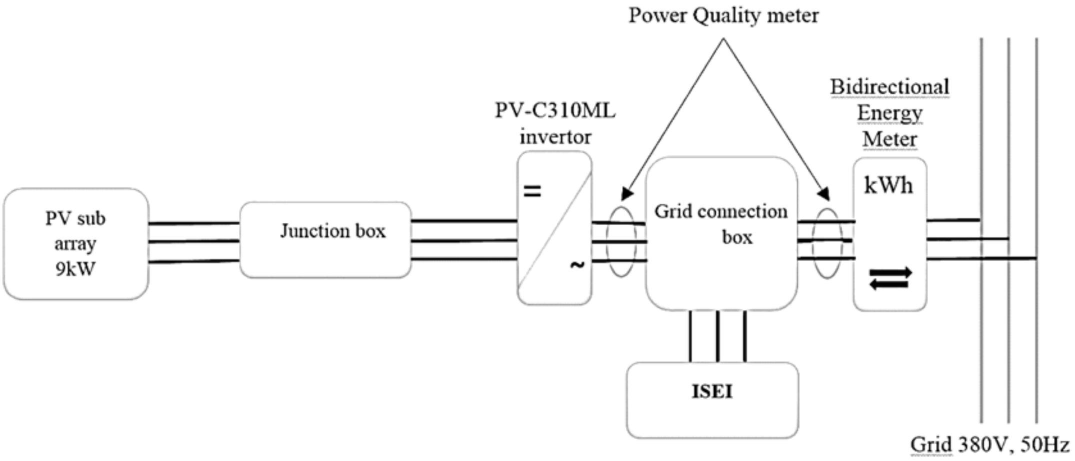

Fig.2.Experimental set-up at the PCC

During the test, the power quality indicators at the PCC were studied (total harmonic distortion, power factor, active and reactive power). These quantities were measured using a power energy meter (ЦЭ6850М). Fig.2 presents the test bench including the PV sub-array, the inverter, and the power analyzer. The PV plant and electrical network parameters were determined using PROVA210A devices (Taiwan, measurement uncertainty 1%), Solsensor200 (USA, measurement uncertainty 0.5%) and Fluke 190-104/S (USA, measurement uncertainty 1.5%).
Electricity generated by high-capacity power station is supplied to users several hundred kilometers away by power transmission lines. In power lines, the grid voltage is monitored and controlled at substations. In the power grid the reactive power consumers and consumers with low active power factor causes voltage drop. Reactive power compensation technologies are used in order to improve the quality of electricity in the distribution networks. Below, some classic compensation methods are briefly described. We are mainly concerned with the management of reactive power transmitted through grid connected PV inverters.
Synchronous generators method, by changing the excitation current, we achieve controlling reactive power [11, 12]. This method gives an effective possibility to control and stabilize the high-voltage power lines. At the same time, the reactive power generated causes large losses in the high voltage power line [3, 13].
Reactive power compensation devices are commonly operated and installed in the distribution power networks from regional utility companies. One of the reactive power compensators is called capacitor bank. These devices consist of several powerful condensers which we can use like as resource of reactive power.

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The inverter belongs to an emerging class of reactive power control that is not widely deployed, but there are several reasons to develop the inverter solution as a reactive power controller:

- The proximity of the reactive generation reduces the thermal losses in the line.
- The distributed nature of PV generators allows flexible and optimal reactive power control by inverters.

The grid-connected PV inverter is a limited resource of reactive power. PV inverters capacity depends (to generate reactive power) on its full power value and the active power injected from the PV modules. Therefore, the inverter can generate maximum reactive power if the generated active power equals zero (no irradiation). In the other extreme, active power equal apparent power, the minimum of reactive power is produced. This minimum can be increased by over-sizing the inverter as shown in figure 3.
To describe this functioning, the inverter model is given by:

$$|Q_{max}(t)| \leq \sqrt{S_{max}^2 - P_{PV}^2(t)} \quad (1)$$

In addition to support reactive power continuously, PV inverters should operate very fast.
According to [14], the output power factor of new inverters currently in use will not be lower than 09% PF during the season.
Another method of power control in PV stations is a method that provides a fixed PF and a constant reactive power [4]. Power control via the inverter is much easier and there are remote monitoring and control options. At the same time, can be widely promoted to the manufacture of power control through the inverter. The constant reactive power method requires additional data and the load capacity and the capacity of the PV station must be constantly monitored.

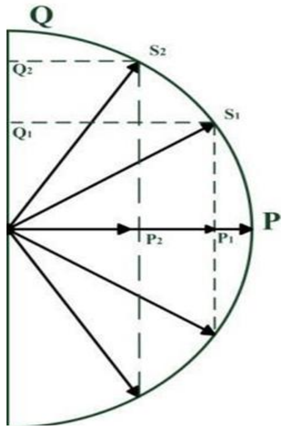

Fig.3.Inverter phasor diagram

IV. SIMULATION & RESULTS

Fig. 4 shows the active power generated by the PV station. According to the data obtained, the active power output from the inverter through the PV station is inextricably linked to solar radiation. We observed that the variations of active power were transmitted to the distribution grid. Assuming a high number of PV stations connected to the grid, the unpredictable PV generation may influence to the quality of electricity and the stability of the network [8, 15-18]. The graph shows that the maximum power supplies of the PV station at 12:17 midday. The PV station is currently generating 8.5kW of active power. During the same period, the voltage frequency was 49.9 Hz. Inverter input voltage and current is 504V and 173A respectively. Given that the inverter has an 8.7kW input, our inverter works with a 99.7% payload ratio.

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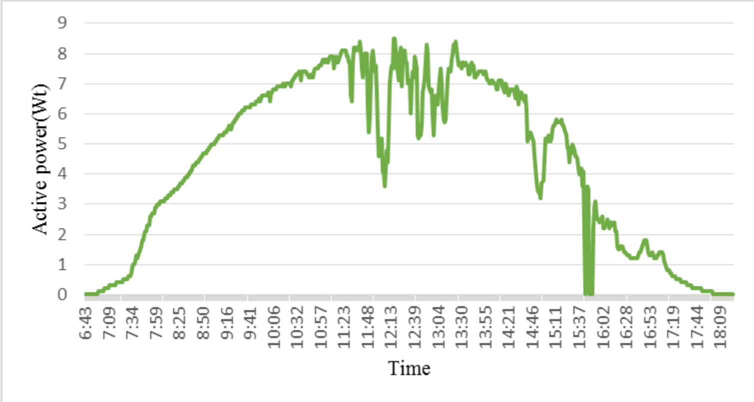

Fig.4.Active Power measured at sunny conditions

Figure 5 illustrates the reactive power transmitted to the grid via a PV inverter, as can be seen the change in reactive power is related to the change in solar radiation. The graph shows that the maximum power supplies of the PV station at 11:39 midday. The PV station is currently generating 8.1kWAR of reactive power. During the same period, the voltage frequency was 50.0 Hz. Inverter input voltage and current is 485V and 173A respectively. Given that the inverter has 8.4kWAR input, our inverter works with a 96.4% payload ratio.

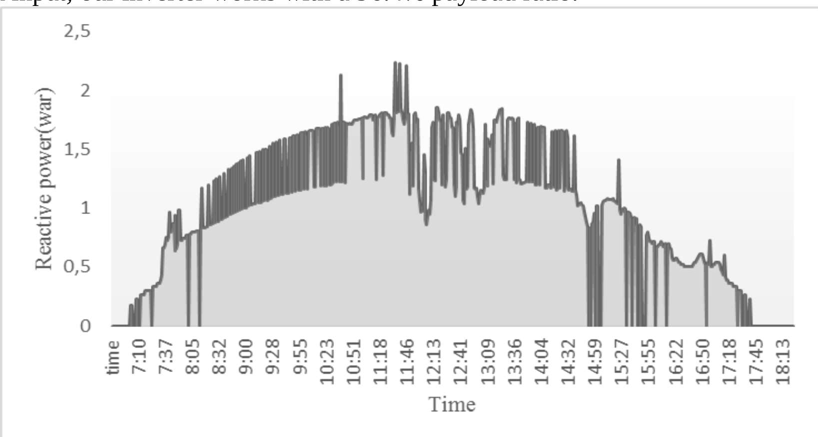

Fig.5.Reactive Power at sunny conditions

Figure 6 shows a graph of the change in power factor during the day. The graph shows that the change in the power factor is sufficiently satisfactory during the day, but in the morning (till 8 a.m.) and evening (after 5 p.m.) we can see that the power factor has fallen below the limitation values. You can see that our PV works with an almost 100% power factor. From 6:50 in the morning the PV station power supply to the inverter has begun. The power supply to the inverter was not supplied by the PV station at 17:56 pm.

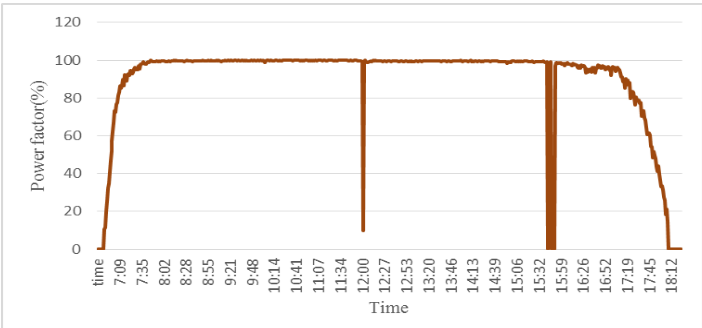

Fig.6.Power Factor measured at sunny conditions

The analysis of current and voltage total harmonic distortion (THD) is important. In industrial and tertiary sectors, the harmonic pollution is the responsibility of the consumers. In comparison, the provider is in charge of delivering a clean voltage.

V. CONCLUSION

The results of the power quality monitoring from the PV station connected to the power grid installed in ISEI are presented. Experimental work was carried out at the PCC of the PV station connected to the power grid. At the PCC, it was observed that power quality indicators are inextricably linked to solar radiation. The possibility of reactive power transmission through a PV inverter was evaluated and it was suggested that this reactive power should be used to control the grid voltage. It was found that the radiation level had a significant effect to the quality of power produced from the PV station. Data analysis shows the high harmonic content in the waveform of the grid current and the role of the grid compensation harmonics connected to the PV inverter, and also the possibility of PV inverters providing reactive power.

VI. THANKS

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AUTHOR'S BIOGRAPHY

Muratov Khakim Makhmudovich

DSc, Professor Muratov Kh. is currently the Director of the Scientific and Technical Center of the Academy of Sciences of the Republic of Uzbekistan. He received his doctorate in electrical drive engineering. In addition to his academic career, Kh. Muratov is engaged in teaching activities as well.

Turaev Akramjon Ikromjonovich

TuraevA. is currently a senior scientific researcher at the Scientific and Technical Center of the Academy of Sciences of the Republic of Uzbekistan. He received his master's degree in electrical engineering at the Tashkent State Technical University. In addition to his academic career, A. Turaev was engaged in teaching activities.