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Distribution Network Analysis with small Static Generator Integration

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ABSTRACT: There was a problem with a low-voltage distribution network supplying electricity to houses. The voltage levels were too low, and the network was overloaded. To fix this, solar panels were installed to generate additional power. The PowerFactory program was used to simulate and analyze the network. As a result, the overload was resolved, and the voltage levels in the houses were improved to meet the required standards.

KEY WORDS: Renewable energy, energy sources, distribution network, transformer, electricity, consumer, mechanism, algorithm.

I.INTRODUCTION

The growing demand for electricity and the declining reserves of traditional energy sources necessitate the widespread adoption of renewable energy sources. In our country, the quality of electricity in distribution networks does not meet the increasing demand due to the expanding number of consumers. This leads to overloading of transformers and longer distribution networks than recommended.

The President of the Republic of Uzbekistan issued an important decree on October 4, 2019, approving the strategy for transitioning to a green economy from 2019 to 2030. This decision plays a crucial role in guiding the efforts in this direction.

The distance between consumers and transformer points results in voltage drop and increased power loss. Consequently, consumers located at the farthest points experience lower-quality electricity. The proposed solution aims to address these issues.

This article focuses on the analysis of a specific distribution power grid that supplies 13 apartments through a transformer point in a particular location. The phase voltage in the last apartments was measured at 180 V. To mitigate this issue, four additional small-scale solar photovoltaic plants were connected to the network. The PowerFactory software was used to model the distribution network, study voltage fluctuations, and analyze network load. The results showed that the voltage levels in all apartments, even the ones furthest away, were satisfactory, and the network overload was eliminated

II. SIGNIFICANCE OF THE SYSTEM

As nowadays, our country had 89,520 km of 10 kV overhead power transmission networks, 14,8 km of 6 kV overhead transmission power networks, and 146,8 km of 0.4 kV distribution power networks. The number of household consumers stands at 7.2 million, indicating a significant demand for green energy sources.

III. LITERATURE SURVEY

The distribution network under analysis is a real object located in Syrdarya streets in the village are supplied with electricity through a 160 kVA transformer. The focus of the research is on the distribution network of Syrdarya street, as it experiences the lowest voltage levels and overloads. The length of the network on Syrdarya street is 0.7 km, and there are 13 houses connected to it. However, at the end of the street, the phase voltage in the houses measures 180 V instead of the required 220 V. This voltage level is completely inadequate in terms of meeting the quality standards for electricity demand.

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To model the network, solar photovoltaic stations were installed in the 1st, 4th, 9th, and 13th houses. Each PVP has a maximum installed power capacity of 15 kW.

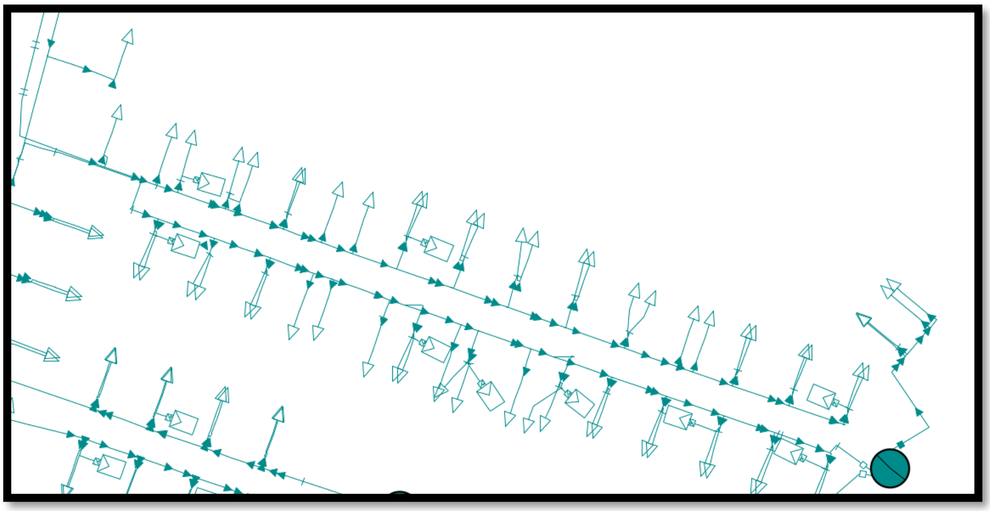

Figure 1. PowerFactory software model of power supply and distribution network

IV. METHODOLOGY

The research methodology involved analyzing the quality indicators of electricity in the distribution network, as well as studying voltage fluctuations. Rather than relying on maximum power alone, the daily consumption graph of each consumer was used to obtain more precise results. To calculate the daily electricity consumption, the load correction coefficient was first determined. The expression for calculating the daily consumption of electricity using the daily consumption graph of the apartments was utilized [9].

$$e_{Ist,}daily = \sum P_{oniy} daily \Delta t \tag{1}$$

where, $e_{Ist,}daily$- daily- one-day electricity consumption (for working days and weekends) [kW], P_{oniy}- instant-short-term electricity consumption [kW], Δt- duration of the daily consumption graph interval [hours].
The load correction coefficient is determined by the ratio of the daily power consumption to the maximum power consumption during the day and is expressed as follows:

$$f_{yuk} daily = \frac{e_{Ist} daily}{24 * P_{Ist.Mak}} \tag{2}$$

where, $f_{yuk} daily$- daily adjustment coefficient of load, $P_{Ist.Mak}$-maximum consumption capacity of the consumer. The Newton-Raphson method was used in the analysis of power flows and networks [10].
To determine the coefficient at any time, the ratio of the consumption power at an instant to the maximum power is obtained:

$$f_{oniy} = \frac{P_{oniy}}{P_{Ist.Mak}} \tag{3}$$

To determine the power consumption of electrical appliances in the apartments, the maximum power consumption of 10 kWh was assumed. However, it's important to note that this maximum power consumption may not remain constant throughout the day due to varying usage patterns. Therefore, the operational duration of each electrical appliance was taken into account. Based on this, the power consumption of the apartments was expressed as coefficients of the maximum power. The daily schedule of consumers was divided into two types: one type that has maximum power consumption during the day, and another type that has maximum power consumption at night. This division helps capture the different usage patterns of consumers. Please refer to Figure 2 for a visual representation of these two types of daily schedules.

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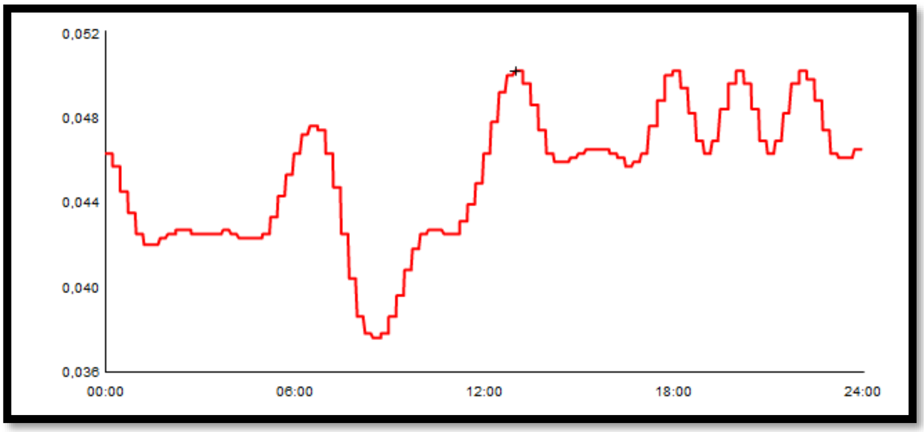

Figure 2. Changes in daily consumption power coefficients of households

Upon analyzing the daily operational pattern of the power grid on Syrdarya Street on April 29, 2022, it was observed that the grid experienced overloading from 08:00 in the morning until 13:00 in the afternoon. Additionally, from 18:00 to 20:00 in the evening, the network operated with a load close to its maximum power transmission capacity. The daily load graph of the network is depicted in Figure 3. The conductor used in this network is AS-150/19, which is an aluminum wire type.

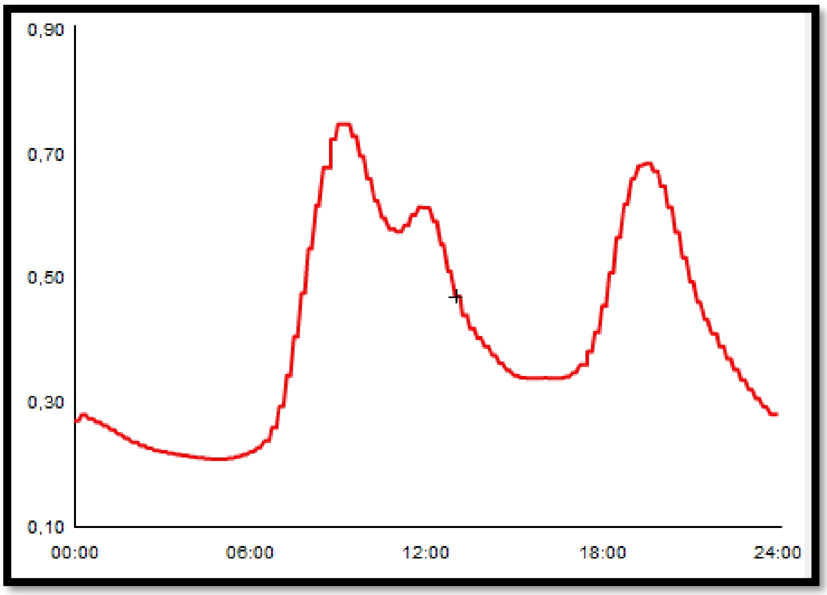

Figure 3. Daily load graph of the distribution network on Syrdarya Street

The graph presented in Figure 4 illustrates the voltage values of each household within the distribution network. The analysis reveals that the network overload leads to a decrease in voltage beyond the acceptable threshold for voltage drop, starting from the 6th house. At the houses located at the end of the street, the phase voltage dropped to approximately 180 V, indicating a reduction of approximately 20% from the nominal voltage. According to the specified standards, a maximum voltage drop of 10% is permissible [3].

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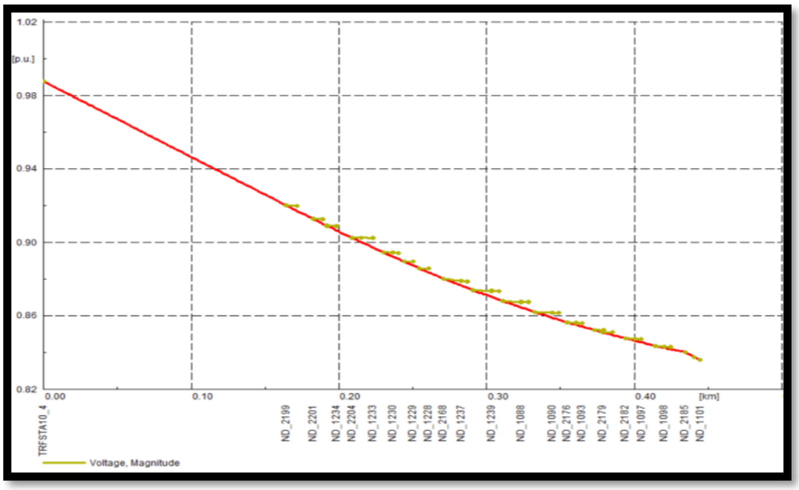

Figure 4. The voltage drop of each consumer of the distribution network on Syrdarya street

V. EXPERIMENTAL RESULTS

There are different types of improvement of the power quality indicators of the distribution network discussed above, among which the following can be cited:

- reconstruction of the transformer station;
- reconstruction of distribution power network;
- build a new transformer station and connect some consumers to it;
- installation of additional generation devices in some apartments;
- restriction of households from electricity consumption.

All the measures to get rid of the overload or bring the voltage to normal cost money. The possibility of installing additional generation equipment in some houses was considered, and solar photoelectric stations with a capacity of 15 kW were installed in houses 4, 8, and 13, and the distribution network was modeled using the "PowerFactory" program. (Figure 1). The daily production graph of the solar photovoltaic plant is depicted in Figure 5. The fact that QFES transmits power from 06:00 in the morning to 20:00 in the evening and operates in the maximum mode from 12:00 to 16:00 in the afternoon can be a solution to overcome the overload of the distribution network.

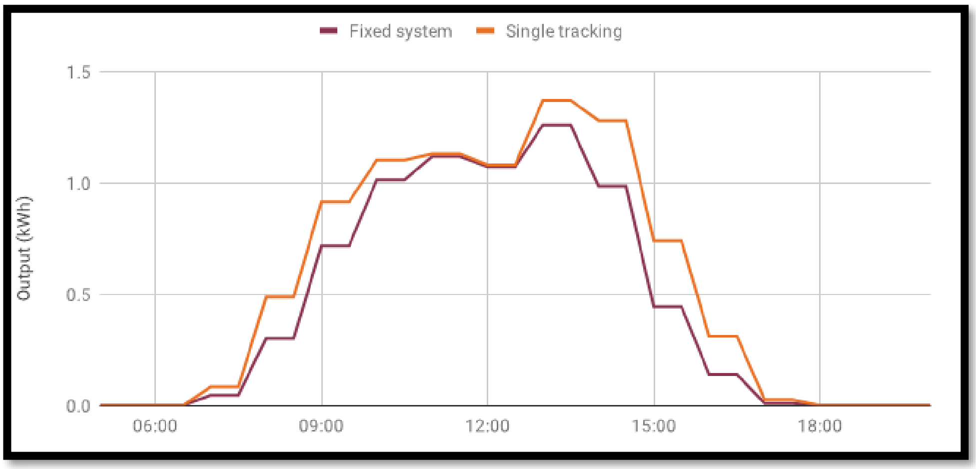

Figure 5. Changes in the coefficients of the daily production capacity of PVP installed in the distribution network on Syrdarya Street

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From the load graph of the Syrdarya Street distribution network (Figure 3), it is evident that the load at 09:00 in the morning reached a maximum value of 103.7%, and the overload persisted until 13:00 in the afternoon. However, after connecting the QFES to the same network, the daily values of the network load are reflected in Figure 6. Notably, the network load at 14:00 dropped to a minimum value of 52.6%. The maximum network load occurred at 21:00 during the night, reaching 93%. Consequently, the overload in the distribution network on Syrdarya Street has been successfully eliminated.

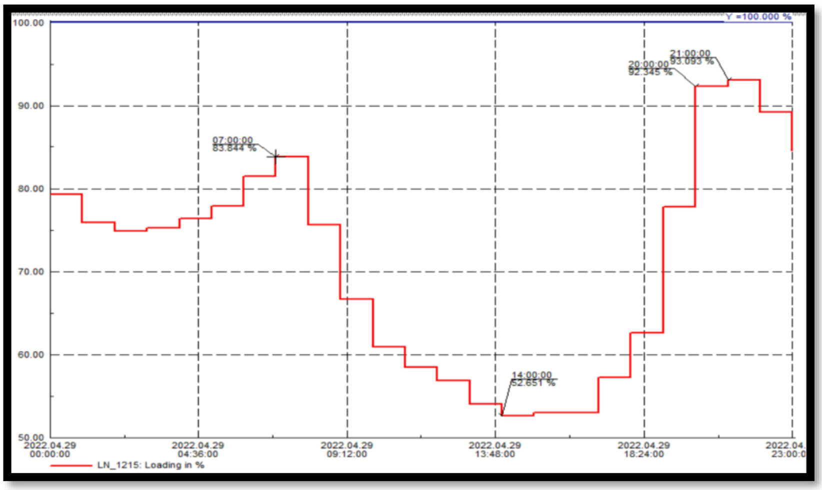

Figure 6. Daily load graph of the distribution network at the SPV connected facility

VI. CONCLUSION AND FUTURE WORK

Therefore, the installation of additional generation equipment, such as solar photovoltaic stations, in distribution networks not only ensures reliable electricity supply to consumers but also enhances the quality of electricity. Moreover, it helps prevent overloads in the distribution networks, consequently reducing electrical energy losses in the conductors.

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