*European Research Studies Journal*
*Volume XXV, Issue 2, 2022*

*pp. 432-443*

# The Impact of RES Development on the Distribution Network, Based on the Example of the Polish DSO

*Submitted 12/05/22, 1st revision 23/05/22, 2nd revision 12/06/22, accepted 30/06/22*

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***Abstract:***

***Purpose:*** *Apart from many challenges and new development directions, the energy transformation also determines many variables that fit into the new realities of the industry with fairly well-established foundations. One of them is certainly the power generation sector. A huge challenge for the European Union Community is the creation of new legal regulations that will be universal for all EU members, but above all, possible to be implemented in the target countries.*
***Design/methodology/approach:*** *With regard to national regulations in Poland, new legislative solutions are necessary for the implementation of innovative technological solutions, based, for example, on the operation of hydrogen buffers or a huge number of new prosumers i.e. entities simultaneously producing and consuming electricity for their own use.*
***Findings:*** *There are many benefits to using renewable energy sources on your farm. It also allows for great independence from energy supplies from power plants, but above all, they are environmentally friendly (they do not emit practically any harmful compounds into the atmosphere).*
***Practical implications:*** *The presented study contains basic information on the types of micro-installations and their development over the years. A detailed list of connections to the grid of new installations in 2020 on the distribution grid of Enea Operator (DSO) was also presented.*

***Keywords:*** *Renewable energy sources, distribution system operator, distribution grid*.

***JEL codes:*** *A19, B55, Q20, Q40.*

***Paper type:*** *Research article.*

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## 1. Introduction

Public awareness of Renewable Energy Sources (RES) has grown to a very high level. Zdaniem J. Maćkowiak-Pandery z „Forum Energii" – spadający udział węgla I wzrost udziału RES I gazu, to nieodwracalne trendy, które stanowią dopiero poczatek tej transformacji.[3] Their dynamic development is associated with the use of modern technologies in the field of energy production and, more and more often, energy storage, which in the case of excess energy (night) can be taken out of the grid and fed into the grid in the event of a lack of demand (during the day). Renewable energy sources are used in the so-called micro-installations (with a total capacity of no more than 50kw) converting a specific source into electricity or in the form of generating farms, i.e., producers with a capacity of over 50kW and less than 500kW of installed capacity and a producer of the so-called large installation, i.e., sources with a total power above 500kW.[4]

The most popular solutions are solar energy conversion plants, which can be used in two ways. The first is the use of solar collectors, which convert solar energy into thermal energy, which is a carrier vector. In an installation, this vector is usually water, glycol or gas.[5] The second solution is to install photovoltaic panels that convert solar energy into electricity. Another source is wind energy, the power of which depends on the location of the investment (directly through the wind speed in a given area).

The downside of this solution is the formation of quite characteristic noise during the operation of the turbine. Another solution is to obtain geothermal energy, which uses a special heat pump to extract energy from the ground or groundwater. At this point, it is worth paying attention to the great independence of this solution from environmental conditions, such as weather conditions and climate.

Finally, modern solutions in the field of biomass and biogas should also be distinguished. Biomass is a specific type of agricultural (or forest) waste and residues that are subject to degradation. To use this type of raw material, a special furnace is necessary, which can be quite expensive for an individual customer, but allows quite a lot of autonomy of work. This article analyzes renewable energy sources connected to one of the four largest DSOs in Poland, which is Enea Operator. Figure 1 shows the approximate area of Enea Operator's operation and the installed capacity from micro-installations expressed in MW.

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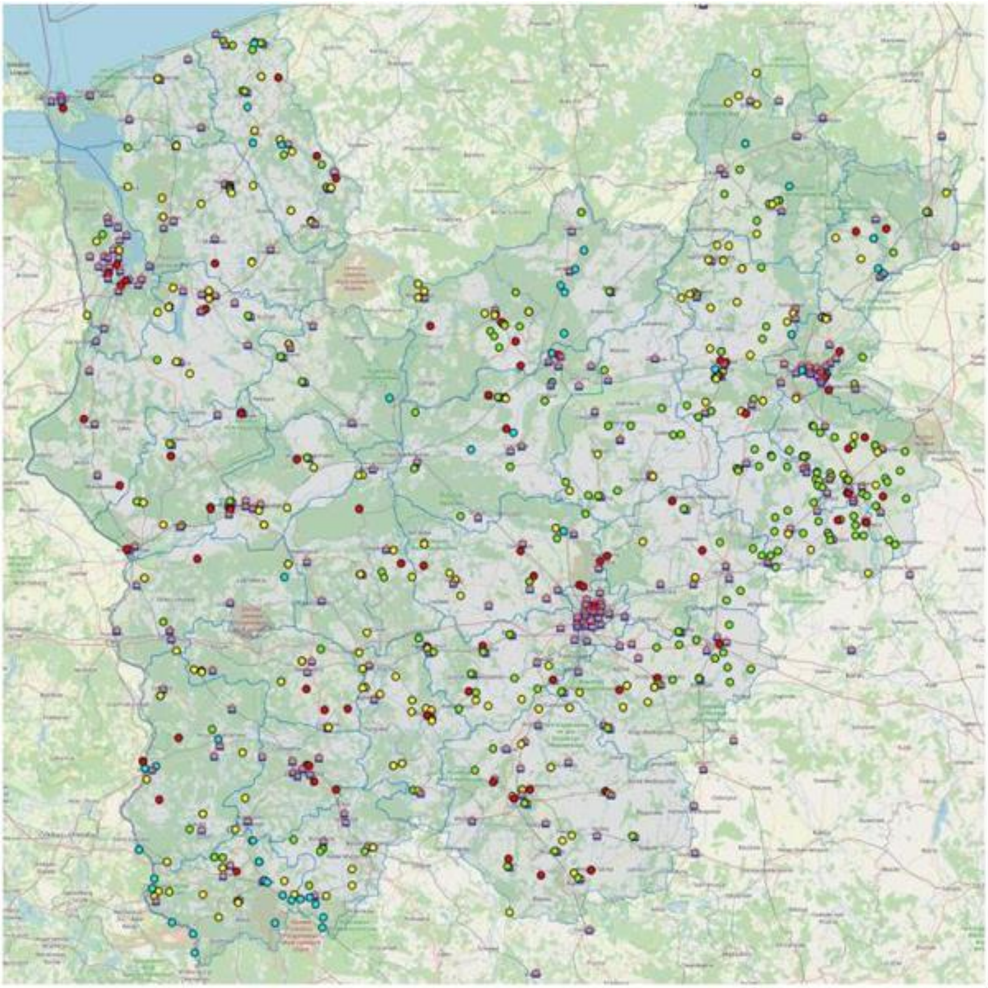
[3] *https://forum-energii.eu/pl/analizy/polska-transformacja-energetyczna [access on 12.05.2022]*

[4] *B. Igliński, Badanie sektora energii odnawialnej w Polsce, potencjał techniczny, badania ankietowe, analiza SWOT, analiza PEST; Wydawnictwo Naukowe Uniwersytetu Mikołaja Kopernika, Toruń 2019, p. 81.*

[5] *G. Wiśniewski; Energia Słoneczna: przetwarzanie i wykorzystanie energii promieniowania słonecznego; wyd. Fundacja Ekologiczna Silesia, 1999, p. 49-56*

The total number of micro-installations connected to the Enea Operator grid acc. To as of March 31, 2022, it reaches the level of 124,849 units, with a total capacity of 970,423 MW. In a detailed breakdown by voivodship, the largest share is in Wielkopolska (397.5 MW), then Lubuskie with 146.8 MW, and Zachodniopomorskie and Kujawsko-Pomorskie which are classified at a similar level, ieapprox. 130MW. As much as 99.9% of all installations of this type are photovoltaic installations, and 89.9% are end users from tariff G. These data are summarized in Tables 1 and 2.

***Figure 1.*** *The approximate area of Enea Operator's operation and types of renewable energy installations.*



***Source:*** *Enea Operator, as at the end of 2021.*
*Green – wind farms*
*Yellow – PV*
*Light blue – hydroelectric power stations*
*Red - thermal power plants*
*Light red – main power points*

***Table 1.*** *List of micro-installations broken down by source types.*

| RES Type | quantity | power |
|---|---|---|
| **BG** | 0 | 0 |
| **BGR** | 6 | 0,26 |
| **BM** | 1 | 0,034 |
| **PV** | 124753 | 968,069 |
| **WI** | 9 | 0,111 |
| **WO** | 69 | 1,753 |
| **HYB** | 11 | 0,197 |

***Source:*** *Enea Operator.*

***Table 2.*** *List of micro-installations by tariff groups.*

| *tariff group* | average installed capacity in this group | quantity | % |
|---|---|---|---|
| **B** | 44,41 | 802 | 0,64 |
| **C2x** | 39,52 | 1301 | 1,04 |
| **C1x** | 14,38 | 10411 | 8,34 |
| **G** | 6,53 | 112335 | 89,98 |
| **Total** | 7,77 | 124849 | 100% |

***Source:*** *Enea Operator.*

## 2. Research Methods

The research methodology was selected in the field of statistical models. The linear regression method[6] was used Figure 2) - in statistical modeling, methods based on linear combinations of variables and parameters adjusting the model to the data.

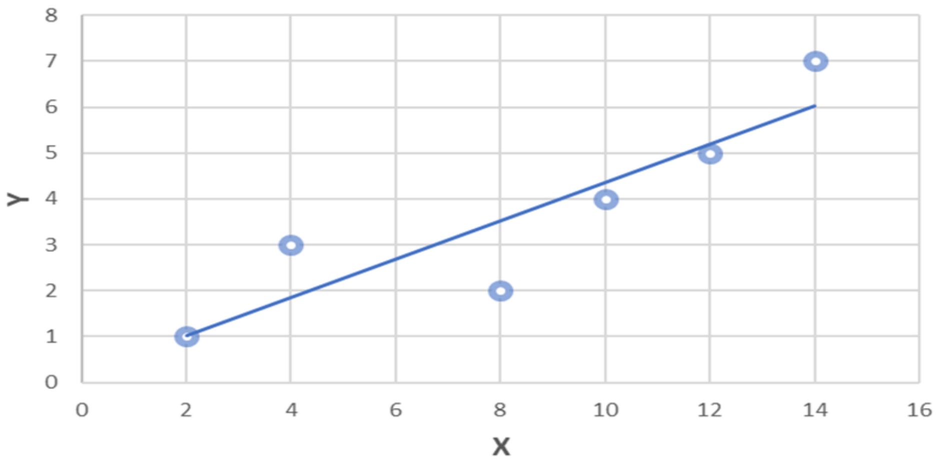
A fitted regression line or curve represents the estimated expectation of a variable y given specific values of another variable or variables x. In the simplest case, a

[6]*W.J. Conover, Ronald L. Iman Rank Transformations as a Bridge Between Parametric and Nonparametric Statistics, „The American Statistician", 1981, p. 124–129*

constant or linear function is fitted. Linear regression analysis allows you to predict the value of a variable based on the value of another variable.

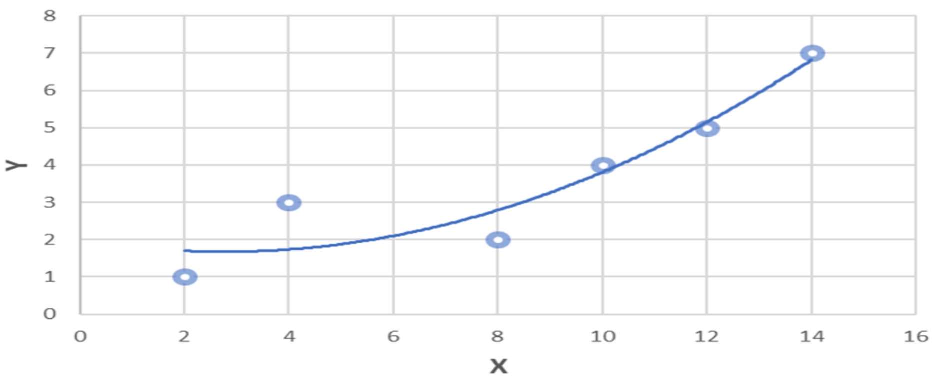
In addition, the Holt-Winters method was also used, which is one of the forecasting techniques using the so-called exponential smoothing. Smoothing consists in creating a weighted moving average, the weights of which are determined according to the scheme - the older the information about the studied phenomenon, the lower the value it represents for the current forecast. The model calculates expired forecasts, i.e. those relating to the period in which the actual value has already been achieved, and the actual forecasts for a period that has not yet arisen.

***Figure 2.*** *Linear regression method*




***Source:*** *Own study.*

***Figure 3.*** *Holt-Winters method*




***Source:*** *Own study.*

The growth dynamics in terms of the number of connected micro-installations maintains a similar trend, looking at the increase in installed capacity in RES sources with a capacity of up to 50 kW, as summarized in Tables 3 and 4.

***Table 3.*** *Growth rate of micro-installations in 2016-2021.*

| Years | Power installed [MW] | ~Q y/y |
|---|---|---|
| **2016** | **17,400** | |
| **2017** | **30,603** | **76%** |
| **2018** | **50,716** | **66%** |
| **2019** | **135,635** | **167%** |
| **2020** | **434,995** | **221%** |
| **2021** | **829,763** | **91%** |
| **mar 2022** | **970,425** | **100%** |

***Source:*** *Enea Operator.*

In SCADA systems, Enea has 100% real-time measurements for wind and photovoltaic power plants connected to the 110 kV grid (MWE type D) [7]. It does not have real-time measurements from two hydropower plants (EW Koronowo and EW Żur) connected to the 110 kV grid. For MWE types B and C, DSO has 99% of metering for photovoltaic power plants and 88% of metering for wind power plants. For MWE type A (main PV prosumer micro-installations) and for MWE B and C with no metering (no telemechanics), power estimation mechanisms are implemented based on the efficiency of wind and PV power plants in a given area of operation (Distribution Department). Moreover, over 1000MW of installed power in prosumer micro-installations is connected to the DSO[8]. For over 100,000 prosumers, DSOs are assigned PPE along power supply paths to HV / MV transformers in GPZ stations, which is used to aggregate PV power to individual nodes in SCADA systems.

When further analyzing the connection of RES in the DSO, the average power installed to the grid over the recent years has remained fairly constant at about 7.20 kW, which places Enea Operator above the national average of 6.61 kW in 2016-2021. However, the percentage increase in micro- installations in Poland in relation to the level in 2016, which finally amounted to as much as 5127% - as shown in Figures 4 and 5, should be taken into account.[9][10]

However, by making an in-depth analysis, this period allows us to conclude that the trend in the scope of micro-installations connected has been maintained, and approx.

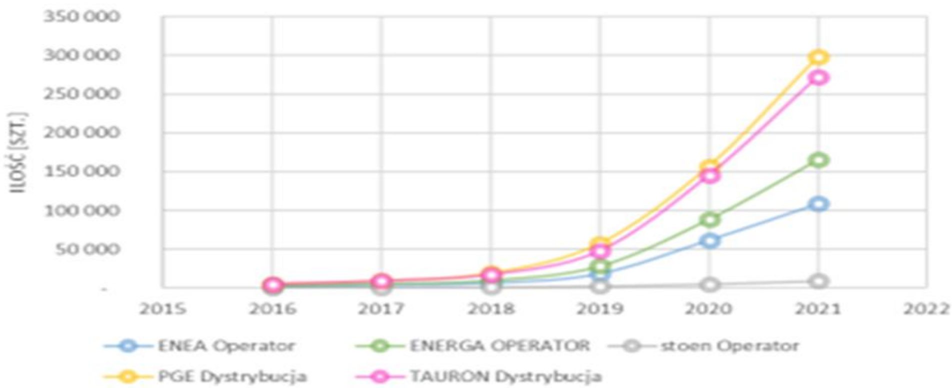
[7] *https://myscadaworld.com/what-is-scada/ accessed on June 9, 2022.*
[8] *R, Szczerbowski, P. Kwiatkiewicz; Energetyka Aspekty badań interdyscyplinarnych; wyd. Fundacja na rzecz czystej energii, Poznań 2018, p 142.*
[9] *https://stat.gov.pl/obszary-tematyczne/srodowisko-energia/energia/energia-2022,1,10.html [access on 12.05.2022 r. ]*
[10] *http://www.ptpiree.pl/energetyka-w-polsce/energetyka-w liczbach/mikroinstalacje-w-polsce*

3 591 units / month is the average number of micro-installations connected during one month in 2020, 3 907 units / month is average number of micro-installations connected in one month in 2021. The monthly increase in 2022 is an average 6,194 units / month and is slightly lower than the increases at the end of 2021, while the trend is maintained compared to previous years. The marked data for the increment in June and December are the data containing the semi-annual adjustment for the increment of micro-installations. The monthly growth of micro-installations is shown in Figure 6.

***Figure 4.*** *Average power of micro-installations connected to the DSO network in Poland in 2016-2021.*

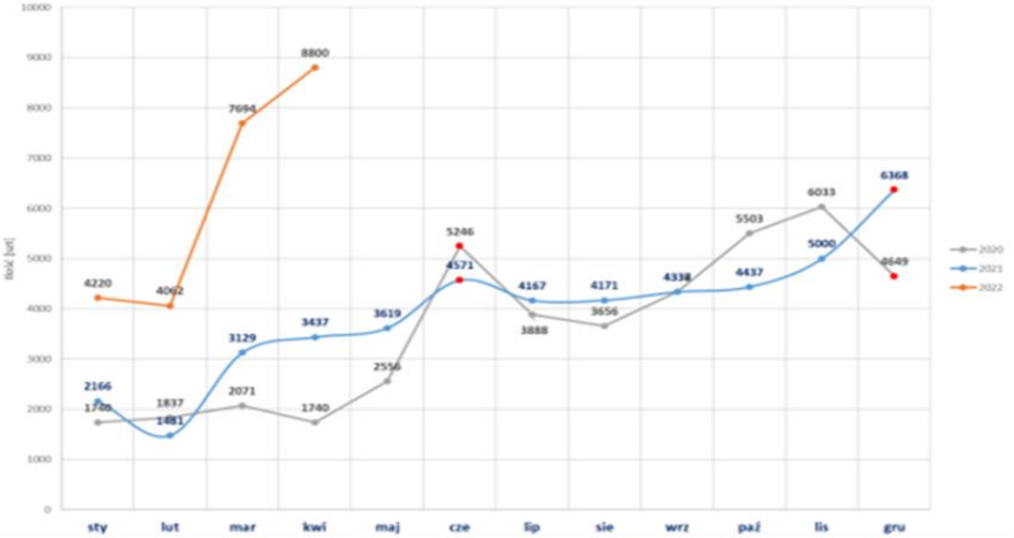

***Source:*** *Own study.*

***Figure 5.*** *Growth of micro-installations connected to the grid in 2016-2021. Source: own study*




***Source:*** *Own study.*

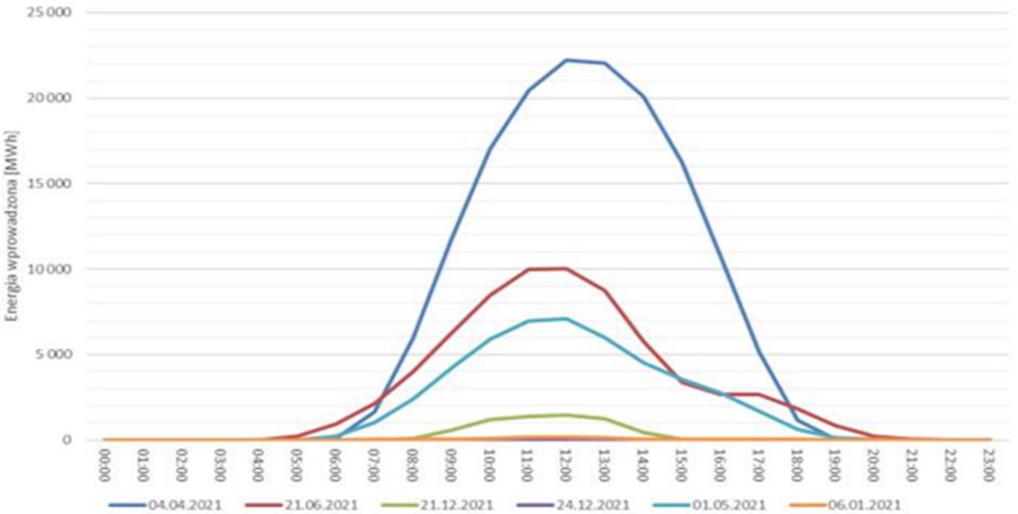
***Figure 6.*** *Growth of micro-installations on a monthly basis.*




***Source:*** *Own study.*

The above figure shows that in the warmer months there is a peak of growth, in addition to the constant upward trend discussed above. Taking into account the characteristics of RES, the structure of energy introduced for selected days during the year should also be analyzed. Such a list is presented in Figure 7.

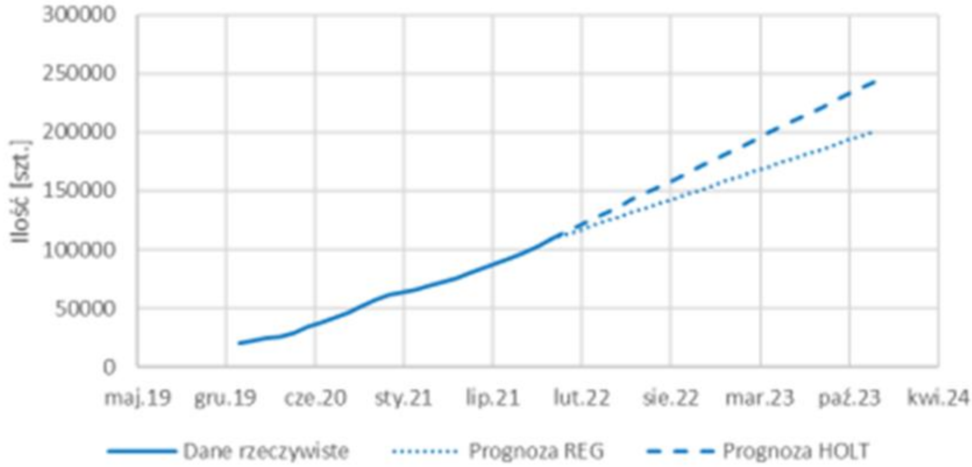
***Figure 7.*** *Energy characteristics of the introduced micro-installation for selected days of the year.*




***Source:*** *Own study.*

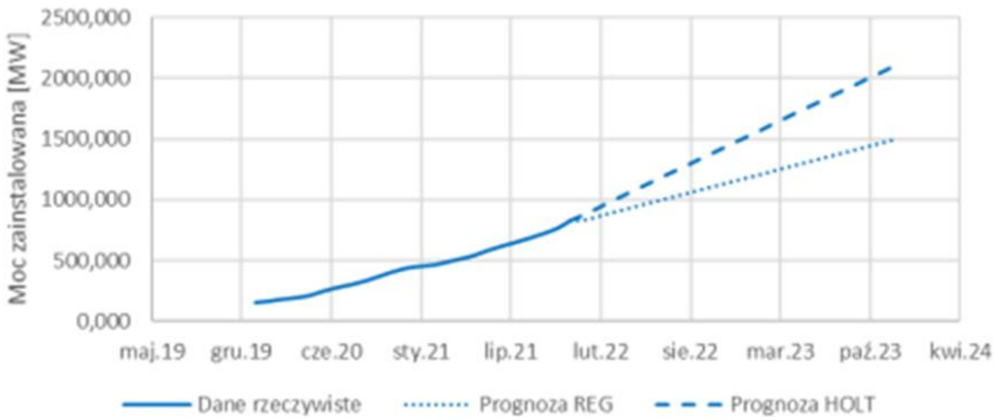
Based on historical data, a forecast of micro-installation connections in the perspective of 2022 was prepared in two variants, assuming the maintenance of the current trend or an increase in the dynamics of connections resulting e.g. from the next edition of the Mój Prąd program , a noticeable increase in electricity prices on energy exchanges for the market, etc. Figure 8 shows the projected growth of micro-installations, while Figure 9 shows the increase in installed capacity.

***Figure 8.*** *Projected increase in micro-installations.*




***Source:*** *Own study,*

***Figure 9.*** *Projected increase in installed capacity for future micro-installations.*




***Source:*** *Own study.*

Therefore, the proposed forecast in two scenarios assumes an increase in micro-installations from 154,812 (December 2022) to 201,016 (December 2023) in the case of the linear regression scenario. However, in the case of the Holt-Winters method, from the level of 176 317 in December 2022 to the level of 243 953 in December

2023. In the case of the installed capacity, by analogy with the above- mentioned methods, the REG forecast is 1151.6 MW (December 2022). to the level of 1,496.9 MW (December 2023) and for the HOLT scenario, the December level of 2022, respectively, is the value of 1,472.3 MW and 2,117.6 for December 2023.

## 3. Conclusions

The growing dynamics of connecting micro-installations to the DSO network, and thus the increase in the transformation of electricity from the LV voltage level to the MV level, results in an increase in the volume of losses and, consequently, its costs. The dynamic increase in the number of connected prosumers creates new challenges for DSOs and creates a number of problems for the power grid. The result of this is that the voltage in the grid is too high in some areas where many buildings have a PV installation. Power surges cause the inverter to shut down and thus stop the operation of the entire installation.

In addition, too many micro-installations in relation to the capacity of the local grid means the risk of failure to meet the power quality parameters at a specific point in the grid or in the entire LV circuit, which is to result from the increase in voltages caused by the operation of PV micro- installations. Moreover, reducing the volume of electricity supply, which is the basis for charging fees for electricity distribution services, related to the installation of generation sources by prosumers, will naturally reduce DSO's revenues from these customers due to the variable component of the grid rate.

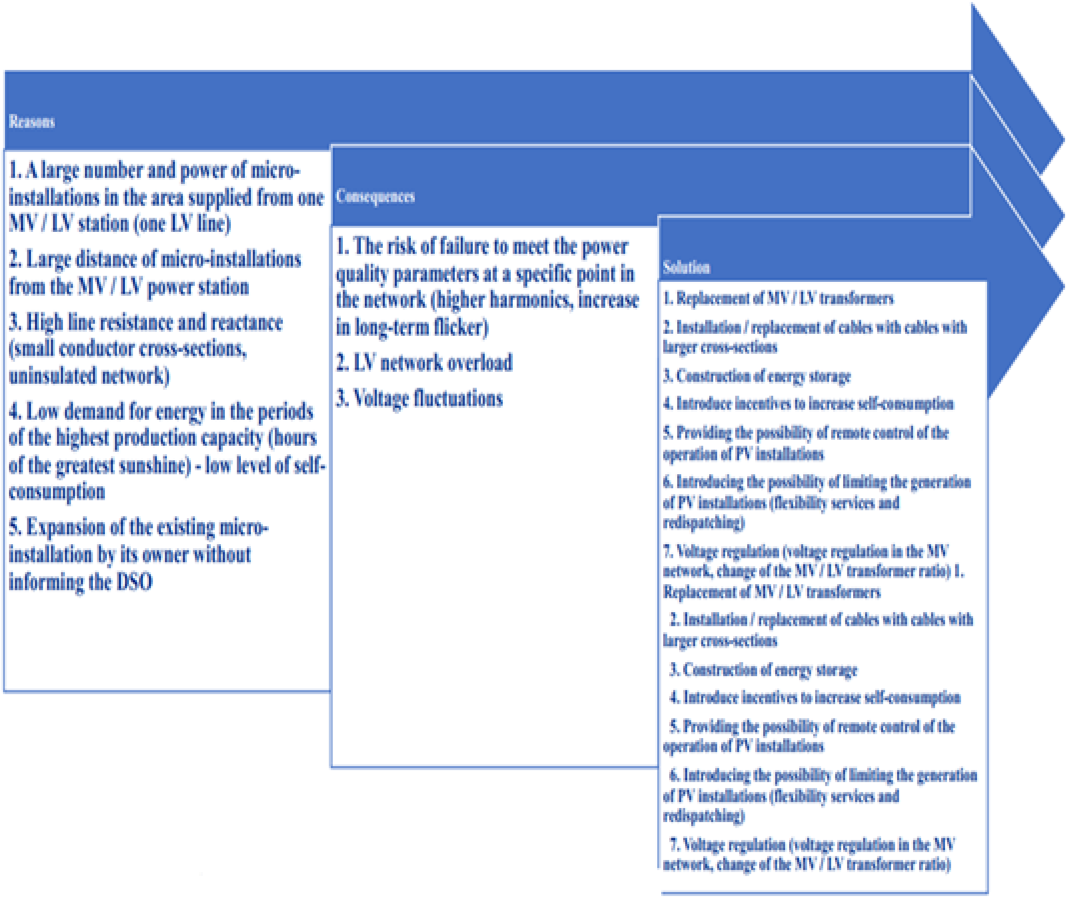
However, the above will not reduce the proportional costs of DSO's operations. This is due in particular to two basic elements:

A. Lowering the supply volumes in connection with the installation of generating sources does not result in a reduction of the contracted capacity of the recipients and, consequently, does not reduce the investment outlays on the network incurred by the DSO. In some cases, it may even require additional investments due to the "flexibly" necessary networks (temporary two-way flows).

B. Most of the DSO's operating costs are fixed costs, independent of electricity consumption by consumers (over 83% of reasonable operating costs without taking into account the fees incurred). Correspondingly, for the fee components directly related to the operations of DSOs, revenues from fixed fees constitute approx. 38% of total revenues from fixed fees.

The above causes the DSO's loss of revenues in a given year and the inability to cover the costs incurred in this respect. At the same time, in the following years it will result in the necessity to take into account the "missing" revenues in the fee rates and to cover some of the fixed costs. The suggested solution for the situation is shown in Figure 10.

***Figure 10.*** *Proposed solutions to the indicated risks in the RES area for DSOs.*




***Source:*** *Own study.*

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