Journal of Sustainable Development of Energy, Water and Environment Systems

http://www.sdewes.org/jsdewes

Year 2025, Volume 13, Issue 2, 1130543

Original Research Article

Impact of Photovoltaics Power Plant Penetration on a Closed-Loop Distribution Network's Power Quality Indices

Klajdi Kamberi1, **Donard Shaliu**2, **Marialis Çelo**3, **Andi Hida**4, **Viktor Rrotani**5,*
1,2,3,4,5 Department of Electric Power System, Polytechnic University of Tirana, Tirana, Albania
1e-mail: klajdikamberi@fie-upt.edu.al
2e-mail: donard.shaliu@gmail.com
3e-mail: celomarialis@yahoo.com
4e-mail: hidaandi@gmail.com
5e-mail: viktor.rrotani1999@gmail.com

Cite as: Kamberi, K., Shaliu, D., Çelo, M., Hida, A., Rrotani, V., Impact of Photovoltaics Power Plant Penetration on a Closed-Loop Distribution Network's Power Quality Indices, J.sustain. dev. energy water environ. syst., 13(2), 1130543, 2025, DOI: https://doi.org/10.13044/j.sdewes.d13.0543

ABSTRACT

The integration of high levels of photovoltaic power plants into existing networks in recent years has brought significant opportunities in terms of greenhouse gas reduction, help to increase the security of supply, and creating new job options as well as challenges for power systems regarding the power quality. In this research work the power quality in a closed-loop distribution system which is a particular type of operation of distribution feeders, under the condition of large-scale penetration of photovoltaics is well investigated. Exploring different operation scenarios helps in understanding the complexities and impacts of integrating photovoltaic power plants for two different operation scenarios of the system, based on the minimum and maximum load during the day. These scenarios are interlocked each into considering three variants of integrability: the connection of photovoltaic power plants in the low voltage nodes, in the medium voltage nodes and on both sides. Accommodations of the above scenarios renders in designing action policies to manage and optimize the integration of PV power plants, securing reliable and efficient quality power delivery. The chosen connection strategies of the tested photovoltaic system lead to many benefits, such as reduction of the network power losses, decrease in the number of overloaded transformers and an increase in voltage levels among the nodes, but without exceeding the rated values. The only parameter that exceeds the permissible limits in all studied scenarios is the total harmonic distortion level of the voltage, which can be easily addressed by applying mitigations strategies (filter applications, better management and optimal placing of photovoltaics). As a conclusion the outputs of these study are a good starting point for extended research in the way toward a smooth, qualitative and cost-effective large-scale integration of photovoltaics into the existing power system in Albania.

KEYWORDS

Power quality, Photovoltaic plant, Distribution network, Harmonic distortion, Voltage quality, Maximal load.

INTRODUCTION

Challenges of meeting the growing demand for electricity, as according to national strategic documents, projections the electricity demand will be doubled by the end of 2050, due to electrification of transportation sector, electrification of space and cooling demand affected by climatic conditions, increase in quality of life and expected economic growth of energy related

---

* Corresponding author

branches. Human activities are tightly related to power generation enabling to meet industry, transportation, residential and services, agriculture and other branches of the electrical system (ES) in Albania. The National Energy and Climate Plan (NECP) plan [1] predicts to fully electrify sectors driven by fossil sources by the end of 2050, which unfortunately does not consider how the process of this transition will affect the qualitative aspects of renewable energy sources (RES), expected to replace actual fossil powered systems as the main greenhouse gases footprint in Albania [2]. In addition to that fact, Albania has drawn attention to photovoltaics (PV) as one of the options with the highest potential due to sunshine hours in our country, ease of installation and low cost. In the last few years, the installation of micro-generation panels from commercial users on the low voltage (LV) side and the connection of PV arrays on the medium voltage (MV) side have a significant contribution in the increase of energy generation, and the government has willing to promote incentives and supportive schemes to encourage power additions from RES, but unfortunately not well complied. PV energy is the most common source of power in distribution grid [3] and investments in PV have found uses in many other fields such as: water production systems in water-scarce regions [4], CO_2 capture and liquefaction systems from combustion gases [5], in hydrogen liquefaction processes and in industrial processes [6, 7]. PVs are also favorited by their small impact on the environment [8] and the reduction in CO_2 values [9], making them more attractive in terms of carbon footprint [10]. Furthermore, PVs are widely used in providing energy to charge electric vehicles (EVs) [11, 12] where the integration of both together using different methodologies [13, 14] , brings better management and reduction of the impact that the integration of EVs cars brings.

However, besides to the benefits given above, PV generation integrated into existing networks designed for the passage of power flow (PF) in one direction, should be studied considering power quality (PQ), in addition to its dynamic stability. The future is determined and should be in the direction of RES, where almost all countries worldwide have their projections for generating electricity at a rate of 100% from RES. Such systems are a target of more illusions and uncertainty with “bias and pros”, especially affected by inaccurate or insufficient data that may lead to improper identification of harmonic issues [15].

The installation of converters to the system has been proven to affect the quality indicators of energy, mainly the content of current and voltage harmonics [16]. Poor PQ parameters affect the performance of other devices and consumers connected to the network. Identification of the causes helps in the proper determination of the measures and possibilities to improve the indicators and stay within the normalized and standardized limits [17]. The presence of current and voltage harmonics brings additional loss of power to the electrical system [18]. The solution to eliminate this disadvantage is by controlling their level in the inverter, which lattermost can be equipped with special filters for managing harmonics that guarantee improved quality indicators at the point of common coupling (PCC), where the PV plant is connected [19] and also augments the security of the grid-tight PV systems [20].

Also, the PV connection induces many troubles in the level of voltage (overvoltage) and changes in frequency [21], mainly in existing lines passing and supplying rural areas with low density population and quality of power lines. Many studies are showing that the installation of PV in rural areas can be a good opportunity to minimise the dependence on the current network, converting the rural area in a self-supplied power system in a form of a microgrid type, increasing financial benefits [22] for end-users and advancement of social-economic development [23]. PVs represent a good investment opportunity, especially for rural areas as the only source of supply and using different algorithms such as power flow management [24], used for direct water cooling systems [25], equipped with maximum point tracker charge controllers [26] and response surface methodology [27] can increase the energy produced and their efficiency. Impact of the distributed generation (DG) on the voltage profile and power losses is impacted directly by the PCC and through the use of different optimization techniques [28], optimal location and size of the DG can be found in order to have a positive impact on the voltage level, power losses, and leading to cost-effective options [29]. Those methods are valid in cases where investments in

RES have high values, mainly connected to high voltage, while today many PV systems are built by consumers at LV levels without analysing the impact on the distribution network (DN).

The problems that DGs bring to the electrical network depend not only on the PCC, its size but also on the type of DG [30]. Albania's power distribution system is changing due to the addition of various DG units at all voltage levels, EV charging connections, static var compensator, phasor measurement units, active filters, and many other smart technologies still developed or in progress. All these changes require deeper and finest studies to analyse the techno-economic impact, bringing more sustainable new transformed systems, operating safely with improvements and more qualitative parameters. In the study carried out from authors in [31], the challenges, voltage level changes, power losses, reverse power flow (RPF), and financial impact were analysed for the case that integrates small and medium-sized hydropower plants connected to the Albanian DN, but in contrast to previous years, the idea behind this paper promotes PV panels as required by [32].

Thanks to the geographical location, the territory of Albania lies in a high radiation potential region, enabling faster implementation and development of PV plants actually connected to the DN, moreover a lot of PV power plants result in the construction and design phases. The main focus of this research work is the integration of PV power plants on domestic consumers encouraged with supportive schemes and incentives from the government to convert them prosumers, a strategy that reduce the energy bills from the DN [33], hence it would increase the profitability of the integrated system at the end user's side.

The objective of this scientific paper is to validate and extend the previous research by examining and canalizing step by step the parameters of the energy's PQ in the closed-loop distribution system (CLDS) typology, a matter never touched in any of the previous works in Albania. Consequently, to better clarify and attain main objectives in a very simple and transparent way, this paper is organized as follows: first, the methods and materials used for this study are discussed followed by the PQ approach, a general overview of the CLDS with dual feeder connections between substations, the case studies, and finally, the results and discussion and conclusion followed by the relevant literature block.

METHODS AND MATERIALS

In generally there are a lot of approaches and methodologies for assessing the quality features of PVs tighten to the existing DN, computer modelling and simulation (CMS), Monte Carlo Simulation (MCS), Genetic Algorithm (GA), Differential Evolution (DE), Chance-Constrained Framework and On-Site Measurements.

In our case study, the methodology used to investigate the quality aspects in the case of tighten PV sources connected to the existing DN is fully designed by using:

- Real data of the DN provided by the distribution system operator (DSO);
- Target scenarios employing different connections of tested PV power plants.

In this way, our approach differs from the others as reliable and real data on the behaviour of the system during the day are used appropriately and are depicted in the sketched diagram in **Figure 1**.

The results of this study are derived from a comparative analysis of the scenarios for different connection points of generation from PV plants, observing several parameters simultaneously to calculate PQ while taking into account the network's two extreme regimes and examining the parameters that are impacted by PV penetration. Load flow for each case study is carried out to see the voltage magnitude at each node, power losses and loading of elements. Harmonic analysis of every case study is performed to see the Total Harmonic Distortion (THD) of voltage in LV and MV nodes. Every set of results is compared to determine the best sustainable future scenario.

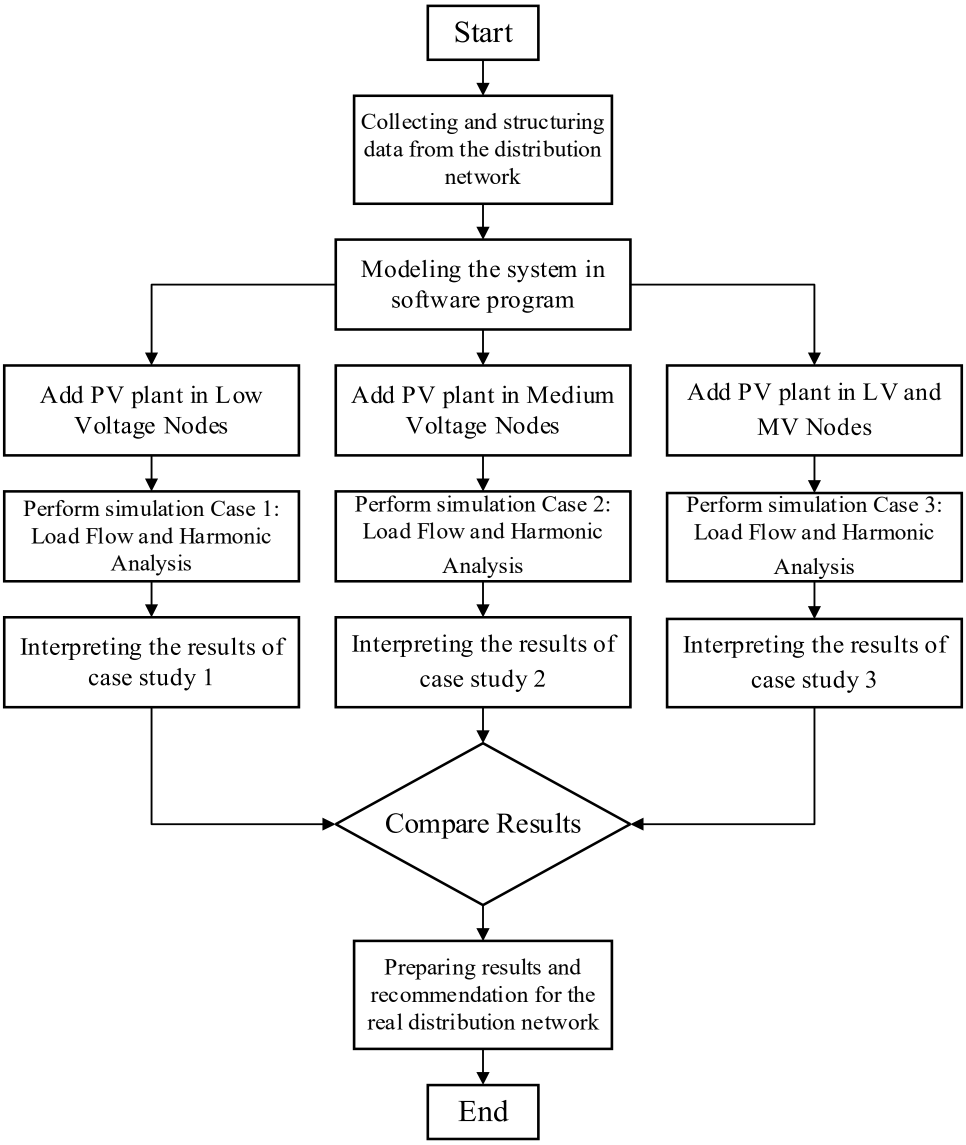

Figure 1. Flow chart of the research method used to assess impact of PV plant penetration on a Closed-Loop Distribution Network's Power Quality Indices

Power quality approach

As far as the existing DN were not built with the aim of adding such new resources to all sectors of the network, which changed all the distribution of PF from unidirectional to multidirectional, it is of reasonable that it will affect the operation, stability and relay protection of the future ESs based on RES as intermittent and fluctuating generations. Users connected to the DN experiencing sudden interruption of electricity supply, may be create a gap following lower quality indices. In this case, if it happens the devices connected to the network won't work normally and optimally. That is why in our approach, parameter quality analysis is considered as a need to protect and extend the lifetime of the devices connected to the future DN's. In the **Figure 2** the connection of PV sources at both voltage levels, that inflict harmonic distortion of voltage and current waves in the network is shown schematically. As a result, phenomena related to the PQ are numerous and include voltage fluctuations, voltage level, changes in frequency, the addition of a DC component on the AC side and interruption of energy caused by overloading.

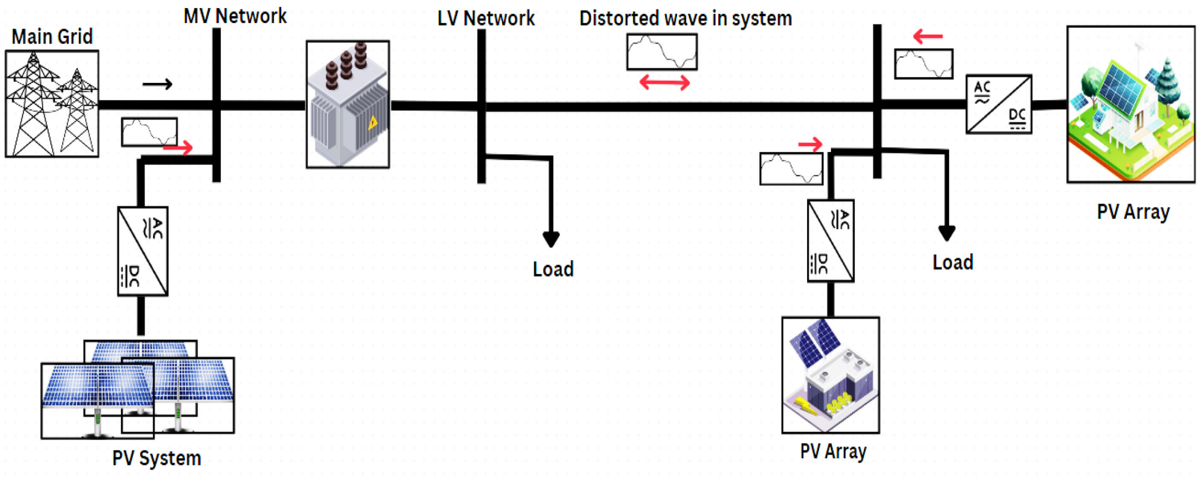

Figure 2. Schematic design of tested PV plants integrated in the DN

In order to design a good PQ of electricity supply, the criteria mentioned in the mathematical expressions given in eq. (1) and (2) must be met, fully in compliance with country contexts, norms, standards, and guides:

$$0.9V_\mathrm{n} \leq V_\mathrm{n} \leq 1.05V_\mathrm{n} \quad \text{for 400 V} \tag{1}$$

$$0.95V_\mathrm{n} \leq V_\mathrm{n} \leq 1.05V_\mathrm{n} \quad \text{for 20 kV} \tag{2}$$

Other restrictions that are applied is the quantity of power losses, maintaining them as minimal as possible as an optimization process, this is calculated using the mathematical expression as given in eq. (3):

$$\min\Delta S_\mathrm{loss} = \sum_{i=1}^{n} \frac{P_i^2 + Q_i^2}{U_i^2} \times (R_i + jX_i) \tag{3}$$

where are: P_i and Q_i – the active and reactive power in the node i; V_i - the voltage in the node i; R_i and X_i – the active and reactive resistance bewtwen node i and $i+1$.

Harmonics in the power system are sinusoidal waveforms with different frequencies in which the waves with the highest magnitude have a frequency that are multiple of the base frequency (50 Hz), as shown in **Figure 3**.

The Furie series can be used to express the harmonics as a sum of sinusoidal waves, which leads to eq. (4):

$$v(t) = V_\mathrm{dc} + \sum_{h=1}^{n} V_\mathrm{rms}^h \cos(h\omega_1 t + \theta_h) = v_\mathrm{dc} + v_{h=1}(t) + v_{h=2}(t) + v_{h=3}(t) + \cdots + v_{h=n}(t) \tag{4}$$

where ω_1 is the angular frequency.

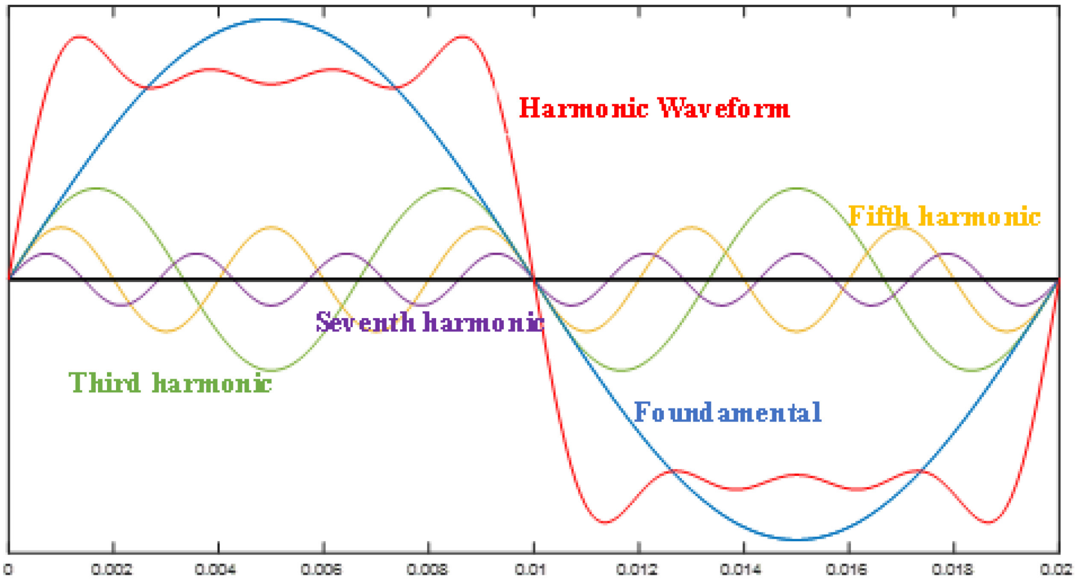

Figure 3. Schematic presentation of a wave with harmonic content

To evaluate the harmonic distortion of the voltage at nodes, the THD is calculated according to eq. (5):

$$\mathrm{THD_v} = \frac{\sqrt{\sum_{h=2}^{n}(v_h)^2}}{v_{h=1}} \tag{5}$$

Based on the standard [34] the PCC's voltage distortion limits (THD) are 8% for ESs under 1 kV and 5% for interval voltage from 1 to 69 kV. Harmonics stimulate many problems in the ES, leading to overload due to the increase of effective currents, overload in the neutral conductor, vibration, noise, reduction of the lifespan of transformers and motor equipment, interference in telecommunication systems, etc.

Closed Loop Distribution System (CLDS) and case study

In this research work, the simulation is scientifically performed in the DN 20/0.4 kV, practically employing two feeders that operate in a ring form with dual connections between substations in the Durres region, which is a city with a share part of feeders operating in ring form and others in radial typology. This grid typology can also run as a radial form under specific circumstances. This kind of connection guarantees an optimized PF for accommodating more RES, such as PVs/wind, etc., positively affecting the level of security in the demand side of the end-users connected to the DN. For the tested PVs, a summary of the data on elements in the CLDS, as listed in Table 1 below is given.

Table 1. Data on the elements in the CLDS case study

Elements	**Nodes**		**Transformer**	**Lines**	**Substation**	**Load**
Number	62 (LV)	64(MV)	73	66	2	68

In the analysed CLDS, two cases of different regimes of the network were simulated, such as the regime with maximum load ($P_{\max} = 28.186$ MW and $Q_{\max} = 16.048$ MVAR) and the minimal load ($P_{\min} = 7.583$ MW and $Q_{\min} = 4.456$ MVAR) of the day with sunny hours. The graph of the load demand for a single summer day is shown in Figure 4.

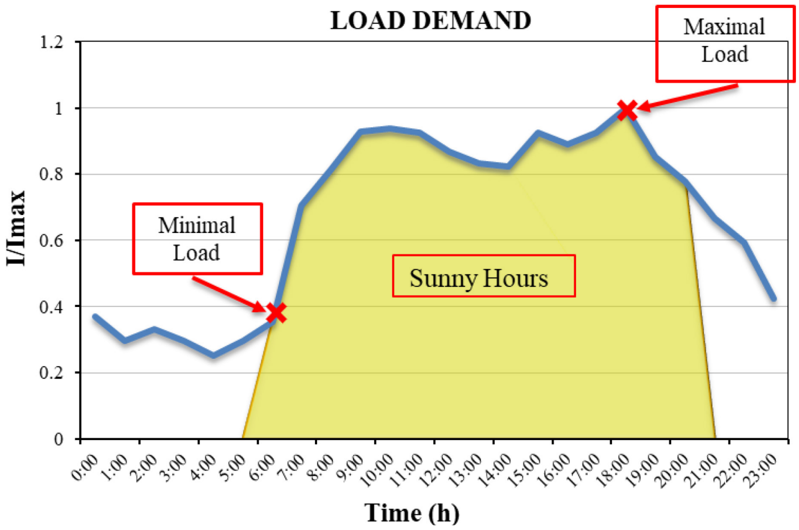

Figure 4. Load Demand chart for a summer day in Durres City

Figure 5 shows the schematic representation of the network for the proposed methodology, built-in Neplan software.

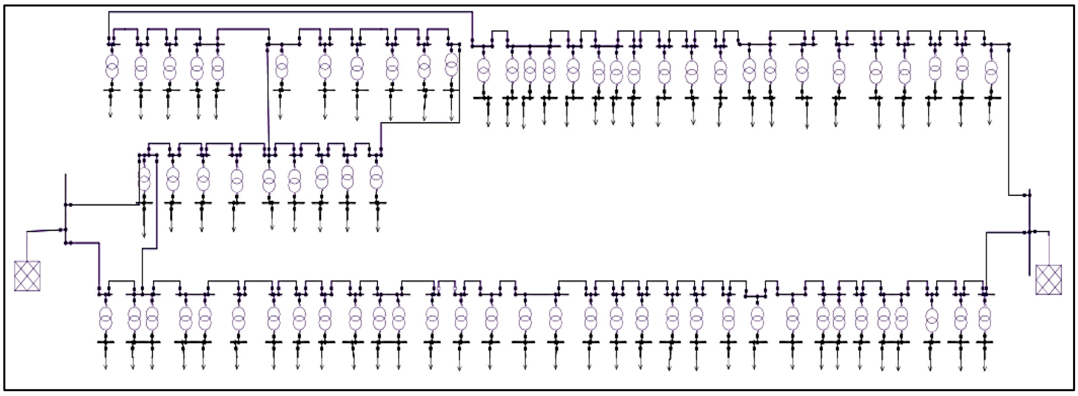

Figure 5. Schematic design of CLDS using Neplan software

PV plants with a production capacity of 500 kW have been added at nodes, and their total power is equal to 100% of the maximum power of the load. The chosen capacity power value of 500 kW was chosen based on legal and technical restrictions:

1. the first refers to the law of the Albanian government that maximum production capacity is set in this value [32], and
2. the second restriction is that the PV production on the LV cannot exceed the nominal power of the existing transformers.

The PV plants are connected to the DN through an inverter, which, based on the technical specifications of the most widespread inverters in the field, has a THD of less than 3%.

To analyse the impact on the PQ parameters, three operating conditions are analysed for the two different regimes of maximum load and minimum load, which include:

Case 1: Adding PV generation only on the LV side;
Case 2: Adding PV generation only on the MV side;
Case 3: Adding PV generation on the LV and MV sides.

These cases are carefully evaluated and comprise all possible scenarios that the chosen real network is expected to be fitted and running in the coming years, based on national strategic plans related to power capacities addition in the future driven by electrification of transportation sector, electrification of the space and cooling demand coupled with high coefficient of performance heat pumps (High-COP-HP), that need qualitative energy supply in the future [35].

RESULTS AND DISCUSSION

An interesting part of the proposed model is the fact that results are carried out thorough simulation work, securing the idea of covering 100% of the active power required by the maximum load from tested PV panels.

In the three tested scenarios simulated in the Neplan software, the generation from the PV panels covers 100% of the active power required by the maximum load, therefore, in the minimal load mode, this network switches to the supply source.

Power losses

The connection of PV plants affects the distribution of PF passing through the lines and transformers, thus reducing the power losses in power chain sections. According to **Figure 6**, reactive power losses are higher compared to active power losses in both network regimes. From the examination of the graph, in the maximum regime, the scenario with the highest reduction of losses results in the case where PV plants are connected only to the 0.4 kV nodes. For this case losses are reduced by approximately 69% for reactive power losses and 76% for active power losses, respectively. On the other hand, losses for all three scenarios are reduced compared to the case without the integration of the tested PV power plant.

On the contrary, in the scenario of the regime with minimal load, losses in the system increase from the base case due to the energy generation, which is directed into RPF, causing losses of power in the network. Based on the simulation results, a significant interest appeared in the case of the scenario employing the connection of the PV plant only on the MV side, since the losses have the lowest value. Such losses are due to the fact that they consist mainly of the power losses in the MV lines, while the losses from the transformers result in minimal values.

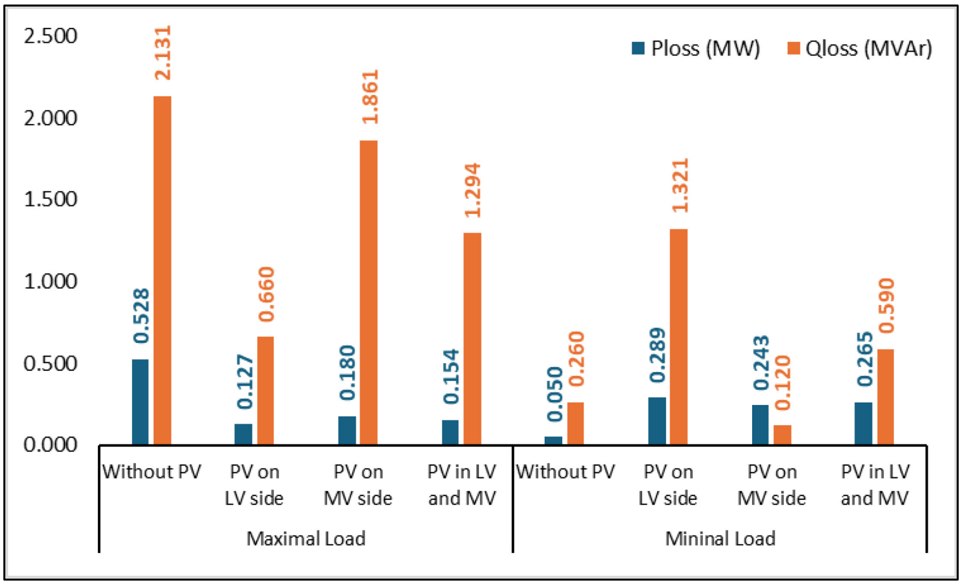

Figure 6. Level of power losses on the system for different case studies

Overloading of transformers

Referring to the load flow analysis in the model designed for this purpose, the highest value of transformer overload results of 134%, and the other values are below 134%. The number of overloaded transformers for each scenario operating in both regimes is depicted in the graph in **Figure 7**. In the maximum regime, the number of overloaded transformers without PV plant results the same comparing to the case when PVs are connected only on the MV side, since the same amount of power passes through to supply the load required, while in the other two cases the number of overloaded transformers is reduced. During the minimal regime, PV plants connected on the LV side cause RPF, which in turn lead to an increase in the number of overloading transformers, an increase in power losses, and also affects the working life of the transformers [36]. In this regime, it is proved that when the PVs are connected only on the MV side, it does not create conditions of overloads in the transformers of the tested DN.

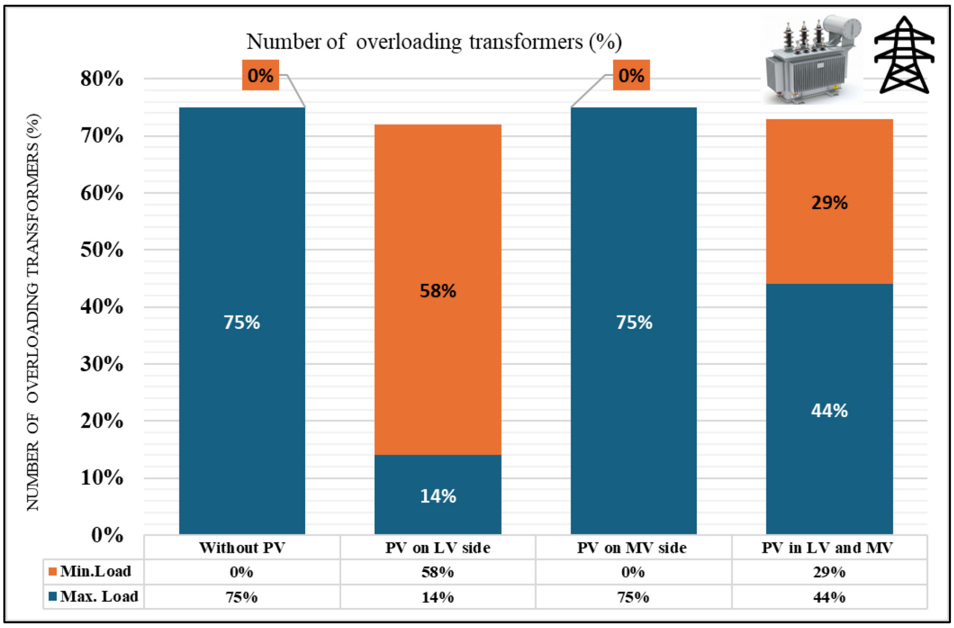

Figure 7. Number of overloading transformers in percent of the total number of transformers

Quality of voltage

Figure 8 and Figure 9 shows the voltage profile at each node of the 20 kV side for the tested scenarios that include RES-PVs. During the maximum load, the level of voltage results in the lowest values, but it is within the accepted limits and after connecting the PVs, it is observed that for the three case studies, voltage increases approaching tightly to its nominal value of 20 kV. In the cases when the PV panels are connected only on the LV side, the increase in voltage is higher than in the other two scenarios. This phenomenon derives from the reduction of voltage losses in the MV lines as the current coming from the substations is reduced. The simulations have shown that changes on phase, may have the largest observed value of 0.5° compared to the case without PV plants integrated to the system.

During the minimal load, the increase in the voltage level in the MV nodes exceeds the value of 20 kV, but once again the range of acceptable voltage values is guaranteed. The biggest increase in the voltage level result if the tested PVs are connected on the MV side, inversely to the case having maximum load.

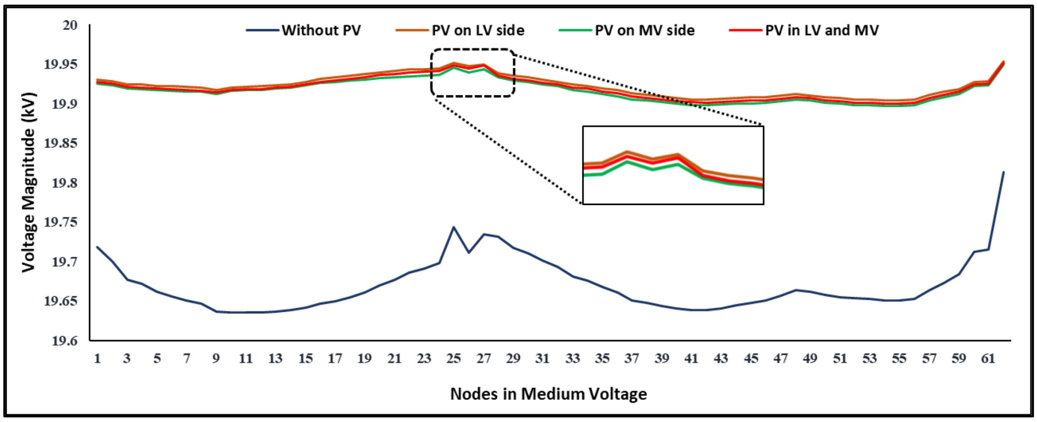

Figure 8. Level of MV voltage nodes during the maximum load in the system

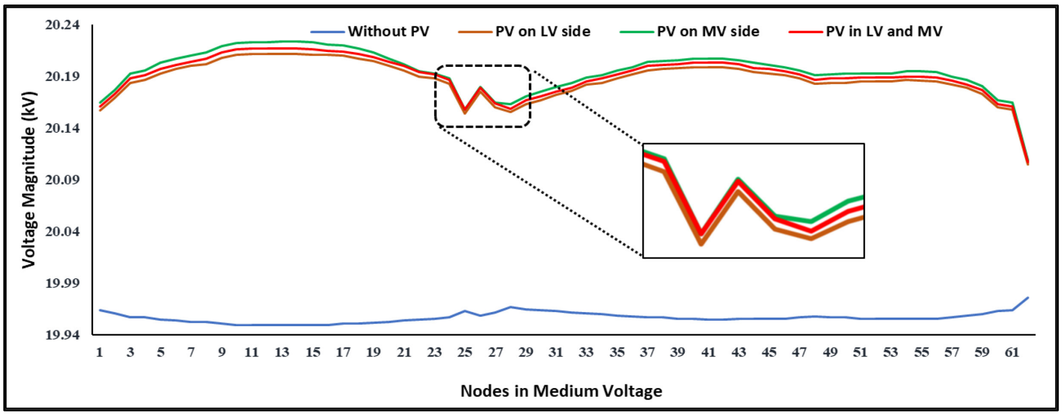

Figure 9. Level of MV voltage nodes during the minimal load on the system

The situation in the LV nodes is different, since the values in each node vary with larger ranges. As shown in **Figure 10**, the voltage during the maximal load is near the lower limits and if the PVs are connected as stated for each one of the selected scenarios. In these scenarios the amplitude of voltage is improved approaching the nominal voltage. From the simulations it is shown that the most significant impact result is the case when the PV sources are connected on the LV side.

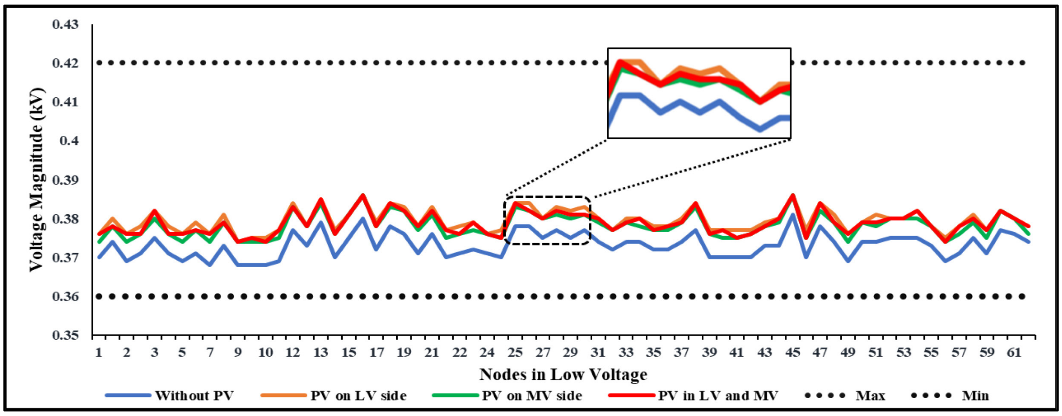

Figure 10. Level of LV voltage nodes during the maximum load on the system

Figure 11 shows the voltage profile for the tested scenarios which are analysed during the minimum load of the grid in the LV nodes. According to the simulation results, the voltage is improved approaching very close to 0.4 kV. In the case where supply from tested PVs is higher than demand, in other words this is a case where generation from the PV plant is over 100% of the maximum demand, creates overvoltage in the LV nodes.

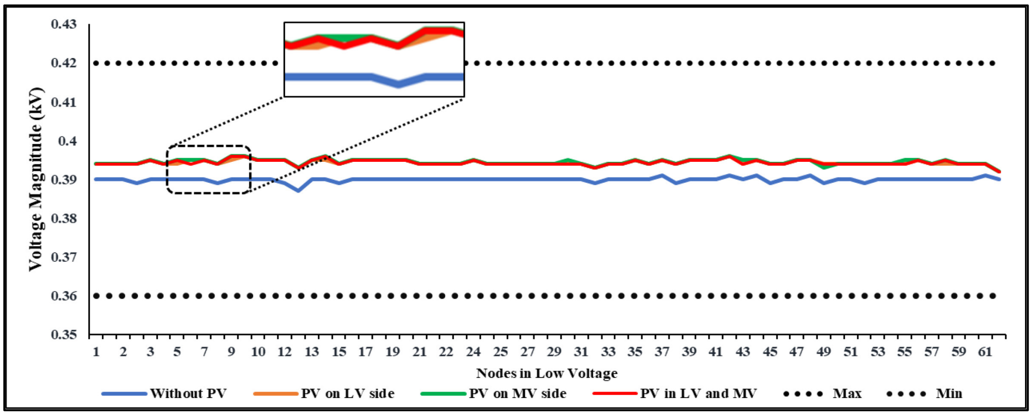

Figure 11. Level of LV voltage nodes during the minimum load of the tested energy system

Harmonic analysis

Figure 12 shows the level of THD in MV nodes during the maximum load, from which the THD values for the three case studies exceed the normalized values, respectively by 5% for the 20 kV voltage nodes. In the scenario where the PVs are strictly connected to the MV nodes, the THD values result higher compared to the other two cases, but once again, they remain closely distinctive between each other. In the cases of operations with minimal load in the DN, the THD values in the 20 kV nodes have increased even more compared to the maximum load regime. As shown in **Figure 13**, the THD values result higher in respect to the case if PVs are connected to the MV network. Generally, the harmonics that presented greater values of harmonic voltage distortion were the 5rd, 7th, and 11th harmonics.

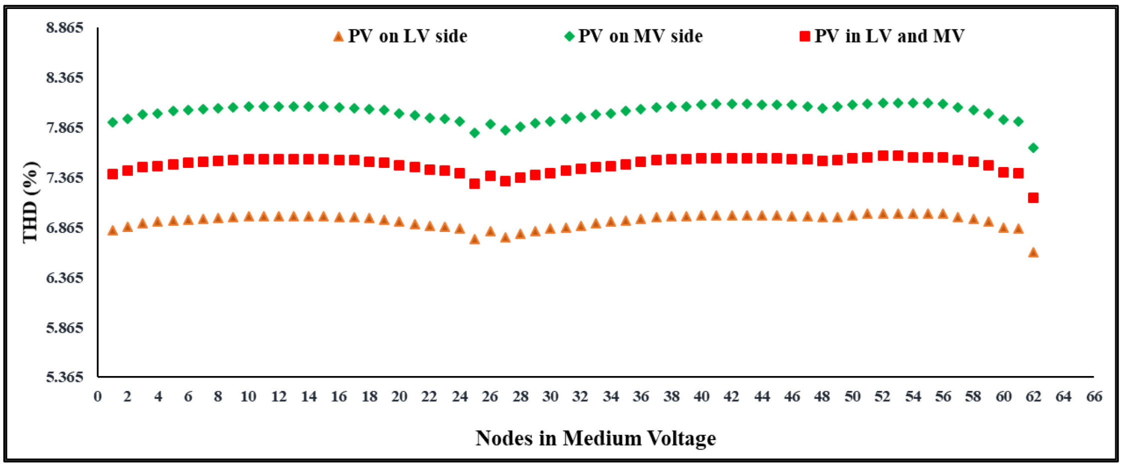

Figure 12. THD level on MV nodes during the maximum load of the tested energy system

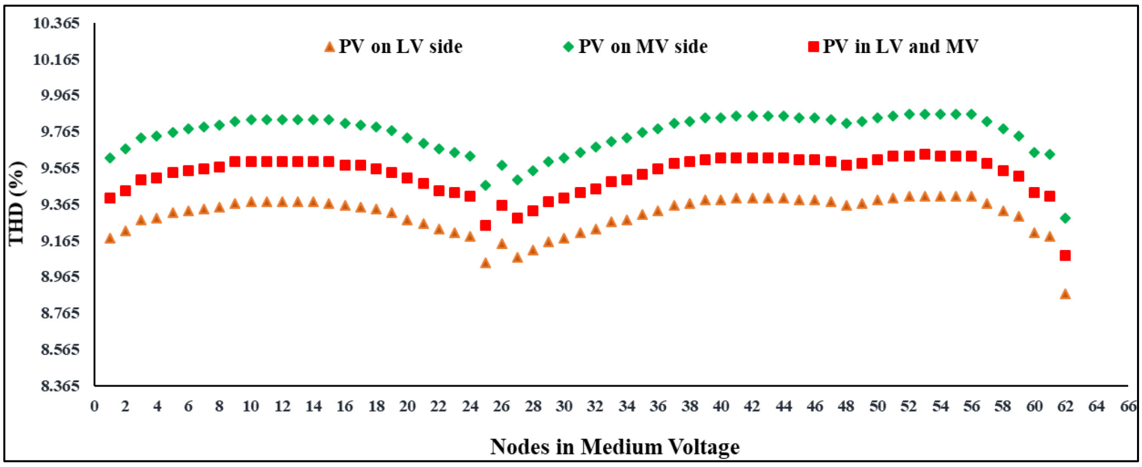

Figure 13. THD level on MV nodes during the minimal load of the tested energy system

The situation of THD in the LV nodes, according to **Figure 14,** appears to be significantly different from other scenarios. In particular, some LV nodes connected with PV plants result in higher THD values, which exceed the required limit of 8% as is determined in the standard. This suggests that the integration of PV plants at the LV nodes may introduce more harmonic distortions due to factors such as inverter characteristics, load fluctuations or insufficient filtering mechanisms in the local grid infrastructure. On the other hand, when PV plants are positioned on the MV side, the THD values of LV nodes remain within the allowed limit, leading to the conclusion that the influence of the PV connection position affects the level of harmonics in different nodes of the network. This contrast highlights the importance of carefully considering the location and integration method of PV plants within the grid.

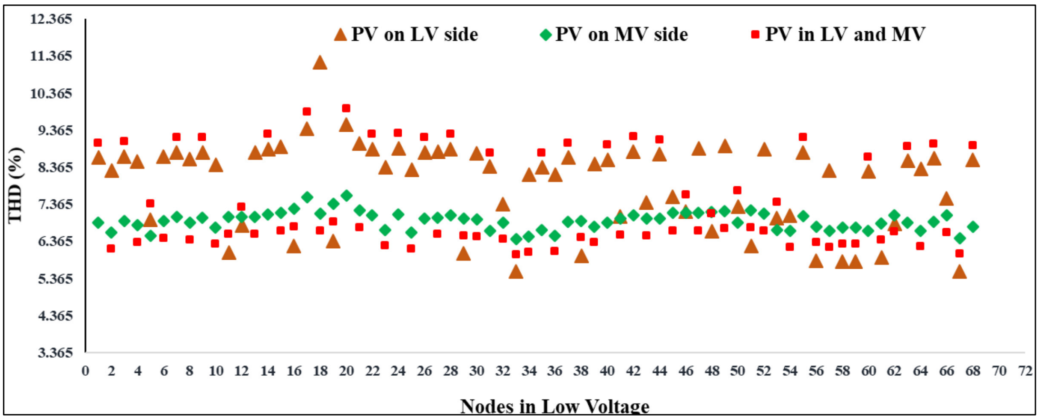

Figure 14. THD level on LV nodes during the maximal load of the tested energy system

Figure 15 shows the values recorded for each of the three tested scenarios during the minimal load condition, resulting to increased values compared to the maximum regime and have exceeded the value required by the norms [34].

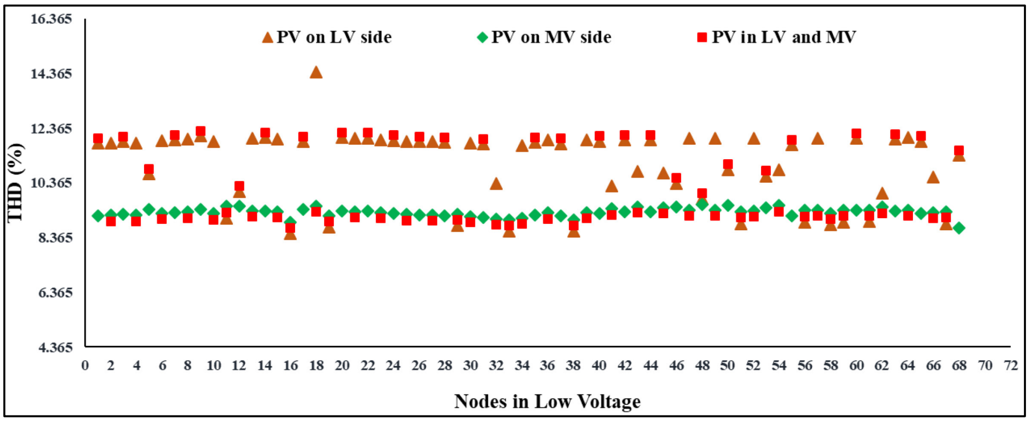

Figure 15. THD level on LV nodes during the minimal load

In conclusion, the factor that plays an important role in the penetration from the tested PVs into the CLDS is the THD value, which necessarily requires the connection of passive or active filters to stay within the limits [37]. Filters significantly reduce harmonics from the system and in this way can maintain the THD values in allowable limits and can extend the lifespan of equipment and components connected in the system.

Comparing the results for three case studies

Based on the results that are analysed in the above paragraphs, in **Table 2** is shown the summary of three scenarios and their impact on the quality parameters.

Table 2. Comparing the scenarios for complying with the quality parameter

Case Study	Effects	Minimize Losses	Overloading Elements	Voltage Level	THD Levels
Scenarios	**Adding PV generation only on the LV side**	√	x	√	x
	Adding PV generation only on the MV side	√	x	√	x
	Adding PV generation on the LV and MV side	√	√	√	x

Based on the performed analysis, the three case studies require special attention and the main factor that must be considered is the harmonic distortion. Another issue that should be considered is that the model generated will play a crucial role in identifying scenarios with large-scale integration of RES considering both quantity and quality and should be included in the energy strategic document of the country. Such research work lacks to the actual Albanian energy system, hence it is a first step for other studies related to the impact of PV's on a CLDS Power Quality Indices, extended on hosting capacity from RES and optimization of this future operation grids. Also, starting from this research work in the future studies, the research will be focused on sensitivity analysis to show how different variables impact the outcomes of the PQ indicators and economic impact.

CONCLUSION

In this paper, the impact of PV plants connection to a CLDS on the PQ parameters is analysed. The results show a reduction in losses, a decrease in the number of overloaded transformers, improvements in voltage levels, but also waveform distortion. In all three tested scenarios, the quality factor included in this kind of composition of the system, known as the value of voltage THD, exceeds the norms set in international standards of 8% for LV and 5% in MV nodes. But it is worthy mentioned that THD value does not differ quite much from the acceptable limits determine in the standards. In this case, other techniques that support the quality of the ES connected with PV needs to integrate a filter at specific nodes, to keep the level of harmonics at a desired level. From the simulation results referring this type of grid, the penetration of PV plants equals to 100% of the maximum load does not fulfill the THD limit level, but satisfies the reduction of losses, voltage levels and overloading limits of the transformers. The conclusions carried out from this research work are a starting point for the future RES projects connected to the existing power system without affecting the PQ parameters. To approach a sustainable future transformed network, must expand the research using PQ analysis to include the possibility of regulating the energy production form RES and investigating various methods of improving the hosting capacity. Options explored in this research work must be carefully analysed and aligned with other plans, to ensure a fully flexible and net zero emission society by the end of 2050. This work will serve as a starting point for the DSO in developing a well-thought-out and strategic plan for transforming the existing network into a more resilient and sustainable one.

NOMENCLATURE

V	voltage	kV
P	active power	MW
Q	reactive power	MVAR
ΔS_{loss}	power losses	MVA
ω_1	angular frequency	rad/sec

Abbreviations

CLDS	Closed Loop Distribution System
PQ	Power Quality
PV	Photovoltaic
RES	Renewable Energy System
THD	Total Harmonic Distortion
DG	Distributed Generation
DN	Distribution Network
DSO	Distribution System Operator
ES	Electrical System
EVs	Electric Vehicles
LV	Low Voltage

MV	Medium Voltage
NECP	National Energy and Climate Plan
PCC	Point of Common Coupling
PF	Power Flow
RPF	Reverse Power Flow

REFERENCES

1. "Draft National Energy and Climate Plan of the Republic of Albania", (In Albanian: "Draft Plani Kombëtar i Republikës së Shqipërisë për Energjinë dhe Klimën,") Tirane, Jul. 2021. [Accessed: Jan. 21, 2025] https://www.infrastruktura.gov.al/wp-content/uploads/2021/11/NECP-Albania_drafti-shqip.pdf.
2. "Decision_480," Jul. 2018, [Accessed: Jan. 21, 2025] https://www.infrastruktura.gov.al/wp-content/uploads/2018/11/Vendim-i-KM_480_31.07.2018.pdf.
3. F. K. Alhousni, F. B. Ismail, P. C. Okonkwo, H. Mohamed, B. O. Okonkwo, and O. A. Al-Shahri, "A review of PV solar energy system operations and applications in Dhofar Oman," AIMS Energy, vol. 10, no. 4, pp. 858–884, 2022, https://doi.org/10.3934/energy.2022039.
4. T. A. H. Almajali, F. B. Ismail, H. A. Kazem, P. A. L. Gunnasegaran, S. M. AL Shurafa, and N. F. O. Al-Muhsen, "Enhanced water production and improving solar water distillation efficiency of double-slope solar stills: Modeling and validation," Thermal Science and Engineering Progress, vol. 53, p. 102712, 2024, https://doi.org/10.1016/j.tsep.2024.102712.
5. A. Ebrahimi, B. Ghorbani, and M. Taghavi, "Novel integrated structure consisting of CO2 capture cycle, heat pump unit, Kalina power, and ejector refrigeration systems for liquid CO2 storage using renewable energies," Energy Sci Eng, vol. 10, no. 8, pp. 3167–3188, Aug. 2022, https://doi.org/10.1002/ese3.1211.
6. M. Taghavi, H.-J. Yoon, J.-U. Choi, and C.-J. Lee, "Innovative Structure of a Liquefied Natural Gas (LNG) Process by Mixed Fluid Cascade Using Solar Renewable Energy, Photovoltaic Panels (PV), and Absorption Refrigeration System," in Computer Aided Chemical Engineering, vol. 53, F. Manenti and G. V Reklaitis, Eds. Elsevier, 2024, pp. 2071–2076.
7. M. Taghavi, H. Salarian, and B. Ghorbani, "Economic Evaluation of a Hybrid Hydrogen Liquefaction System Utilizing Liquid Air Cold Recovery and Renewable Energies," vol. 4, no. 1, pp. 125–143, 2023, https://doi.org/10.22044/rera.2022.11899.1122.
8. T. A. Hamed and A. Alshare, "Environmental Impact of Solar and Wind energy-A Review," Journal of Sustainable Development of Energy, Water and Environment Systems, vol. 10, no. 2, Jan. 2022, https://doi.org/10.13044/j.sdewes.d9.0387.
9. J. Morel, S. Obara, and Y. Morizane, "Operation strategy for a power grid supplied by 100% renewable energy at a cold region in Japan," Journal of Sustainable Development of Energy, Water and Environment Systems, vol. 2, no. 3, pp. 270–283, Sep. 2014, https://doi.org/10.13044/j.sdewes.2014.02.0022.
10. M. Bošnjaković, R. Santa, Z. Crnac, and T. Bošnjaković, "Environmental Impact of PV Power Systems," Sustainability (Switzerland), vol. 15, no. 15, Aug. 2023, https://doi.org/10.3390/su151511888.
11. L. Malka, R. Dervishi, P. Malkaj, I. Konomi, R. Ormeni, and E. Cenaj, "Modelling and Assessing Environmental Impact in Transport to Meet the Sector's Climate Goals in 2050," WSEAS Transactions on Environment and Development, vol. 20, pp. 350–364, 2024, https://doi.org/10.37394/232015.2024.20.34.

12. A. Bugaje, M. Ehrenwirth, C. Trinkl, and W. Zoerner, "Investigating the Performance of Rural Off-Grid Photovoltaic System with Electric-Mobility Solutions: A Case Study Based on Kenya," Journal of Sustainable Development of Energy, Water and Environment Systems, vol. 10, no. 1, Mar. 2022, https://doi.org/10.13044/j.sdewes.d9.0391.
13. I. Karameros, A. Chassiakos, and S. Karatzas, "Design and Evaluation of a Micro-Grid Energy Management Scheme Focusing on the Integration of Electric Vehicles," Journal of Sustainable Development of Energy, Water and Environment Systems, vol. 11, no. 1, Mar. 2023, https://doi.org/10.13044/j.sdewes.d9.0413.
14. Syafii, Krismadinata, Muladi, T. K. Agung, and D. A. Sandri, "Simple Photovoltaic Electric Vehicles Charging Management System Considering Sun Availability Time," Journal of Sustainable Development of Energy, Water and Environment Systems, vol. 12, no. 1, Mar. 2024, https://doi.org/10.13044/J.SDEWES.D11.0476.
15. T. Furubayashi, "Design and analysis of a 100% renewable energy system for Akita prefecture, Japan," Smart Energy, vol. 2, May 2021, https://doi.org/10.1016/j.segy.2021.100012.
16. P. Kedarnath Magadum and S. G. Sakri, "Effects of Non Linear Loading on Power Quality," 2023. [Accessed: Jan. 21, 2025] https://www.researchgate.net/publication/372139118.
17. D. Ogheneovo Johnson, "Issues of Power Quality in Electrical Systems," International Journal of Energy and Power Engineering, vol. 5, no. 4, p. 148, 2016, https://doi.org/10.11648/j.ijepe.20160504.12.
18. W. Yuan, X. Yuan, L. Xu, C. Zhang, and X. Ma, "Harmonic Loss Analysis of Low-Voltage Distribution Network Integrated with Distributed Photovoltaic," Sustainability (Switzerland), vol. 15, no. 5, Mar. 2023, https://doi.org/10.3390/su15054334.
19. D. Galzina, "Voltage quality improvement using solar photovoltaic system," Journal of Sustainable Development of Energy, Water and Environment Systems, vol. 3, no. 2, pp. 140–150, Jun. 2015, https://doi.org/10.13044/j.sdewes.2015.03.0011.
20. P. Sharma, "Analysing the Role of Renewables in Energy Security by Deploying Renewable Energy Security Index," Journal of Sustainable Development of Energy, Water and Environment Systems, vol. 11, no. 4, Dec. 2023, https://doi.org/10.13044/j.sdewes.d11.0463.
21. R. Pinto, S. Mariano, M. D. R. Calado, and J. F. De Souza, "Impact of rural grid-connected photovoltaic generation systems on power quality," Energies (Basel), vol. 9, no. 9, 2016, https://doi.org/10.3390/en9090739.
22. W. Jean and A. C. P. Brasil Junior, "Solar Model for Rural Communities: Analysis of Impact of a Grid-Connected Photovoltaic System in the Brazilian Semi-arid Region," Journal of Sustainable Development of Energy, Water and Environment Systems, vol. 10, no. 3, Sep. 2022, https://doi.org/10.13044/j.sdewes.d9.0405.
23. Mbumba, F. Vieira, and P. Ferreira, "Evaluation of Off-grid Photovoltaic Projects for Schools and Health Posts in Angola," Journal of Sustainable Development of Energy, Water and Environment Systems, vol. 12, no. 4, pp. 1–21, Dec. 2024, https://doi.org/10.13044/j.sdewes.d12.0524.
24. K. Z. Dadjiogou, A. S. A. Ajavon, and Y. Bokovi, "Energy Flow Management in a Smart Microgrid Based on Photovoltaic Energy Supplying Multiple Loads," Journal of Sustainable Development of Energy, Water and Environment Systems, vol. 12, no. 1, Mar. 2024, https://doi.org/10.13044/j.sdewes.d11.0473.
25. K. Sornek, W. Goryl, and A. Głowacka, "Improving the Performance of Photovoltaic Panels Using a Direct Water Cooling System," Journal of Sustainable Development of Energy, Water and Environment Systems, vol. 11, no. 4, Dec. 2023, https://doi.org/10.13044/j.sdewes.d11.0468.

26. H. Adamu, F. Njoka, and G. Kidegho, “Performance of MPPT Charge Controller Under Moderate - to High - Temperature Field Condition,” Journal of Sustainable Development of Energy, Water and Environment Systems, vol. 12, no. 3, pp. 1–15, Sep. 2024, https://doi.org/10.13044/j.sdewes.d12.0504.
27. A. Mohammad, M. Al-Obaidi, H. Dakkama, and H. Bahlol, “Modelling and optimisation of solar photovoltaic power using response surface methodology,” Journal of Sustainable Development of Energy, Water and Environment Systems, vol. 12, no. 4, pp. 1–16, Dec. 2024, https://doi.org/10.13044/j.sdewes.d12.0519.
28. O. A. Al-Shahri et al., “Solar photovoltaic energy optimization methods, challenges and issues: A comprehensive review,” J Clean Prod, vol. 284, p. 125465, 2021, https://doi.org/https://doi.org/10.1016/j.jclepro.2020.125465.
29. A. M. Eltamaly, Y. Sayed Mohamed, A. H. M. El-Sayed, M. A. Mohamed, and A. Nasr A. Elghaffar, “Power Quality and Reliability Considerations of Photovoltaic Distributed Generation,” Technology and Economics of Smart Grids and Sustainable Energy, vol. 5, no. 1, Dec. 2020, https://doi.org/10.1007/s40866-020-00096-2.
30. A. Alhussainy and T. S. Alquthami, “Power quality analysis of a large grid-tied solar photovoltaic system,” Advances in Mechanical Engineering, vol. 12, no. 7, Jul. 2020, https://doi.org/10.1177/1687814020944670.
31. M. Çelo and R. Bualoti, “The challenges faced in the process of the integration of small and medium size hydro power plants on the distribution network in albania,” Journal of Sustainable Development of Energy, Water and Environment Systems, vol. 9, no. 4, Dec. 2021, https://doi.org/10.13044/j.sdewes.d8.0325.
32. “Law no.24-article 20.” Tirane, Mar. 23, 2023, [Accessed: Jan. 21, 2025] https://qbz.gov.al/eli/ligj/2023/03/23/24/520e80c0-c904-41e4-b0b3-7666ddb132d7.
33. J. Schallenberg-Rodriguez, “Photovoltaic techno-economical potential on roofs in the Canary Islands,” Journal of Sustainable Development of Energy, Water and Environment Systems, vol. 2, no. 1, pp. 68–87, Mar. 2014, https://doi.org/10.13044/j.sdewes.2014.02.0007.
34. “IEEE Standard for Harmonic Control in Electric Power Systems.” IEEE, Piscataway, NJ, USA, May 13, 2022, https://doi.org/10.1109/IEEESTD.2022.9848440.
35. L. Malka and A. Kuriqi, “Residential Heating Demand Projections in Albania by Integrating Heat Pumps and Passive Energy Efficiency Measures,” in 2024 International Conference on Renewable Energies and Smart Technologies (REST), Jun. 2024, pp. 1–5, https://doi.org/10.1109/REST59987.2024.10645458.
36. B. Majeed and N. I. Nwulu, “Impact of Reverse Power Flow on Distributed Transformers in a Solar-Photovoltaic-Integrated Low-Voltage Network,” Energies (Basel), vol. 15, no. 23, Dec. 2022, https://doi.org/10.3390/en15239238.
37. L. Alhafadhi, C. M. Lai, J. Teh, and M. Salem, “Predictive adaptive filter for reducing total harmonics distortion in PV systems,” Energies (Basel), vol. 13, no. 12, Jun. 2020, https://doi.org/10.3390/en13123286.

Paper submitted: 10.11.2024
Paper revised: 28.01.2025
Paper accepted: 29.01.2025