21th International Conference on Renewable Energies and Power Quality (ICREPQ'23)
Madrid (Spain), 24th to 26th May 2023
Renewable Energy and Power Quality Journal (RE&PQJ)
ISSN 2172-038 X, Volume No.21, July 2023

Energy Consumption Optimisation of Emergency Shelters for Ukrainian War Refugees

Olena Rubanenko [1,2]

[1] Research Innovation Center for Electrical Engineering
University of West Bohemia
Univerzitni 8, 30614 Plzen (Czech Republic)
Phone/Fax number: +00420 377 634146, e-mail:
rubanenk@fel.zcu.cz

[2] Department of Power Station and System
Vinnytsia National Technical University
95 Khmelnytske shose, Vinnytsia, Ukraine, 21021
Phone/Fax number: +380977480285, e-mail:
olenarubanenko@vntu.edu.ua

Abstract. The paper deals with optimisation of energy consumption of emergency shelters (tiny houses) for Ukrainian War refugees. Significant amount of Ukrainian citizens lost their homes or were forced to leave their properties. These refugees overcrowd the rest of the country and bring huge problems with accommodation and inclusion into existing communities. Accommodation in schools or gyms is just temporary solution with another unpleasant influence on the society. It is necessary to construct new quarters or communities using cheap but energy very efficient constructions.

Several variants of tiny house with various equipment features and living or comfort standard are being discussed and compared. These studies are based on real project realised between Ukrainian non-government organisation Synergy and German development agency weChange.

Main goal of this research is consumption optimisation of not particular single shelter but rather of large community of shelters containing hundreds or thousands units called shelter city. The tiny houses itself are designed according to passive solar systems standards and with accent to minimal purchasing costs and operational energy needs. Second important requirement is strong optimisation of shelter's load chart to significantly decrease influence of the shelter city to power grid connection point.

Both tasks are important because the Russian attack against Ukraine brings new tasks for power engineering sector. Electricity production, transmission, distribution and consumption must face new challenges. Nowadays more than 35 % of critical infrastructure is being damaged. Remaining infrastructure would be more overloaded, if new customers are connected without energy needs optimisation.

Key words. tiny house, shelter city, load chart optimisation, influence on grid.

1. Introduction

he Russian aggression against Ukraine initiates unseen challenges to the country's security and economy, but also to its environmental protection, power engineering, green energy and sustainable and low-carbon development [1]. The energy security of Ukrainians is severely threatened, more than 50 % of Ukraine's energy infrastructure has been destroyed or temporarily occupied [2].
As of the beginning of September 2022, 785 settlements (about 615 thousand consumers) were left without electricity supply. About 235 thousand persons remained without gas supply. Continuing Russian activities further disrupt energy supply in Ukraine and damage entire power engineering sector. Further attacks make deep chaos in critically vulnerable and centralized energy infrastructure.

Similarly, renewable energy sources (RES) are under attack. 30% of solar power and 90% of wind power were destroyed or occupied by Russian army. In recent years, Ukraine has managed to achieve significant results in the development of renewable energy. By the beginning of 2022 alone, its installed capacity reached 9.5 GW, and the volume of investments in the industry reached $12 billion.

Due to the war, half of RES facilities are at risk of complete or partial destruction - in areas where active hostilities continue, there are 47 % of the installed capacity of power plants based on renewable energy sources. Also, many RES stations are located in regions adjacent to military operations. At the same time, investors are in no hurry to invest money, waiting for the stabilization of the situation and an understanding of the further picture of the war [4].

In [5], noted that the first problem for REs in Ukraine is location RES in the south and southeast of, where active hostilities have been going on for the past 9 months. As of August 2022, 30–40% of RES power plants in these regions, or 1,120–1,500 MW of installed capacities, were affected. The second problem is the deepening of the financial crisis in the RES market. The war aggravated the financial crisis in the energy sector. The lack of funds has become an urgent problem for all sectors of the Ukrainian energy system and have a huge effect on the sector of renewable energy and has very fastly started to be a matter of survival for RES. Before the war RES in Ukraine developed (Fig. 1), it means the usage of RES for power supply to tiny houses and shelter city is actual. Usage RES for householders is more relevant now, than build industrial PV system. In study, which made Razymkov center highlighted that existed RES producers, especially producers of solar and wind energy, did not receive full payment for the electricity supplied in 2021 and continued to bear the operating costs of maintaining their power plants, they had financial obligations both before the state and their staff, as well as international investors, but did not oppose such financial policy in the RES sector, because they realised the importance of stability and reliability of the power system. In addition, "Ukrenergo" from June 2022 began to pay RES producers located out of the occupied territories and generating electricity in Ukraine (made only 21% of what was required).

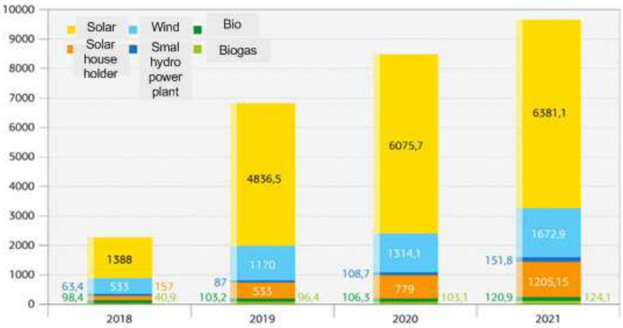

Fig.1. Istalled capacity RES inUkraine

In fig. 2 shows destroyed house with RES.


Fig. 2. Damaged power engineering infrastructure.

The implementation of RES in power grids, such as photovoltaic and wind power plants, can influence power balance [6-8].

2. The power balance in the power system, taking into account RES, storages and schedule of load limitations

The power balance equation for power grid can be written as (1) [9-11]:

$$P_{CS}(t)+\sum_{i=1}^{n}P_i(t)-\sum_{j=1}^{m}P_{TSj}(t)-\Delta P(t)\pm P_{stor.}(t)\pm P_{limit.}(t)=0, \quad (1)$$

where $P_{CS}(t)$ is power transmitted to the PS from centralized electricity sources; $P_i\ (t)$ is power generation of RESs in the PS; $P_{TSj}(t)$ is loading of transformer substations; n is the number of RES in the PS; m is number of substations; $P_{stor.(t)}$ is capacity storages; $P_{limit(t)}$ is load limitations. In equation (1) to the generating component can be attributed to the power transmitted to the PS from centralized power sources, RESs generation power, and storage capacity in the discharge mode, the consumption component can include the load capacity of transformer substations, active power loss, storage capacity and load limitations.

An integrated approach seems to be optimal, when several methods are used to compensate for the unevenness of the RES generation schedule. In this case, the total cost of C_Σ to compensate for the unevenness of the RES generation schedule by power redundancy is minimized. The task of optimizing the cost of redundancy is set as [12, 13]:

$$C_\Sigma = C_{ch}\left(P_{ch}\right)+C_h(P_h)+C_b(P_b)+ \\ +C_s(P_s)+C_{tl}\left(P_{tl}\right)+C_{\lim}(P_{\lim})\rightarrow \min \quad (2)$$

where $C_{ch}(P_{ch})$ is the cost of redundancy with chemical storage; $C_h(P_h)$ is the cost of hydrogen technologies; $C_b\ (P_b)$ is cost associated with the use of biogas technology as a reserve; $C_s(P_s)$ is cost of using the system reserve; $C_{tl}\ (P_{tl})$ is the cost of reserves of capacity of transmission lines; $C_{tl}\ (P_{tl})$ is the cost of limitation of power supply, because deficit power in system; P_{ch}, P_h, P_b, P_s, P_{tl}, P_{lim} are respectively, the optimal values of power, which are determined from each of the backup methods. The costing mechanism for each method of redundancy is complex and requires consideration of features and technological limitations, but now need take into account deficit of active power.

3. Energy efficient project of shelter for war refugees

Initial project dealing with shelter city design was organised by Ukrainian non-government organisation Synergy, German development agency weChange and granted by German Ministry of Industry. More than 100 participants competed with particular projects of single tiny house and its energy needs coverage. 6 best projects proceeded to final lap and stand as initial ideas of shelter city project.

The online educational course consisted of 5 modules: international experience of RES use; adaptation of existing solutions for heating and electricity supply of shelters to the conditions of Ukraine; software for designing the electricity supply of shelters based on solar energy; peculiarities of operation of power supply systems in autonomous mode and in parallel to a centralized system; use of RES for the energy supply of temporarily displaced persons; energy storage systems for off-grid electrification; legislative and regulatory field.

Particular shelters were based on various constructions from prefabricated wooden structures through industrial containers to reconstructed existing abandoned buildings. Various shelters were equipped on different comfort levels leading to different energy needs and load chart. Fig. 2 shows project of prefabricated low energy wooden shelter for 4 person family.

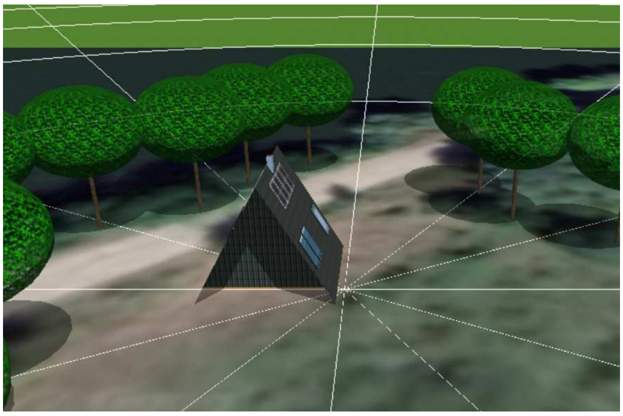

Fig. 2. Project of prefabricated low energy wooden shelter.

Fig. 3 presents original load chart covering 3405 kWh proposed for this project equipped with 4,2 kWp photovoltaic system while Fig. 4 demonstrates optimised load chart supplying 2964 kWh covered by 2,4 kWp PV system.

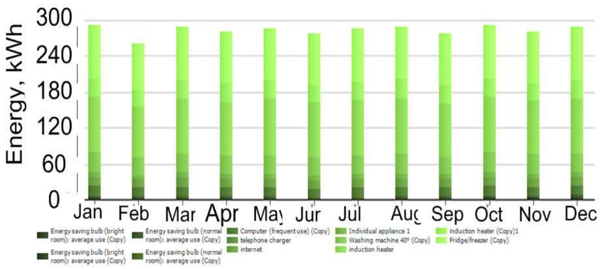

Fig. 3. Original load chart (3405 kWh).

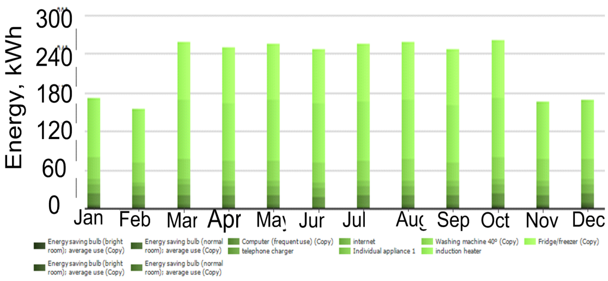

Fig. 4. Optimised load chart (2694 kWh).

Fig. 5 illustrates project of reconstructed farming property modernised to low energy standard and proposed for 3 families. Fig. 6 presents load chard describing energy needs of this small community (3322 kWh).

Fig. 5. Project of reconstructed farming property.

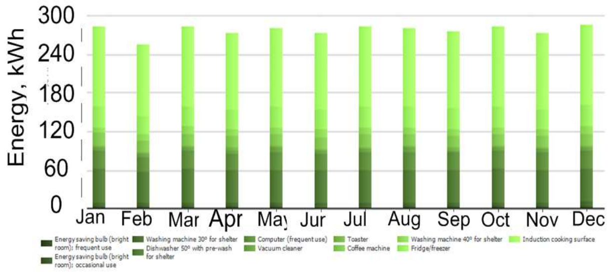

Fig. 6. Proposed load chart (3322 kWh).

Covering the energy needs of the object is just one task of this study. The shelter city will be connected to existing connecting point of the public distribution network. Influence of these objects can be analysed with help of Fig. 7 (wooden shelter) and Fig. 8 (farming property). Simulations were calculated in PV*SOL Premium 2022.

It is evident on Fig. 9 that the power grid is overloaded during high consumption periods (779 kWh) but much more during low consumption periods with overproduction (1249 kWh). The system uses AC coupled battery system consisting from 5,1 kWh LiFePo battery and 3 kW inverter. Fig. 8 shows load chart with more optimised production during low consumption periods (666 kWh) but higher consumption during high consumption periods (1578 kWh). Tis system uses hybrid inverter (1,5 kW) with 2,9 kWh LiFePo battery [16, 17].

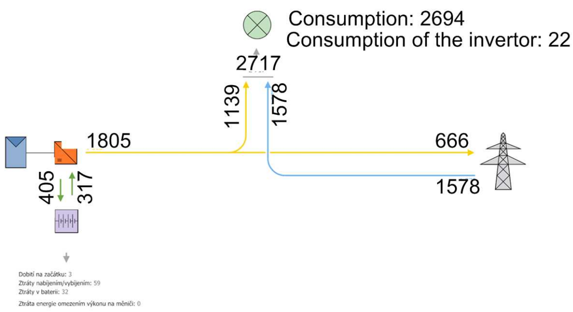

Fig. 7. Energy flow chart (wooden shelter).

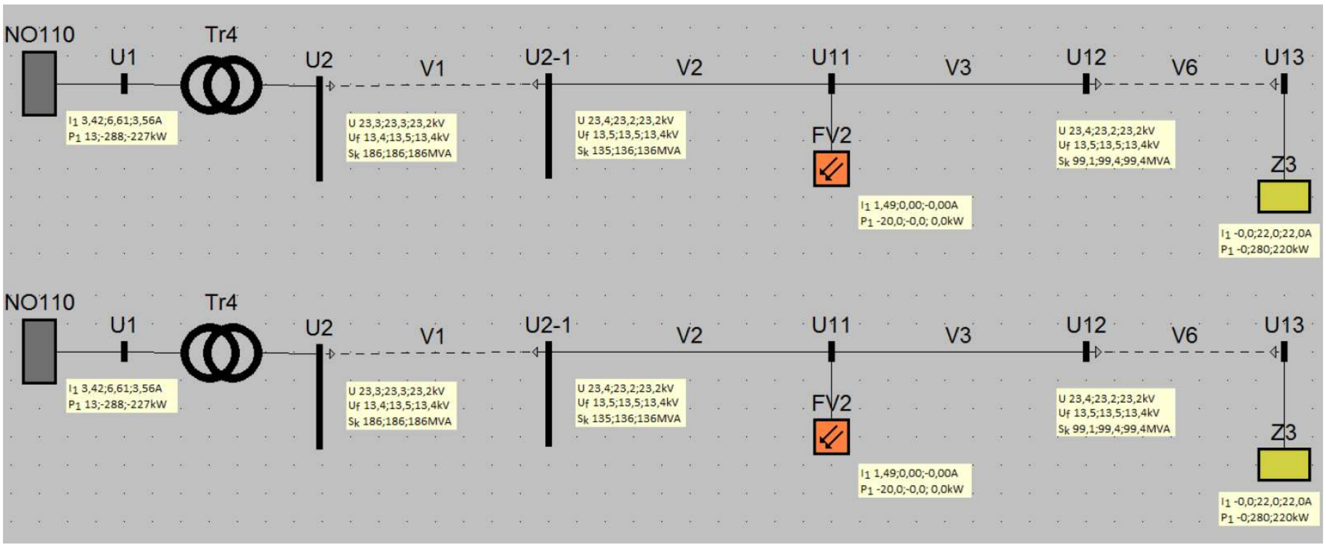

Fig. 9. Energy flow chart (farming property).

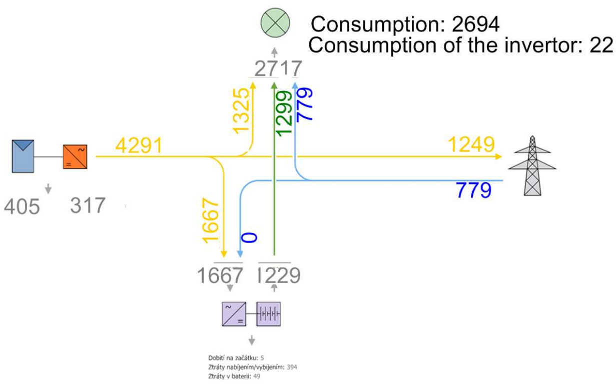

Fig. 8. Energy flow chart (farming property).

4. Influence on public distribution network and power quality

RES inlfuence on power quality Power quality and influence on public distribution network was calculated using DNCalc software. The instability of power generation of RESs, exactly PV and wind power plants, has an effect on system operations including voltage and frequency, harmonics, and power quality (PQ) in general, and influences the overall performance of the power network as well as the power grid. Inverters connected with RESs, nonlinear customer loads, and power electronics appliances deal harmonics in the power grid that cause overheating of transformers, tripping of circuit breakers, and reducing the life of connected equipment and negative influence on other households. In this case, need presently assess installed capacity RES, and equipment and minimize the negative influence on the grid [17-19]. Fig. 9 presents the basic scheme of shelter with photovoltaic plant connected to U11 connection point in grid with existing consumption in point U13 and supplied via transformer T4 from 110 kV grid.

5. Conclusion

Notpredictible situations in war conditions slow the dawn process of clear planning total rebuilding, including the implementation of RES. In this case project of shelter for war refugees with usage RES for power supply can be actual. Since the war is still ongoing, it is still difficult to predict how many citizens will return to Ukraine and their regions of residence after the end of the war, and what part will remain life in other regions or abroad. Also, the development of territorial development plans should take into account the needs for recovery; energy balance forecast; development prospects unblocking of trade routes, etc.

RES can be also used for power and heat supply shelter-city. Shelter-city is a community of citizens (refugees), who lost their homes in war condition. Building of shelter-cities generates problems in existing PS and inpacts power quality. Tiny houses with RES will help to decide two problems: wars refugees' accommodation and decrease the load on the central power grid, if made this in the correct way. Proposed method design PV system in a tiny house with usage PVSol software allows increased efficiency PV system and minimize negative influence on power grid.

Acknowledgement

I want to say thanks to the University of West Bohemia in Pilsen for all round support in this research work. This result was supported by project MSCA4Ukraine ID number 1233365 and 23-PKVV-011.

References

[1] Russia's war on Ukraine: Implications for EU energy supply. European Union, 2022 [Online]. Available: https://www.europarl.europa.eu/RegData/etudes/ATAG/2022/729281/EPRS_ATA(2022)729281_EN.pdf

[2] German Galushchenko, Minister of Energy of Ukraine. 50% of Ukraine's energy infrastructure has been damaged, 2022 Speech at the United for Justice international conference in Lviv. [Online]. Available: https://www.kmu.gov.ua/en/news/poshkodzheni-50-enerhetychnoi-infrastruktury-ukrainy-rosiia-maie-vidpovisty-za-tse-herman-halushchenko

[3] Draft Ukraine Recovery Plan Materials of the "Audit of war damage", 2022 working group. [Online]. Available: https://uploads-ssl.webflow.com/621f88db25fbf24758792dd8/62c48b51bd97677a3c4d7b1c_Audit%20of%20war%20damage.pdf

[4] The future of green energy is in the hands of the Armed Forces of Ukraine and investors [Online]. Available: https://ecopolitic.com.ua/en/news/majbutnie-zelenoi-energetiki-v-rukah-zsu-ta-investoriv-ukrinform-2/

[5] Volodymyr Omelchenko, Ukraine's renewable energy sector before, during and after the war https://razumkov.org.ua/en/articles/ukraines-renewable-energy-sector-before-during-and-after-the-warA. Author1, Book Title, Publisher, City (2019), pp. 154-162.

[6] M. Belik and L. Nohacova, "Small Hydro Power Plants Operating As Backup Source In Local Island," 2019 20th International Scientific Conference on Electric Power Engineering (EPE), Kouty nad Desnou, Czech Republic, 2019, pp. 1-6, doi: 10.1109/EPE.2019.8777948.

[7] Belik, M. Passive solar systems enhanced efficiency. Renewable Energy & Power Quality Journal (RE&PQJ), 2019, p. 235-239. ISSN 2172-038X.

[8] Lezhniuk P, S. Kravchuk, I. Kotylko, Sobchuk and Hunko, "Modelling of electrical supply restoration in local electrical systems after loss of centralized power," 3rd International Conference on Intelligent Energy and Power Systems, 2018

[9] P. Lezhnyuk, V. Komar, S. Kravchuk and D. Sobchuk, "Mathematical modeling of operation quality of electric grid with renewable sources of electric energy," 2017 International Conference on Modern Electrical and Energy Systems (MEES), Kremenchuk, Ukraine, 2017, pp. 324-327, doi: 10.1109/MEES.2017.8248923.

[10] P. Lezhniuk, V. Komar and S. Kravchuk, "Regimes Balancing in the Local Electric System with Renewable Sources of Electricity," 2019 IEEE 20th International Conference on Computational Problems of Electrical Engineering (CPEE), Lviv-Slavske, Ukraine, 2019, pp. 1-4, doi: 10.1109/CPEE47179.2019.8949118.

[11] Faraji, J, Hashemi-Dezaki, H, Ketabi, A. Optimal probabilistic scenario-based operation and scheduling of prosumer microgrids considering uncertainties of renewable energy sources. Energy Sci Eng. 2020; 8: 3942–3960. https://doi.org/10.1002/ese3.788

[12] M. Belik, "Emergency island grids with small hydro power stations," in Proceedings of the 10th International Scientific Symposium on Electrical Power Engineering, ELEKTROENERGETIKA 2019, 2019, pp. 116-121.

[13] S. Fedorchuk, A. Ivakhnov, O. Bulhakov and D. Danylchenko, "Optimization of Storage Systems According to the Criterion of Minimizing the Cost of Electricity for Balancing Renewable Energy Sources," *2020 IEEE KhPI Week on Advanced Technology (KhPIWeek)*, Kharkiv, Ukraine, 2020, pp. 519-525, doi: 10.1109/KhPIWeek51551.2020.9250155.

[14] M. Bělík, J. Škorpil, and J. Muhlbacher, "Mathematical model of 20 kWp photovoltaic system," in Proceedings of the 4th International Scientific Symposium on Electric Power Engineering, ELEKTROENERGETIKA 2007, 2007, pp. 197-199.

[15] M. Belik, "Optimisation of energy accumulation for renewable energy sources," Renewable Energy and Power Quality Journal, Article vol. 19, pp. 205-210, 2021, Art. no. 258.

[16] M. Bajaj, A. Singh, M. Alowaidi, N. Sharma, S. Sharma, and S. Mishra, "Power Quality Assessment of Distorted Distribution Networks Incorporating Renewable Distributed Generation Systems Based on the Analytic Hierarchy Process," IEEE Access, vol. PP, pp. 1-1, 08/05 2020.

[17] Qawaqzeh, M., Dudnikov, S., Miroshnyk, O. Development of Algorithm for the Operation of a Combined Power Supply System with Renewable Sources, (2022) 2022 IEEE 3rd KhPI Week on Advanced Technology, KhPI Week 2022 - Conference Proceedings

[18] J. Faraji, A. Ketabi, H. Hashemi-Dezaki, M. Shafie-Khah and J. P. S. Catalão, "Optimal Day-Ahead Self-Scheduling and Operation of Prosumer Microgrids Using Hybrid Machine Learning-Based Weather and Load Forecasting," in IEEE Access, vol. 8, pp. 157284-157305, 2020, doi: 10.1109/ACCESS.2020.3019562.

[19] Standart NERCEP about requirements for wind and solar power plants when working with the united power system of Ukraine,. [Online]. Available: https://ua.energy/wp-content/uploads/2019/06/SOU-NEK-341.001_2019.pdf