Smart Demand Side Management for Techno-Economic Analysis of Microgrid System

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Abstract: - The world uses about 20 trillion kilowatt hours of electricity annually. Because of this great level of necessity, the use of green energy is growing and is becoming more and more significant in today's society. Demand-side management (DSM) programs are described as the procedures for planning, carrying out, and overseeing the tasks assigned by electric utilities to encourage customers to adjust their loads and energy usage in order to reduce power consumption and lower their electricity costs. It is utilized in smart grid systems to balance energy generation and consumption in a way that benefits both customers and utilities, to achieve the goals of utility energy policies, and to modify the quantity and quality of power and electricity used. Customers should have the capacity to control their energy consumption, especially during peak usage, to enable them to make better informed decisions. Demand response (DR) and energy efficiency techniques were employed by DSM to assist energy users in lowering their consumption. to increase resilience, economy, sustainability, and efficiency. The main objective of this study is to apply two demand side management strategies, examine power flow analysis on distribution networks utilizing IEEE rules both before and after PV cells are integrated, and assess the impact of doing so. The approaches' practicality is confirmed by comparing the simulation results from one technique with the other. For the end user, lowering their electricity cost is their primary goal.

Key-Words: - Demand Side Management (DSM), Smart Grid (SM), Demand Response (DR), Renewable Energy (RE), Energy Management, Electricity Market Price.

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1 Introduction

The global energy transformation is gaining momentum due to the recent acceleration of change and massive increases in electrical power consumption. This creates a critical need to find new resources and ways to meet demand without having a significant negative impact on the environment and achieving sustainable growth. The introduction of new machinery and equipment that heavily rely on power consumption, such as smart appliances, electric vehicles, and whole-house monitoring systems, is anticipated to result in a 30% rise in the demand for electricity in 2035, according to the U.S. Department of Energy [1]-[2].

Because of the extensive use of oil, fuel, coal, and gas to meet power demand, CO2 emissions are rising, and nonrenewable energy sources are becoming less available. To try to solve this problem, many organizations and governments have begun to use renewable energy as the primary power resources in all of their forms, such as wind turbines and solar panels. The photovoltaic (PV) system is receiving the most attention out of all the renewable energy sources because it is the easiest to install and calculate, and because PV cell efficiency is rising, battery system technologies are improving, and the initial cost of PV modules is falling [3]-[4].

The energy sector is particularly important in Palestine, owing to the numerous constraints that exist in the Palestinian energy sector. The Palestinian government is unable to develop a domestic electricity resource, and the loss of all authority over the energy sector has a negative impact on the power electric distribution network in Palestine, depriving many Palestinians of electrical power throughout the day. From an economic standpoint, Palestine faces significant challenges importing electricity and fuel. All of this stems from the country's political viewpoint. The majority of the power used in Palestine originates from Israel, whose government fully controls all energy resources and can decide how much power to grant the Palestinians due to political disputes. Site investigations reveal that the Israel Electric Company (IEC) supplies 92.6% of the power used in Gaza and the West Bank. Jordan accounts for 1.5% of the remaining electricity demand, Egypt for 0.6%, and the Gaza Power Plant for 4.4% [5].

Due to its heavy reliance on imported energy resources from Palestine, the Palestinian Authority (PA) has an estimated debt of $574 million USD. Furthermore, the cost of energy (CoE) in Palestine is relatively high; for the residential sector, it is estimated to have reached 0.6215 ILS/kWh [6]. The decision-makers are under tremendous pressure to find solutions to the problem that benefit the PA as well as the Palestinian end users as a result of all of this pulling at their strings.

The development of multi-source energy systems is linked to the implementation of smart grids, and these systems are acknowledged as the fundamental building blocks of smart grid architecture. Whether the source is multi-source, integrated into the transmission network or distribution system, uses direct current (DC) or alternative current (AC), high voltage or low voltage, or any combination of these, using smart energy management is always the best and most effective way to control these power system components [7].

One of the major problems the utilities face is the peak demand in the electricity grid, which used to be solved by supply side management in the past. However, nowadays, the new techniques of demand side management have been taken into consideration. Also, the main problem that affects the end user more this time is the price of electricity. Consumers prefer to have minimum electric bills as much as possible. While the implementation of the DSM in SG can easily solve these two problems by handling direct load control (DLC) programs that use load patterns and profiles, analyze them and reshape them which keeps the demand for electricity in balance with the available supply. Applying all the previous techniques reduces the peak load demand of customers, thereby improving grid stability, sustainability, and security; additionally, it decreases the grid operation and electricity cost; minimizes carbon emission levels; and reduces the monthly electric bill [8]- [10].

Demand side management technologies were initially examined in the 1970s as a potential remedy for the world energy crisis. DSM has been widely used in a variety of measuring tools recently. For example, in 2019, the US regional transmission operator PJM almost activated 11 GW for demand-side resource market delivery. [11]. Demand Side Management (DSM) is crucial because it gives users control over how much energy they use, which lessens the strain on the network.

In general, there are three main types of DSM that divide into [12]-[15]:

1.Energy Efficiency: This technique aims to reduce the high loads of power consumption by adopting more new appliances that have energy saving technologies like inverter air condition system or LED technology in homes, and public places, or even the streets, and sometimes adding the PV systems.

2.Dynamic Demand: This technique involves raising the factor of load diversity by moving the working cycles for the appliances and sometimes-huge machines by a few seconds, or in some cases delay this cycle if needed.

3.Demand response: that can be explained as using the electricity tariff and load demand pattern in order to create offers and incentives to the end-users, to encourage them to changes their form of energy consumption in a way that achieves noticeable reduction in the consumption of power and saves energy.

The DSM techniques are: load shifting, flexible load shape, strategic load growth, valley filling, strategic conservation and peak clipping [12], [16]-[18]

1.Valley filling: increase the load during off-peak hours by reducing tariffs to encourage customers to spend energy. This technique can be achieved by thermal energy storage

2.Peak clipping: decrease the load during peak hours when the generated power is not enough to cover the peak demand

3.Load shifting: the demand is shifted from peak to off-peak hours by reducing tariffs to encourage customers to spend energy

4.Strategic conservation: used to reduce the overall energy consumption

5.Strategic load growth: used to increase the overall energy consumption by reducing tariffs to encourage customers to spend energy

6.Flexible load shape: it is used to shift peak energy at the time of reducing costs, or at the time with more renewable energy resource availability, in order to allow the utility to meet system recruitments. The DSM strategies are shown in Figure 1.

The main objective of this work is the ability to identify, formulate, and solve engineering problems in the field of smart grid technology and the ability to use the techniques, skills, and modern engineering tools necessary for engineering practice in that field of work.

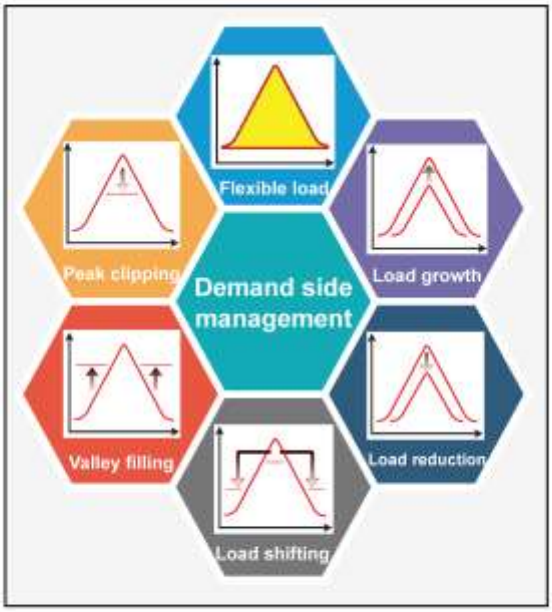

Fig. 1: Demand-side management techniques [12]

Since it is very important to exploit the energy produced as much as possible, many ways have emerged to serve this goal, such as the addition of distribution generators (DG's) on the network to avoid long-distance energy transport and its associated problems, as well as reducing carbon emissions. In this article, the effect of adding two types of DG synchronous and PV to the IEEE 12-bus distribution system that is shown in Fig.1 is being investigated. The optimal location of the DG's is important; the wrong choice of installation of DG's may lead to an increase in system losses and costs; the decided optimal location is based on. The simulation has been carried out by MATLAB Simulink and Excel. After the construction of a 12-bus distribution system with a power factor of 0.92 for the synchronous and PV distribution generators, the voltage profile, the voltage stability margin and power losses were calculated before and after the installation of the DG to study the impact of the DG on it. Then, using DSM technology to improve the system, all results were compared with and without DSM.

2 Problem Formulation

This study discusses the effect of adding two types of DG synchronous and PV to an IEEE 12-bus distribution system with two main types of loads, the constant load with a base case and synchronous generator and the dynamic load with a base case and a photovoltaic case. The single line diagram of the original system that has been investigated is shown in Fig. 2. The optimal location of the DG's is important; the wrong choice of installation of DG's may lead to an increase in system losses and costs.
After the construction of 12-bus distribution system with a power factor of (0.94-0.99) for the synchronous and PV distribution generators, the voltage profile, the voltage stability margin and power losses were calculated before and after the installation of the DG to study the impact of the DG on it. Then, using DSM technology to improve the system. All results were compared with and without DSM.

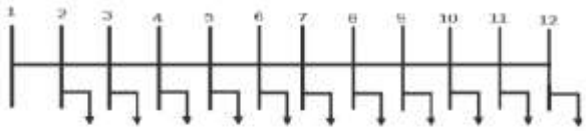

Fig. 2: Single line diagram of the 12-bus radial distribution network

3 Problem Solution

In this study, constant load and dynamic load have been considered.
Figure 3 shows the Simulink implementation for constant load in the IEEE 12 bus system.

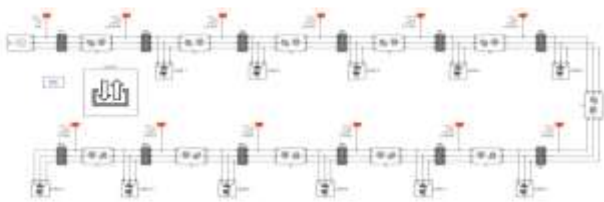

Fig. 3: Simulink implementation for constant load IEEE 12 bus system

Figure 4 shows the voltage profile for the constant load case.

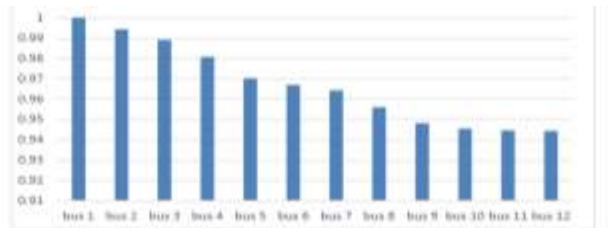

Fig. 4: Voltage profile for constant load case

The second step in the constant load was adding a synchronous generator to the system, then applying different values of penetration levels of the generator on the system where PL= (Penetration level) is the ratio of quantity of power that can DG supply to the Network (0-100%). Figure 5 shows the system with synchronous generator connected at bus 9.

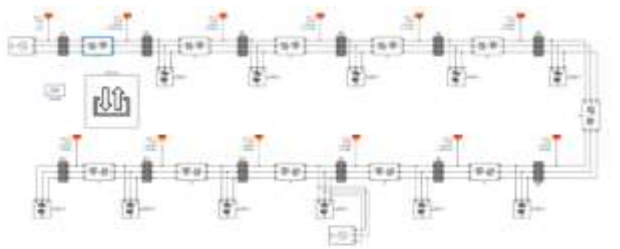

Fig. 5: Simulink implementation for Constant load IEEE 12 bus system with synchronous generator

Figure 6 shows the voltage profile of the system with synchronous generator and with several penetration levels. The increase in penetration level leads to improve the voltage profile and reduce the losses.

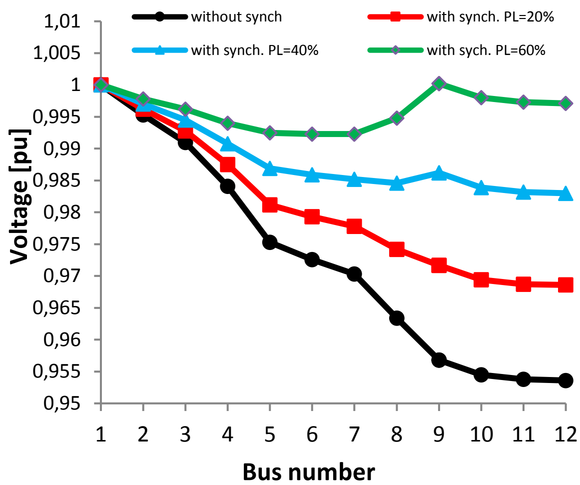

Fig. 6: Voltage profile comparison for the system with synchronous generator and multi-PL.

The second case that has been considered in this study is the dynamic load. Residential load is a term, which is used to describe the amount of electricity entering a residence at any given time. The amount of electricity a residence can access is typically limited by the amount of its service drop. Figure 7 shows the residential load connected on the considered system.

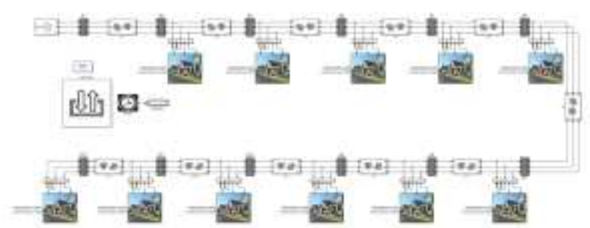

Fig.7: Residential load connected on the system

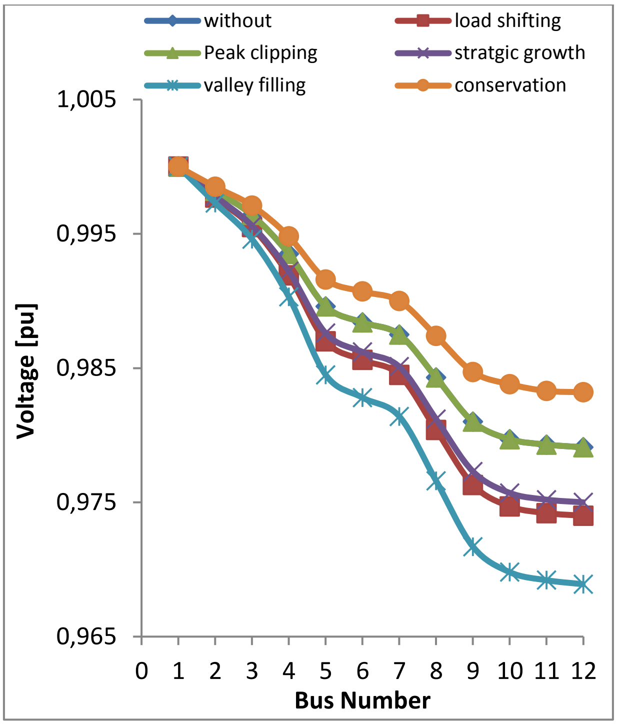

Fig. 8: Voltage profile comparison for the system with residential loads.

Table 1: Comparing the voltage profile between different DSM techniques

DSM tech.	P_{loss} (kW)	Q_{loss} (kVar)
with out	5.609	2.151
load shifting	8.671	3.324
peak clipping	5.609	2.152
strategic growth	8.006	3.069
valley filling	12.372	4.743
conservation	3.628	1.392

4 Conclusion

This article studied the impact of different integrating distribution generators in different sizes on the voltage profile, voltage stability, and power losses of radial systems. The results prove that the integration of DGs on distribution networks, taking into consideration their location (at bus 9) and penetration level, improves the voltage profile and voltage stability and greatly reduces losses. The results also demonstrated the power of DSM in the service of energy systems in many aspects, such as economically and technically.

From the case study above, it’s clear that DSM programs provide a great benefit to both utilities and end users. They don’t have to construct new power plants in order to meet the load, and they turn aside

the network problems that increase the system reliability in a direct manner and improve the industry and market of electricity in general.
From customer's point of view, their electricity bill is reduced by integrated renewable resource planning and the integration of a distribution generator with demand side management technology, which helps in solving the high demand and high cost and achieving the goals for both environmental and social improvement.

References:

[1] Fouad Zaro, Technical and Economic Study of On-Gird Solar Rooftop PV system Using PV Syst Software: A Case Study, *International Journal of Environmental Engineering and Development*, vol.1, pp.127-133, 2023.

[2] Carina Beermann, "Implementation of Energy Management in the Industrial Sectors," *WSEAS Transactions on Power Systems,* vol. 16, pp. 128-138, 2021.

[3] Fouad Zaro, Noor A. Ayyash, Design and Management of Hybrid Renewable Energy System using RETscreen Software: A Case Study, *International Journal of Electrical Engineering and Computer Science*, vol.5, pp. 164-170, 2023.

[4] Dey B, Dutta S, Garcia Marquez F.P. Intelligent Demand Side Management for Exhaustive Techno-Economic Analysis of Microgrid System. *Sustainability*, 15, 1795, 2023.

[5] Palestinian Central Bureau of Statistics. Energy Balance of Palestine 2018. Ramallah—Palestine. 2019. Available online: http://www.pcbs.gov.ps/Portals/_Rainbow/Documents/Energybalance-PHY-E2018.html.

[6] Juaidi, A.; Montoya, F.G.; Ibrik, I.H. Manzano-Agugliaro, An overview of renewable energy potential in Palestine, *Renew. Sustain. Energy Rev.* 65, pp.943–960, 2016.

[7] Mohammad Abolhasanpour, Amir Abolfazl Suratgar, Renewable Energy and Demand-Side Management: Micro-Grid Power Market Control Using Stackelberg Discounting Play, *WSEAS Transactions on Power Systems*, vol. 13, pp. 1-12, 2018.

[8] Hajji Abdelghani, Lahlou Yahya, Abbou Ahmed, Energy Optimization and Management in a Building using Clean Energy, *WSEAS Transactions on Power Systems*, vol. 16, pp. 61-66, 2021.

[9] A. U. Rehman et al., An Efficient Energy Management in Smart Grid Considering Demand Response Program and Renewable Energy Sources, *in IEEE Access*, vol. 9, pp. 148821-148844, 2021.

[10] A. Nawaz, G. Hafeez, I. Khan, K. U. Jan, H. Li, S. A. Khan, and Z. Wadud, An intelligent integrated approach for efficient demand side management with forecaster and advanced metering infrastructure frameworks in smart grid, *IEEE Access*, vol. 8, pp. 132551–132581, 2020.

[11] Bayram, I. S. Demand-side management for PV grid integration. In J. Polo, L. Martìn-Pomares, & A. Sanfilippo (Eds.), Solar Resources Mapping: Green Energy and Technology, *Springer-Verlag*, pp. 313-325, 2019.

[12] Shewale, A.; Mokhade, A.; Funde, N.; Bokde, N.D. An overview of demand response in smart grid and optimization techniques for efficient residential appliance scheduling problem. *Energies*, 13, 4266, 2020.

[13] Eisenmann A, Streubel T, Rudion K. Power Quality Mitigation via Smart Demand-Side Management Based on a Genetic Algorithm. *Energies*, 15(4):1492, 2022.

[14] Shewale, A.; Mokhade, A.; Funde, N.; Bokde, N.D. A Survey of Efficient Demand-Side Management Techniques for the Residential Appliance Scheduling Problem in Smart Homes. *Energies,* 15, 2863, 2022.

[15] Sarker, E.; Halder, P.; Seyedmahmoudian, M.; Jamei, E.; Horan, B.; Mekhilef, S.; Stojcevski, A. Progress on the demand side management in smart grid and optimization approaches. *Int. J. Energy Res.*, 45, pp. 36–64, 2021.

[16] Salameh, K.; Awad, M.; Makarfi, A.; Jallad, A.H.; Chbeir, R. Demand side management for smart houses: A survey. *Sustainability*, 13, 6768, 2021.

[17] Panda, Subhasis, et al. A comprehensive review on demand side management and market design for renewable energy support and integration, *Energy Reports,* 10, pp. 2228-2250, 2023.

[18] Hassan MAS, Assad U, Farooq U, Kabir A, Khan MZ, Bukhari SSH, Jaffri ZuA, Oláh J, Popp J. Dynamic Price-Based Demand Response through Linear Regression for Microgrids with Renewable Energy Resources. *Energies*, 15(4):1385, 2022.

Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

The author contributed in the present research, at all stages from the formulation of the problem to the final findings and solution.

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Conflict of Interest

The author has no conflict of interest to declare that is relevant to the content of this article.