A modern technique to manage energy profile in Iraq: virtual power plant (VPP)

A A Kalaf¹,², O Sh Alyozbaky², A I Alghannam²

¹Master student, University of Mosul, College of Engineering, Electrical Department, Iraq
²University of Mosul, College of Engineering, Electrical Department, Iraq

Abstract. A virtual power plant (VPP) comprises decentralized generation integrated with energy storage and intermittent loads. Such a plant is an independently-controlled single production unit for the electrical grid and market. Frequency changes and power supply interruption are among the several scenarios that lead to peak grid loading. Considering the material and financial challenges, it is necessary to determine an optimal resource scheduling solution; VPP can address these challenges. This study evaluated two different domestic-sector situations in Iraq. MATLAB Simulink was used to simulate a VPP test system comprising loads, energy storage technology, and distributed generation. An analysis of the economic aspects concerning the network and involved resources was performed. The outcomes indicated that home electricity bills reduced by up to 50%. Simulations suggest that using VPP is beneficial as against distribution generators (DG) systems relying solely on intermittent renewable power generation.

1. Introduction
Increasing attention to renewable energy production enhances the feasibility of power generation closer to the consumer. This setting is expected to bring significant change to the energy industry. Distributed generation (DG) will soon account for a significant fraction of electrical power [1]. The increasing expansion of renewable power production is stimulated by the need to reduce reliance on presently-used non-renewable sources of energy. Wind and solar are the most extensively used renewable energy sources [2]. The VPP concept was formulated some years ago. It is based on the principle of a centralized control system integrating, regulating, and controlling several distributed generators [3].
Numerous large DG systems are unable to coordinate power output, specifically when there are rapid unplanned changes in generator power output. This is a challenging concern, and one possible solution is to integrate such DGs so that they can be understood as a single conventional power generator having better stability. The literature lists several aggregation techniques like micro-grids, active distribution networks, virtual power plants (VPPs), and virtual utilities [4][5].
In order to efficiently manage the growing number of distributed energy resources (DERs) and keep their management separate from main grid, researchers introduced a novel concept of virtual power plant (VPP)[6]. These VPPs efficiently support the integration of different variable DERs into energy markets such as solar photovoltaic panels, electric vehicles (EVs), controllable loads, storage batteries, etc. DERs participate in the energy markets in presence of multiple VPPs and carry out joint energy trading. It is possible to use VPP to reduce the load on the power distribution network. The locally generated energy is shared by several entities negating the need for high-tension long-distance power
transmission. There is an extensive shift in city planning and urban development. Cities account for about 70% of global resource consumption; hence, cities have extensive energy requirement and account for a significant fraction of greenhouse gas (GHG) emission. Cities have higher GHG emission because of urban population density, social and economic activity, and inefficiencies cropping from the constructed environment [7]. In the context of the existing scenario in Iraq, the country has been challenged by a serious shortage of electrical power since the Gulf War of 1991 that makes the daily life of the Iraqi people difficult. However, there are a number of prospects for the implementation of Renewable energy to address the current issue of power deficit.

The constantly growing demand for energy, along with the pollution issues related to fossil fuels, resulted in more scientific and practical initiatives associated with the development of RE sources to meet existing and future demand for clean and “green” electricity [8]. RE resources encompass solar photovoltaic panels, wind turbines and biomass. The feasibility of utilizing such resources will depend on whether they are available and if so, the level of availability in a particular location. As such, each country or region has its distinct outcomes in the deployment of RE sources. For instance, wind energy constitutes 14.7% that equals 11.7 gigawatt of overall generation in the European Union (EU) for electric energy in 2018, which continues to increase from year to year [9]. Also, globally, solar power potential was more than 300 GW in 2016, showing an increase of 100 GW in comparison with 2015 [10] according to the “Global Market Outlook for Solar Power, 2017-2021,” report. China was reported to have the capacity to add 34.5 GW to the grid in 2016 only, indicating an increase of 128% compared to the installed output in 2015 [11]. Nonetheless, Iraq’s current capability in respect of RE is modest if compared to the potential estimated for the country to produce by way of the stations that use oil, gas and steam. In 2011, it was reported that 80% of the energy produced were from fossil sources, with only two per cent contributed by hydro stations [12]. Given the many economic advantages of renewable energies and the environment, there is a global trend to increase dependence on it. By 2040, 50% of the energy sources in the European Union will be from renewable energy sources, and 30% of energy sources in China (the second largest global economy) will be produced from alternative energy sources [13].

Many researchers carried out experiments using PV cells in Iraq, but these experiments did not present satisfactory results. The PV cells are generally used for lighting the community street lights. However, these lights were not effective against the Iraqi weather since Iraq is plagued by dusty days. These factors have decreased the application of PV cells. Despite these problems, the PV cells can be used in the community water pump plants or home rooftop systems, where the people cannot access the power grids [14].

Viable solar radiation data helps in understanding the usage of solar energy. The assessment of this data in Iraq is important for evaluating the benefits of renewable energy resources [15]. In their study, Ahmed (1988) [16] mathematically calculated the correlation between humidity, temperature and duration of solar radiation. They determined the relationship constants for 3 different regions in Iraq. Figure 1 describes the monthly and annual solar radiation maps for a fixed duration in 24 plants in Iraq [17]. The fundamental characteristics of solar radiation in Iraq are summarized as follows:

- In the northern regions, the annual radiations varied by 300%, ranging between 7 MJ/m2 (in December-January) and 23 MJ/m2 (in June). On the other hand, in the southern regions, the solar radiations varied by 200%, ranging between 13 MJ/m2 (Dec-Jan) and 27 MJ/m2 (Jun-Jul). In the central regions of Iraq, the annual solar radiation varied by 250%, which was regarded as the average annual variance between the northern and southern regions.
- The solar radiation decreased significantly from the northern to the southern regions and increased during the winter months, while it decreased during summer. During the summer (Jun-Aug), solar radiation showed a uniform distribution throughout Iraq.
- The decrease in solar energy from the eastern to western regions was seen to be the lowest and could lead to inaccurate assessment.

The assessment of the solar radiation was based on the relationship derived from the data which was determined by the meteorological stations located in the urban centres and cities in the country. These
regions were exposed to lesser solar radiation in comparison to the surrounding regions due to higher pollution levels. Thus, the actual solar radiation levels were higher than the measured values [18].

According to [19], Iraq receives an annually-averaged daily solar irradiation intensity of about 2000 kWh/m² to 2500 kWh/m². Figure 2 depicts global and normal solar irradiation distribution.

![Figure 1](image1.png)

**Figure 1.** Solar radiation times for other months in Iraq [16]

![Figure 2](image2.png)

**Figure 2.** Iraq’s direct and global solar irradiation [19].
This paper evaluates a novel method to implement the VPP strategy for engaging in the DA electricity market. The VPP proposed in the study comprises solar-cell based power generation, battery energy storage, conventional energy production, and varying energy loads. We simulated three different domestic load conditions that must be handled using a single VPP. MATLAB-Simulink was used for a small VPP design comprising three loads powered by a single distributed generation (DG) source. The models specified in this paper were designed after processing numerous scenarios concerning load regulation and market price management.

2. Effect of the environment on the VPP
The phenomenon of dust accumulation affects the overall performance of the solar panels. The accumulation of dust particles on the surface of the solar cells reflects the large amount of available solar radiation. Thus, reducing the net incident solar radiation received by the panels. As a result, this reduction will affect the energy output and efficiency of PV systems. This problem can be alleviated by introducing a cleaning mechanism that helps reduce dust build-up on the solar panels. It is suggested that the photovoltaic cells be cleaned periodically to avoid this drop and to ensure that the incident solar radiation is at its highest value in the corresponding weather condition.

On another hand, the capacity of solar cells is usually rated according to the standard test condition (STC), at a temperature of 25 degrees Celsius and solar radiation of 1000 watts per square meter. Solar panel heat, raising the electrical efficiency by one of the indirect or direct cooling methods, reducing the temperature and raising the efficiency of the solar panel.

3. The initial cost of the system
The initial cost is one of the biggest drawbacks of solar panel systems, for example at present the average cost of solar energy in Iraq may be about ($ 1 per watt) in an On grid system without batteries, so a 3 kW solar panel system will cost About (3000 dollars) on average, either in the (Hybrid) system, with batteries added to nearly every six batteries, on average approximately (1000 dollars), where the initial cost varies according to the type of devices, panels, batteries and their capacity.

4. Method and Simulation models
In this work, there are three modes of houses were simulated and the load profiled was validate by actual data. Matlab-Simulink used to build the VPP with different variation of loads. The load of house was classified into: AC unit, heater, house appliances and lights. Figure 3 illustrate different load at house which has been use in this work.

Figure 3. Illustrate different load at house
The load was measured during 24 hours for three houses and the peak load was measured at appeared in Figure 4. These data of these houses were measured in one day in the summer in the Mosul city in Iraq.

![Figure 4. Load variation during 24 hours](image)

All these house were connected to grid network and supplied by smart meter to measure the Kw/hour observed form the network. The grid network simulated as three-phase has 6.6 KV and 1km transmission line with 50 Hz. Furthermore, the cost of electrical bill was calculated depending on the Ministerial tariff in Iraq. Figure 5. display the power meter and housed connected to the network grid.

![Figure 5. Houses connected to the grid network](image)

The different scenarios use here to appear the flexibility of this method to manage the power flow between the grid and the loads. In the first scenario, all the houses considered as a load only without used any sources. A new power supply from the solar cell which a 5 Kilowatt rate has been to one house added in the second scenario as appeared in Figure 6. The last scenario contained a power supply solar cell (5kw) and storage (batteries).

![Figure 6. Different scenario to simulate the loads](image)
The solar and load data was used to run the simulation for different loads with different scenarios. Figure 7 shown the look up tables for solar and load data.

To manage and monitoring the power flow between the grid and loads, the smart meter was designed. Smart meter consists of different measurements and comparators circuits with scopes. Figure 8 display the smart meter which design to appeared the power flow between the grid with the loads PV and batteries.

5. Results and discussion
The results will be categories into three sections, load, load with PV solar and load, PV solar with batteries. The readings were taken during two days (the first-day name (A) and second-day name (B). On the first day (A) the efficiency of the solar system was 90% and on the second day (B) 87%:
When three houses in two Days connected to the grid the total kilowatt observed from the grid is (9 kw), 2.5 kw, 3 kw and 3.5 Kw on the peak load respectively as shown in Figures 9.

![Figure 9. Houses connected to the grid network](image)

In the part of adding PV solar (5kw) which is usually used in many hoses in Iraq to one house, it is clearly appeared the effect of this PV to the load management. Figure 11 shown the values of power observed from the load.

![Figure 10. Load distribution for three houses during 24 hours](image)
While when used PV and batteries in the first house, the scenario has been different as shown in Figure 12. The load management has been improved and these sources covered most of the loads observed from the grid as appeared in Figure 13.
As an outcome, in the first case for two Days, when there were only loads without a power supply source in the system, the daily consumption cost was great. In the second case, when there were loads with a power supply from the PV system, the daily consumption cost was nearly halved as appeared in Table 1. In the third case, when there were loads with a power supply of PV and batteries in the system. In the third case, when there were loads with solar panels with batteries, it was noticed that on the first day, the efficiency of the solar panels was 90%. The profit was 121 dinars during the day from returning the surplus capacity to the national grid. On the second day, the efficiency of the solar system was 87%. It was noticed that there is a total consumption bill during the day, which is only 5 dinars

| Cases | Day | Net Profit from supply the energy to Grid (IQD/Day) | Net Consumption from drawing the energy from Grid (IQD/Day) |
|-------|-----|-----------------------------------------------------|----------------------------------------------------------|
| Case1 | A   | 0                                                   | 728                                                      |
|       | B   | 0                                                   | 1043                                                     |
| Case2 | A   | -                                                   | 298                                                      |
|       | B   | -                                                   | 630                                                      |
| Case3 | A   | 121                                                 | -                                                        |
|       | B   | -                                                   | 5                                                        |

6. Conclusion
A simulation model by using the MATLAB-SIMULINK program to simulate the virtual power system (VPP) and show the effect of its use on the electrical network. Several scenarios were taken for houses with different actual loads to identify the daily peak loads and calculate the cost of electrical energy consumed in homes according to the tariff set by the Iraqi Ministry of Electricity. Explain the circuit’s construction, as well as the smart meter for which the amount of power drawn and supplied to and from the electrical grid or the public line is designed. The results show that by using the VPP system, the electricity bill has been reducing in a half for the households combined. Also, one of the important results is that adding any energy sources, whether it be wind energy, batteries, or any clean energy, and managing it through VPP, will reduce the electricity bill and can be brought into the market and of economic benefit for homes that share you as sources of energy.

7. Acknowledgment
The authors would like to thank Mosul University, College of Engineering, Electrical Department, for the support given during this work.

8. References
1. Naina PM, Rajamani HS, Swarup KS. Modeling and simulation of virtual power plant in energy management system applications. In: 2017 7th International Conference on Power Systems, ICPS 2017. IEEE; 2018. p. 392–7.
2. Guerra G, Martínez Velasco JA. A virtual power plant model for time-driven power flow calculations. AIMS Energy. 2017;5(6):887–911.
3. Nikonowicz Ł, Milewski J. Virtual Power Plants-general review: structure, application and optimization. J Power Technol [Internet]. 2012;92(3):135–49.
4. Ruiz N, Cobelo I, Oyarzabal J. A direct load control model for virtual power plant management. IEEE Trans Power Syst. 2009;24(2):959–66.
5. Renewable IET, Generation P, Hasanuddin U. Artificial Neural Network-Polar Coordinated Fuzzy Controller Based Maximum Power Point Tracking Control Under Partially S .... Artificial neural network-polar coordinated fuzzy controller based maximum power point tracking control under partially shaded c. IET Renew Power Gener. 2018;1(July 2009):10–6.
6. Hassan MU, Rehmani MH, Chen J. VPT: Privacy Preserving Energy Trading and Block Mining Mechanism for Blockchain based Virtual Power Plants. 2021;1–17. Available from: http://arxiv.org/abs/2102.01480
7. Agbozo E, Masih A. Virtual power plants: Powering smart cities of the future. Int Multidiscip Sci GeoConference Surv Geol Min Ecol Manag SGEM. 2018;18(4.1):815–22.
8. Cazzaniga R, Rosa-Clot M, Rosa-Clot P, Tina GM. Integration of PV floating with hydropower power plants. Heliyon [Internet]. 2019;5(6):1–8.
9. Henderson AR. Offshore wind in Europe 2017 Annual Report. Refocus. 2017;3(2):14–7.
10. Solar Power Europe (SPE). Global Market Outlook for Solar Power: 2019-2023 [Internet]. Global Market Outlook. 2019. content/uploads/2019/05/SolarPower-Europe-Global-Market-Outlook-2019-2023.
11. Blaga R, Sabadus A, Stefu N, Dughir C, Paulescu M, Badescu V. A current perspective on the accuracy of incoming solar energy forecasting. Prog Energy Combust Sci [Internet]. 2019;70:119–44.
12. https://www.moelc.gov.iq/home/part/annual-reports/view/home-news-1561985056. 2019.
13. Europe, S., Global market outlook for solar power 2017-2021. Solar Power Europe: Brussels, Belgium. 2017. 2021.
14. Khalifa AJN. Evaluation of different hybrid power scenarios to Reverse Osmosis (RO) desalination units in isolated areas in Iraq. Energy Sustain Dev [Internet]. 2011;15(1):49–54.
15. Ahmad I, Al-Hamadani N, Ibrahim K. Solar radiation maps for Iraq. Sol Energy. 1983;31(1):29–44.
16. Ahmed ST. Sudy of Single-Effect Solar Still With an Internal Condenser. Sol Wind Technol. 1988;5(6):637–43.
17. Curtis Austin, Ralph Borja and JP. Operation Solar Eagle: a study examining photovoltaic (PV) solar power as an electrical power generation infrastructure NAVAL POSTGRADUATE. 2005.
18. Ahmed ST. A review of solar energy and alternative energies applications in Iraq. In: In The First Conference between Iraqi and Germany Universities DAAD, Arbil, Iraq. 2010.
19. Raumfahrtzentrum. DL. Concentrating Solar Power for the Mediterranean Region; Final Report; German Aerospace Center (DLR): Cologne, Germany., 2005.