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# Performance of Vehicle-to-Grid Integrated with PV-Diesel Microgrid System in Libya's Southern Region

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**Keywords:**
Off Microgrid (PV-V2G-Diesel)
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**ABSTRACT**

In Libya's southern region, where there is abundant solar energy potential and frequent power blackouts, reliable and cost-efficient microgrid solutions are essential. This case study suggests implementing a Control based approach to assess using Vehicle-to-Grid (V2G) technology for off microgrid consists of (PV-EV-diesel) to operate AC motor pump. The setup involves a 60 kWh Electric Vehicle linked through an 11-kW bidirectional charger to deliver frequency support and manage energy trading. A control optimizes the EV's charging and discharging to reduce diesel consumption, taking into account initial battery state of charge as well as charging limits, and soiling effect. Results from MATLAB/Simulink simulations on a summer day indicate decrease in diesel usage, it is only 14.6 KWh equivalent to about 2.5 hours out of 12-hour daytime operation, and maintaining frequency deviation within ±0.5 Hz. The control system proves effective for V2G performance. This paper results confirm that V2G technology is a practical solution for improving the resilience islanded microgrids.

# أداء المركبة الى الشبكة بالتكامل مع شبكة صغيرة (الالواح الكهرو شمسية ومولد ديزل) في جنوب ليبيا

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قسم الطاقات المتجددة ، كلية الهندسة ، جامعة سبها ، ليبيا

**الكلمات المفتاحية:**
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**الملخص**

في المنطقة الجنوبية من ليبيا، التي تتمتع بإمكانات هائلة للطاقة الشمسية وتعاني من انقطاعات متكررة في التيار الكهربائي، تبرز الحاجة الملحّة لحلول الشبكات المصغرة (microgrids) التي تتسم بالموثوقية والجدوى الاقتصادية. تقترح هذه الدراسة تطبيق نهج يعتمد على "التحكم بتقنية "المركبة-إلى-الشبكة" (V2G) في شبكة مصغرة هجينة (تجمع بين الطاقة الشمسية الكهروضوئية ومولدات الديزل). يعتمد النظام على مركبة كهربائية بسعة بطارية 60 كيلوواط-ساعة، متصلة عبر شاحن ثنائي الاتجاه بقدرة 11 كيلوواط، وذلك لتوفير دعم للتردد وإدارة عمليات تبادل الطاقة. ويضمن تحكماً سريعاً في التردد، ويعمل نظام التحكم على تحسين عمليات شحن وتفريغ المركبة الكهربائية لتقليل استهلاك الديزل، مع مراعاة حدود حالة شحن البطارية. وتشير نتائج المحاكاة باستخدام برنامج (MATLAB/Simulink) ليوم صيفي إلى انخفاض في استهلاك الديزل، حيث استخدم حوالي 14.6 KWhوهدا يكافئ حوالي ساعتان ونصف تشغيل من 12 ساعة عمل يومي مع الحفاظ على انحراف التردد ضمن نطاق ±0.5 هرتز. وقد أثبت النظام فعاليته. وتؤكد النتائج أن تقنية (V2G) تُعد حلاً عملياً لتعزيز مرونة الشبكات المصغرة في المناطق المعزولة عن شبكة الكهرباء العامة.

## 1. Introduction

The rise in the use of renewable energy sources like photovoltaic systems, along with frequent power outages in the southern part of Libya, has posed significant challenges for the reliability of rural microgrids. Southern of Libya, known for its high solar irradiance of more than 2200 kW/m² and temperatures surpassing 45°C, heavily depends on diesel generators to power agricultural equipment, especially water pumps. However, the inconsistency of PV power generation and the expensive operation of diesel generators lead to an unreliable and economically inefficient energy provision [1].

At the same time, the adoption of Electric Vehicles (EVs) is expected to increase rapidly in the MENA region, with modern EVs having battery capacities ranging from 60 kWh to 100 kWh [2]. Typically, EVs are seen as one-way power consumers. The concept of Vehicle-to-Grid (V2G) changes this by allowing bidirectional power flow,

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enabling the EV battery to function as a distributed energy storage system (DESS). [3][4]

By using a bidirectional charger, the EV can take in surplus PV power during peak sunlight hours and feed power back into the microgrid when demand is high or generation is low. It is important that when a power disturbance happens, the V2G power modifies the net electrical load in the swing equation. EVs discharge power into the grid to stop the frequency from dropping. [5]

Hybrid energy management optimization is crucial for Libya's local ecosystem, as it enables the incorporation of renewable energy sources, such as PV systems and EV, into the current microgrid. This transition aims to lessen reliance on fossil fuels [1]. Through the adoption of hybrid systems, Libya can successfully tackle the issues related to inconsistent power supply while attaining a reduction in greenhouse gas emissions of about 50% in comparison to traditional energy sources.

This case study suggests an optimization control -based V2G approach for a PV-EV-diesel microgrid system. The setup consists of a 10.25 kWp PV array, a 6-kW induction motor pump representing a common agricultural load, and a 60 kWh EV connected through an 11-kW bidirectional charger. The control algorithm keeps grid frequency within ±0.5 Hz by using the EV as a quick buffer. Performance evaluation demonstrates a significant decrease in diesel fuel usage [5] [6].

The structure of this paper is as follows: Section 2 details the system modelling, Section 3 introduces the V2G control approach, Section 4 displays MATLAB/Simulink outcomes, and Section 5 wraps up the paper.

## 2. System Modelling

Generally, V2G in Smart Load Management. In the peak shaving phase, energy from electric vehicles is used during high-demand periods to alleviate pressure on both the electrical grid and power generation systems. In the valley-filling phase, vehicles charge during nighttime or off-peak hours to take advantage of excess, low-cost energy resources. Renewable Energy Integration is capturing surplus energy from solar sources in batteries and releasing it when those renewable resources are not generating power [7][8].

Frequency and voltage stability support quick battery response helps to prevent disruptions in microgrid power supply. A backup power source can provide energy to essential facilities within a microgrid [5][9].

The proposed V2G-enabled microgrid consists of a PV array considering soiling in the southern region, a bidirectional V2G charger interfacing a 60 kWh EV battery, a grid-forming inverter, and a 6-kW induction motor pump load. A backup diesel generator is included for reliability during extended low-irradiance periods.

### 2.1. Photovoltaic Array Model

The PV output power is modeled considering irradiance $G$, cell temperature $T_c$, and soiling loss $D_s$ typical of southern Liya's desert climate [8],

$$P_{pv}(t) = \frac{G(T)}{1000} P_{pv,STC}(t)|1 - \gamma(T_c(t) - 25)|(1 - D_s) \quad (1)$$

where $P_{pv,STC}(t)$ is limited to $10.25$ kWp, $\gamma = 0.004\ /°C$ is the temperature coefficient, and $D_s = 0.3$ is assumed for a 15-day dust accumulation period without cleaning that reduce peak of the solar power generation to $P_{pv}(t) = 8.25$ kWp. The cell temperature is estimated as $T_c(t) = T_{amb} + 0.03G$, with $T_{amb} = 45°C$ at midday [8].

### 2.2. EV Battery and Bidirectional Charger Model

The EV battery State of Charge (SoC) is given by Coulomb counting [8],

$$SoC(\mathrm{t}) = SoC(t_0) - \frac{1}{E_{ev}} \int_{t_0}^{t} \eta_{ch} P_{v2g}(\tau)\, d\tau \quad (2)$$

where $E_{ev} = 60\ KWh$, $P_{v2g} > 0$ denotes discharge to grid V2G, and $P_{v2g} < 0$ denotes charge G2V. $\eta_{ch} = 0.95$ is the round-trip charger efficiency. The charger power is limited as $|P_{v2g}| \le P_{v2g,max} = 11\ KW$ and $20\% \le SoC \le 90\%$ to prevent deep discharge and thermal stress. EV's battery degradation is not considered in this paper.

### 2.3. AC Microgrid and Pump Load Model

For grid form inverter, the AC bus frequency dynamics are represented by the swing equation,

$$H\frac{df}{dt} = P_{gen} - P_{load} - D\Delta f, \quad (3)$$

where $H = 2$s is the equivalent inertia, $D$ is the damping coefficient, $\Delta f = f - f_{nom}$ , $and$ $f_{nom} = 50$ Hz, and when a power disturbance happens, the V2G power $P_{v2g}$modifies the net electrical load $P_{load}$ in the swing equation, $P_{e,\text{new}} = P_e - P_{v2g}$. Substituting this back into the swing equation shows how the V2G control loop actively dampens frequency changes,

$$f(t) = f_{nom} - R(P_{v2g}(t)) \quad (4)$$

It means the system is configured with a 10% droop characteristic ($R = 0.1$). [5]

The pump load is for the 6 kW, 4-pole motor at 1450 rpm, 50 Hz, considered as a torque proportional to speed squared, assuming its power factor is compensated in order to mitigate voltage drop in the microgrid.[10]

The diesel generator power is considered in an optimization base rule, which can be considered as a dispatchable source with a minimum loading constraint and is selected to cover the microgrid load [7].

**Table I**: System Parameters for the Case Study

| Component | Parameter | Value |
|---|---|---|
| PV Array | Rated Power, $P_{pv,STC}$<br>Soiling Loss, $D_s$ | 10.25 Kw<br>30% |
| EV Battery | Capacity, $E_{ev}$<br>V2G Power Limit<br>SoC Limits | 60 kWh<br>±11 kW<br>20% - 90% |
| Pump | Rated Power | 6 kW |
| Microgrid | $f_{nom}$ | 50 Hz |

## 3. V2G Control Strategy

To coordinate the PV, EV, and diesel generator, optimization is considered for fast frequency stabilization, and for optimal power scheduling and SoC management.

The bidirectional charger operates in grid-forming mode and emulates a virtual inertia. The V2G power reference is set using a *P-f* droop characteristic [5] [9], if $f < 49.5$ Hz, the EV discharges to support the grid. If $f > 50.5$ Hz due to PV surplus, the EV absorbs power G2V. This ensures frequency deviation $\Delta f$ is kept within ±0.5.

A discrete-time optimization is formulated to minimize using diesel fuel and to charge /discharge between battery limits values, while meeting a dynamic pump load. The controller-based rule firstly, gives PV priority then secondly V2G to meet demand load and avoid to operate diesel as can as possible. The optimization aims to provide represent of the minimization of diesel and battery degrading. For a microgrid or hybrid power system involving Vehicle-to-Grid (V2G) integration and diesel generation. heuristic rule-based optimization can be

$$P_{pv}(k) + P_{v2g}(k) + P_{diesel}(k) = P_{load}(k) \quad (5)$$

subjected to the following constraints,

$$SoC(k+1) = SoC(k) - \frac{\eta_{ch} P_{v2g}(k) \Delta t}{E_{ev}}$$

$$20\ \% \le SoC(k) \le 90\ \%$$

$$|P_{v2g}(k)| \le P_{v2g,max}.$$

$$49.5 < f < 50{,}5$$

It can be noted that EV's battery degrading with temperature and Diesel fuel cost are excluded from constrains.

## 4. Results and Discussion

The V2G operations is validated in MATLAB/Simulink for a 12-hour summer day with $PV - Load$ profile shown in Fig. 1. In 12-hour daytime operation, the PV produced power is considered according to equation (1), assuming $D_s = 0.3$, causing decrease in PV power from 10.25 kWp to 8.25 kWp, it covers time period between 6:00 and 17:00. During this period PV feeds a constant dynamic load of 6 KW. It can be noted that PV power only for just 2 hours is greater than load demand, so energy management is crucial for this type of PV system.

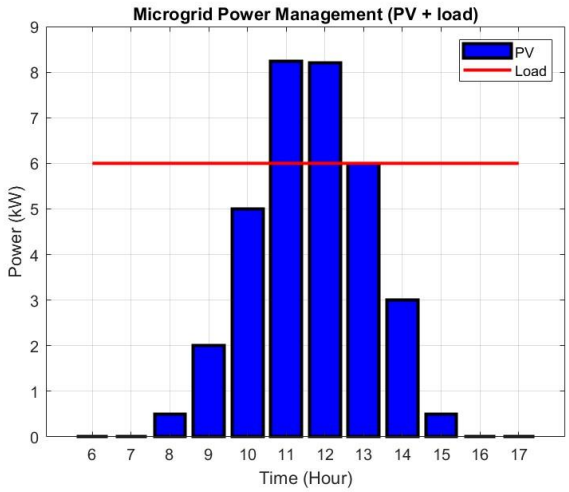



**Fig.1:** PV & Load Distributions

Fig. 2 shows the SoC of EV, which decreases during morning and evening peaks, while increases at midday because of charging from PV surplus. It can be seen that, when the initial SoC is maintained at 50%, and then it reaches to the lower limit (20%) at time of 15, ensuring the EV stops discharging. Consequently, by limiting the initial SoC to lower than 50%, the model performance is degraded and diesel consumption increases.

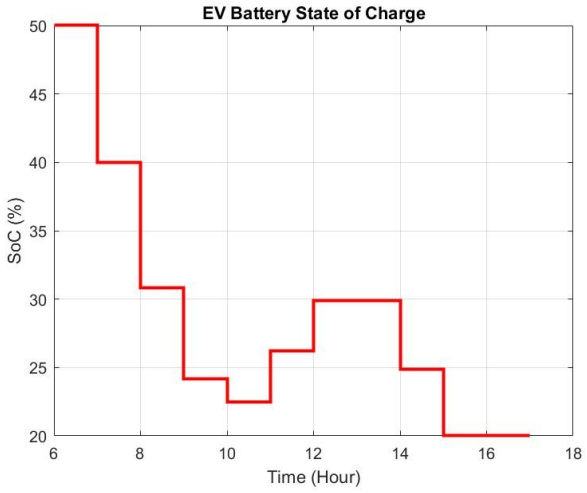



**Fig.2:** EV SoC

Fig. 3 shows the performance of the microgrid controller, it shows bar chart represent discharging hours (negative values) and charging hours (positive values) in blue color and diesel operating hours in red color. The EV discharges for 5 hours during morning and 2 hours during evening peaks, while charging for just 3 hours from PV surplus at midday. It can be seen that morning peaks lie in the V2G power limit, so diesel generator is off. At the time 15 when EV battery at lower limit, energy demand to be covered partially by diesel at 15 and fully by diesel for 2 hours after 15. It can be observed that V2G can lead to save fuel consumption when combined with PV system.

It can be observed from Fig. 4 the pie sectors for load demand for 29 KWh direct PV, 28.4 KWh V2G discharge and 14.6 KWh diesel generator contributions to the load, which represents 40%, 39% and 20% respectively. It can be seen the contribution of V2G is approximately equal to the contribution of the PV ensuring how it is important to exploit V2G technology to support micro grid performance led to decrease Diesel operation hours.

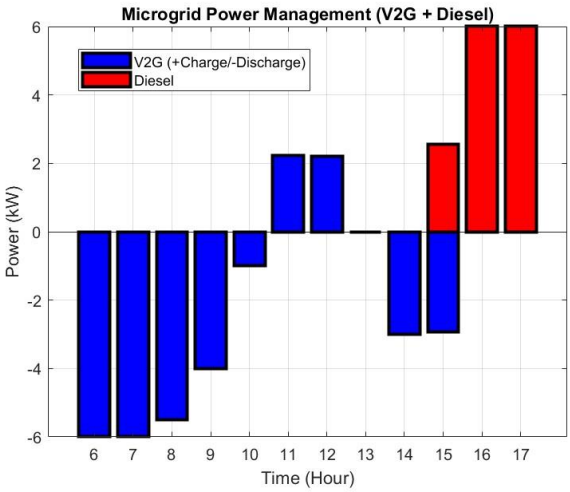



**Fig.3**: Microgrid Energy Distributions

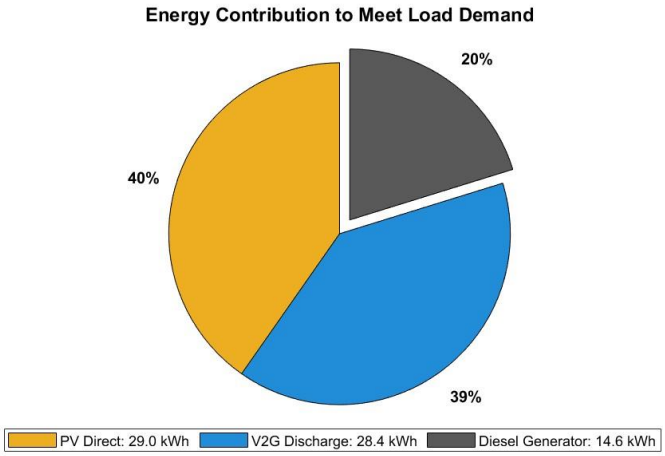



**Fig. 4** shows the sectors of energy contributions to meet load demand

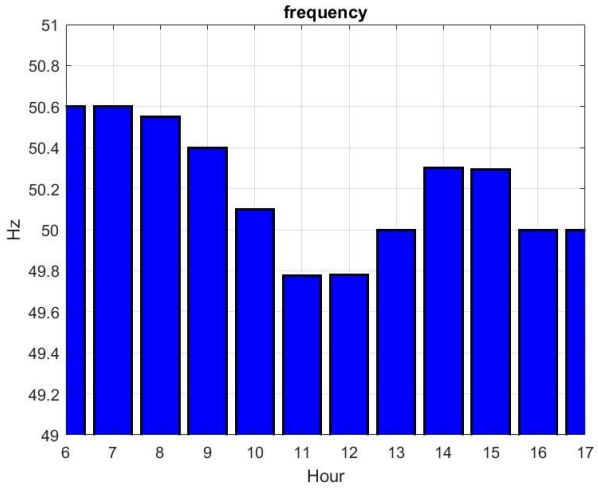



**Fig.5:** Micro grid Frequency deviation.

Fig. 5 shows the results based on equation (5), the V2G control loop actively dampens frequency changes. It can be seen that frequency remains within the limiting when switching micro grid power sources. By limiting f deviation, the model can operate AC load safely.

## 5. Conclusion

This paper introduced the importance of V2G technology in energy management plan for a PV-diesel islanded microgrid. To guarantee AC load operation when intermittent renewable energy source with stabilize frequency, the power exchange of a 60 kWh EV can be exploited to reduce diesel usage; the system is energy is managed through rule base logic controller.

Results from simulations illustrated that the suggested approach slashed daily diesel operation hours and kept grid frequency within limits approximately. we took into consideration specific challenges in southern Libya, such as PV dust accumulation.

The study affirms that EVs can act as movable energy storage to boost the dependability and sustainability of rural microgrids in arid climates. Furthermore, to extend the study for southern Libya climate challenges, a battery degrading over higher temperature as well as fuel cost and diesel generator power limits, can be further optimized by using optimization scheme based on linear/nonlinear objective function. In conclusion, V2G is technically viable in Libya's southern region with harsh environment.

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