MAXIMISING DIESEL GENERATOR FUEL EFFICIENCY WITH LTO BATTERY INTEGRATION

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Diesel generators are indispensable in areas lacking electricity infrastructure or requiring alternative power sources. However, while they offer significant advantages, they also suffer notable drawbacks, particularly in fuel efficiency during lower loads. Typically, generators operate in tandem with load profiles, resulting in inefficient operation during reduced loads. This article proposes a solution by integrating generator operation with a battery system. By combining the generator with batteries during periods of lower efficiency, we aim to enhance overall system efficiency.

Keywords:
diesel generator,
battery storage system,
energy management system,
round trip efficiency
lithium titanate oxide

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I Introduction

A diesel generator's (DG) performance is crucial for its effective operation in providing electrical power. Several key factors contribute to its overall performance. A diesel generator's power outputIzkor is typically measured in kW or MW. It should match the electrical load requirements to ensure efficient and reliable operation. Users must ensure that the generator's capacity is adequate for the connected load to avoid overloading or underloading, which can impact efficiency and longevity.

While diesel generators have many advantages, they also come with certain disadvantages. Considering these drawbacks when evaluating whether a diesel generator is the right choice for a particular application is essential. While the full article will delve into the pros and cons comprehensively, it is worth noting that one drawback is the lower efficiency observed at smaller loads.

Despite some disadvantages, diesel generators remain widely used due to their reliability, durability, and ability to provide continuous power for extended periods. When choosing a generator, weighing the advantages and disadvantages based on the application's specific requirements is essential. Additionally, technological advancements and alternative fuels may address some of these drawbacks.

In this article, we delve into the operation of DG for a particular load scenario in the absence of a local network. Within this framework, we analyse the challenge of low efficiency at lower loads, prompting the consideration of a Battery Energy Storage System (BESS) solution. The objective is to synchronise the operation of both components to minimise primary fuel consumption, thereby optimising DG efficiency at higher loads.

II Diesel Genset and Battery Energy Storage System

A Diesel Generator

The DG's efficiency exhibits notable variations in response to load fluctuations, as seen in Fig. 1 [1]. Notably, the system attains peak efficiency in 50 to 95% of the load, while performance diminishes significantly at lower values. This underscores the economic inefficiency associated with operating the generator at lower loads; however, it highlights the generator's adaptive nature to the supplied load.

In the same graph, we observe the efficiency curve representing the return cycle of the BESS LTO alongside the converter. Notably, this curve demonstrates significantly higher efficiency, reaching approximately 85%, and remains relatively constant across a broad operating range. This consistency makes it a compelling choice for integration with DG systems, offering potential synergies and improved overall performance.

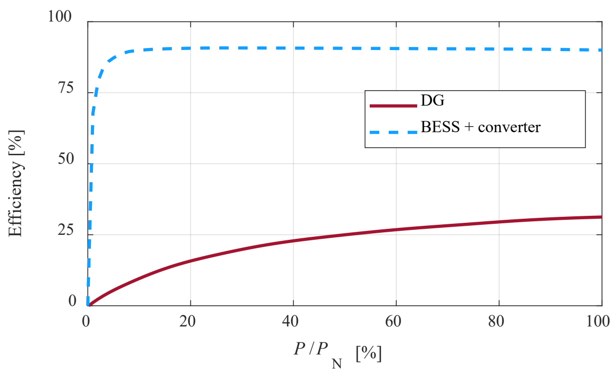

Figure 1: System with nonlinear elements.

B LTO Technology Efficiency

The graph in Figure 2 illustrates the round-trip efficiency (RTE) for BESS utilising LTO (Lithium Titanate Oxide) battery technology. Notably, the efficiency curve demonstrates variability contingent on the C ratio. A battery's "C rate" refers to the charging or discharging rate relative to its capacity. It is expressed as a multiple of the battery's capacity. In other words, the C rate measures how fast a battery is charged or discharged relative to its capacity. For example, a C rate of 1C means the battery is charged or discharged in one hour, while a 2C rate implies it would take half an hour to complete the process. Higher C rates generally result in faster charging or discharging but may also impact the battery's lifespan and efficiency.

Indeed, the relationship between the C ratio and losses in the battery is evident: larger C ratios correspond to increased losses in the battery. Simultaneously, a well-recognised observation is that efficiencies tend to degrade at lower temperatures. These characteristic curves play a pivotal role in comprehensively analysing BESS and DG performance. Understanding these dynamics is crucial for optimising system efficiency and making informed decisions about integrating BSS and DG technologies.

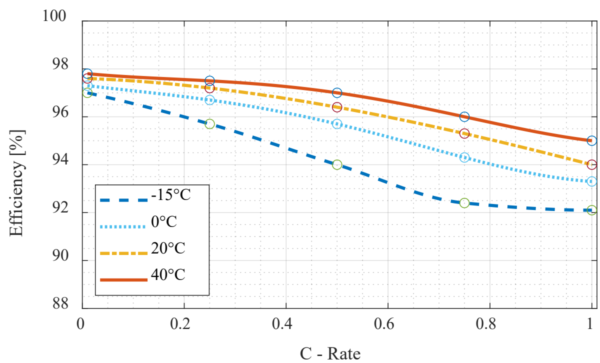

Figure 2: Measured round-trip efficiency of LTO BESS technology.

III Results

The load's characteristics heavily influence the choice of the suitable DG to power the load, whether constant or variable. In the case of variable loads, the DG's output power dynamically adjusts to match the load, ensuring seamless adaptation. However, depending on the efficiency profile, there is a risk of energy loss, emphasising the importance of selecting a DG with optimal efficiency characteristics.

The role of BESS in conjunction with DG is distinctly defined: when the load power is reduced, the DG operates at an increased power level, supplying both the load and fully charging the BESS. Once the BESS is charged, the DG ceases operation, and the load is sustained from the BESS until it discharges to a predetermined limit. In executing this process, it is imperative to assess the characteristics of the BESS, considering inherent losses.

A Constant Electric Loads

A simple generator power supply scenario is depicted in the selected example of a 450 kW DG and a 225 kW constant load. When the load remains constant, and the DG operates autonomously, the scenario is straightforward and serves as a benchmark. However, introducing a 450 kWh LTO battery alters the performance dynamics, as illustrated in Figure 3. The green curve represents the battery's starting state of charge (SoC) at 50%. In this setup, the designated DG operation was set at 90 % of its rated power, with a portion of the energy dedicated to meeting the load demand and the remainder allocated to charging the BESS.

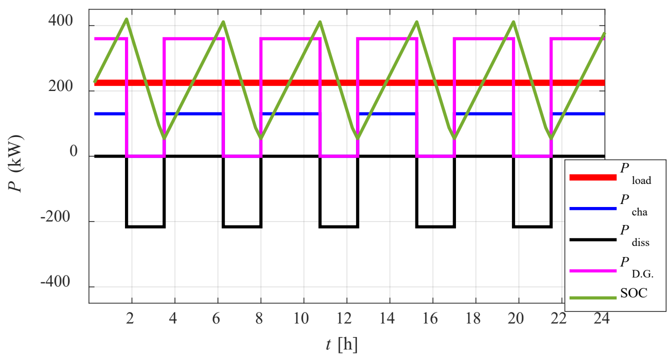

Figure 3: Power curves of charging and discharging BSS for constant load curve.

Once the BESS reaches its maximum set value (e.g., 90 % charge), the DG is stopped, and the BESS solely powers the load until it approaches the specified lower limit (in this instance, up to 10 %).

In this example, we observe five complete BESS charge and discharge cycles, prompting our interest in comparing fuel consumption. Although the DG operates at a higher power level in this scenario, the periodic interruptions due to BESS discharge diminish the clarity of potential savings.

B. Dynamic Two-Peak Electric Load

In scenarios with fewer but pronounced peaks in the load profile, the operational dynamics become notably more compelling. To illustrate this, we introduce a load profile example depicted by the red curve in Figure 4. All other simulation parameters remain consistent, allowing us to observe the charging and discharging profiles of the BESS relative to the State of Charge (SoC). The charging power P_{cha} is represented by the blue curve, while the discharging power P_{dis} is depicted in black. The green curve indicates the *SoC* and the magenta curve $P_{\text{D.G.}}$ illustrates the operation of the DG, set at 80 % of its rated power.

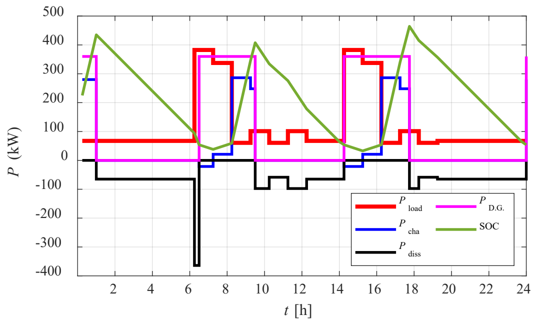

Figure 4: Power curves of charging and discharging BSS for different loads.

The energy balance depicted in Fig. 5 illustrates that a daily requirement of 2864 kWh is necessary to meet the load demand. If we rely solely on DG, this demand translates to 11246 kWh (diesel equivalent) consumed. However, when incorporating BESS with DG, the total consumption decreases to 8235 kWh, with losses accounting for an additional 74 kWh.

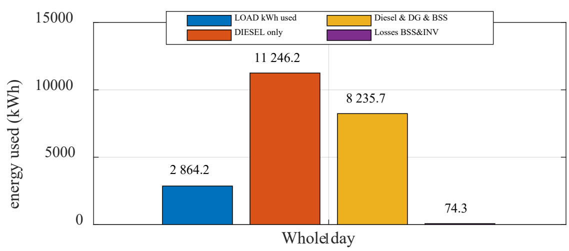

Figure 5: Energy consumption for cases of power supply with DG and combination with BESS and losses,

References

[1] V. Kiray, M. Ohran, J. N. Chijioke," Significant Increase in Fuel Efficiency of Diesel Generators with Lithium-Ion Batteries Documented by Economic Analysis", *Energies*,2021, 14, 6904. https://doi.org/10.3390/en14216904