Poster: Optimization of the Battery Swapping Station to power up mobile and stationary loads

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ABSTRACT

The stored energy of charged batteries at a Battery Swapping Station (BSS) can be used as a source of electricity. This paper discusses, an optimal dispatch of the stored electrical energy at a BSS to power up the external load. The problem is solved using linear programming for a small farm cold storage with a pre-cooling effect. With the precooling effect, a 5% reduction in the price of electricity is obtained. The BSS can be used to provide cheaper electricity to the consumer and gain profits for the BSS owner by selling excess energy enhancing the potential of BSS technology adoption.

CCS CONCEPTS

• **General and reference → Estimation**; • **Hardware → Reusable energy storage**.

KEYWORDS

battery swapping station, electric vehicle, battery energy management system, optimization, efficient reusable energy storage

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1 INTRODUCTION

The batter swapping stations (BSSs) are now widely accepted for EV refueling as they reduce the range anxiety, and are easy to manage. The BSS has two main components, i.e., 1) the energy demand of discharged batteries, and 2) the energy stored in charged batteries. The storage component available at BSS can contribute as a source of electricity for several applications on a small scale using an efficient battery energy management system (BEMS) to offer cheaper electricity to the consumer and gaining profit for the BSS owner.

EV refueling using BSS is a sustainable transportation ecosystem to function as grid-scale energy storage. Based on technical and commercial parameters the BSS can be a promising technology for EV proliferation [4]. The cost of onboard batteries of EV's BSS architecture has a high upfront cost which makes up to 20-25% of total EV cost. A third party is mostly responsible for the replacement of a depleted battery with a charged battery for the EV or with a new battery after the completion of useful life [1].

BSS is viable for fast EVs energy refill and can export power to the grid and benefit from an optimal charging schedule. With the optimal parameters operational cost can be reduced and enhance the adaptability of EVs as a cost-effective mode of transportation by reducing extra burdens of battery charging [3]. A BSS emulates an energy storage station that can reshape its demand so that peaks are shaved rather than increase if the BSS injects electricity back into the power system [5]. A rising trend in stand-alone PV systems has been advised for off-grid solutions also for the case of BSS. Renewable-energy-to-vehicle systems are gaining more and more interest in off-grid nano-grid scenarios where standalone PV systems and BSS fulfill the regional EV demand [2].

The optimal scheduling and efficient methodologies discussed in the literature have a significant improvement for the energy demand of the BSS. However, the stored energy of the BSS requires further investigation. This paper discusses the role of BEMS installed at a BSS to optimize stored BSS energy to feed an external load at minimum cost. In the preliminary results, a 5% reduction in the electricity prices has been observed in fulfilling the external load. The paper is organized as the approach and architecture are discussed in Section 2, the obtained preliminary results are highlighted in Section 3, and the conclusion and future works are discussed in Section 4.

2 APPROACH AND ARCHITECTURE

Figure 1 shows the BSS architecture, with two main resources, i.e, grid, and PV, connected to the smart switch. The smart switch is used for optimal selection of energy resources with the three main objectives 1) maximum PV utilization, 2) minimum cost and 3) demand fulfillment.

The BSS module consists of 16 (1.375kW) batteries, i.e., 22kW. A battery swapping at the BSS is a random process which is reflected in the demand profile. The BSS stored energy is connected to cold storage on a small-scale farm. Similar loads such as rural electrification etc. can also be connected to the BSS. The BEMS will optimize the energy stored and demand to for optimal dispatch.

Figure 2 shows the simplified architecture with a few assumptions, these assumptions are, 1) the optimal dispatched 2) the demand and storage are exclusive, 3) The cold storage has precooling, 4) the system intermittency are reflected in the profiles, and 5) at

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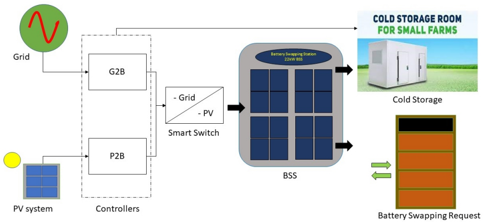

Figure 1: A BSS architecture with small farm cold storage image taken from [Public domain], via Vacker Global on How to build low cost cheap small farm cold storage. (https://www.vackerglobal.com/vacker-videos/).

least one charged battery is available at BSS for the basic formulation.

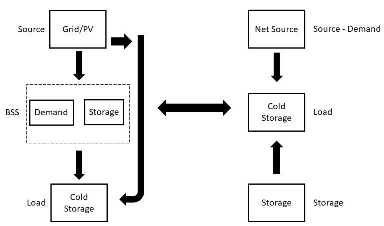

Figure 2: Simplified BEMS infrastructure

The problem is simplified as two independent sources feeding a load, and solved using linear programming. The basic working of the model is that the net source charges the discharged batteries at BSS along with the cold storage while the cold storage is fed by the storage available at the BSS. However, in the scenario where stored energy is less excess energy is procured through a net source to fulfil the energy demand.

3 PRELIMINARY RESULTS

Figure 3a shows the energy procured by cold storage from both resources. The BSS storage available during the day is limited due to high swapping requests which reduces the BSS storage considerably in a random manner. Therefore, to cope with the cold storage demand extra required energy is fulfilled by the net available source which is costly as compared to the storage of the BSS. Although, considerable energy is exchanged between BSS and cold storage still a major share of energy is being purchased from the net source.

The maximum utilization of the BSS storage can be obtained by observing the demand profile for the next 24-hour. From the dataset, it is observed that minimum swapping requests occur from 9 pm to 4 am. During these 7 hours, the maximum BSS storage is available and if the cold storage has optimal pre-cooling, the cold storage demand can be shifted to these hours to minimize the cost as shown in Figure 3b. For uniform dummy prices, there is a 5% reduction in the electricity cost to the cold storage, moreover, in real-time pricing, the reduction will be much higher since the price of electricity during the peak demand hours is high as compared to off-peak hours. The profit gain to the BSS owner can reduce the excess burden of battery replacement inherent in the BSS infrastructure

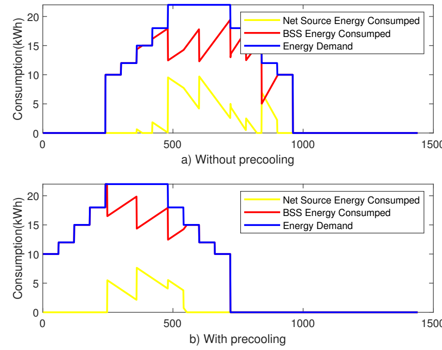

Figure 3: BEMS battery storage utilization for cold storage with and without precooling effect

which is to be borne by the BSS owner. Furthermore, the cost of operation and maintenance (O&M) of the BSS can also be taken care of by selling excessive energy available without increasing the cost of EV refueling. Similar other day-to-day benefits can be obtained from the sale of electricity by the BSS therefore, such an arrangement has the potential for the commercialization and profit maximization of BSS, especially in the worldwide adoption of BSS for EV transportation.

4 CONCLUSION AND FUTURE WORKS

The ease of usage and reduction of range anxiety are major benefits of the BSS, moreover, the stored energy of the BSS can earn profit by serving as a source for several mobile and stationary loads. This study assumes few parameters for simplicity as a generic overview of the BEMS architecture has been defined for further analysis. For basic simulations, a 5% reduction in cost to the cold storage and profit earning to BSS owner has been observed. From the preliminary results, it can be concluded that the excess burdens of O&M, battery replacement, and other expenses can be managed using the BSS as a source of electricity. The way forward is the detailed analysis using widely available real-time datasets, consideration of battery degradation and discharging profiles, and the use of real-time pricing to obtain an accurate result in terms of profit earning and sizing of the cold storage for efficient utilization of BSS as it can be a supportive factor in acceptance and economic feasibility of the swapping stations for refueling process of EV transportation.

REFERENCES

[1] Feyijimi Adegbohun, Annette von Jouanne, and Kwang Y. Lee. 2019. Autonomous Battery Swapping System and Methodologies of Electric Vehicles. *Energies* 12, 4 (2019). https://doi.org/10.3390/en12040667

[2] Mingfei Ban, Danyang Guo, Jilai Yu, and Mohammad Shahidehpour. 2019. Optimal sizing of PV and battery-based energy storage in an off-grid nanogrid supplying batteries to a battery swapping station. *Journal of Modern Power Systems and Clean Energy* 7, 2 (2019), 309–320. https://doi.org/10.1007/s40565-018-0428-y

[3] Mohsen Mahoor, Zohreh S. Hosseini, and Amin Khodaei. 2019. Least-cost operation of a battery swapping station with random customer requests. *Energy* 172 (2019), 913–921. https://doi.org/10.1016/j.energy.2019.02.018

[4] Swapnil R. Revankar and Vaiju N. Kalkhambkar. 2021. Grid integration of battery swapping station: A review. *Journal of Energy Storage* 41 (2021), 102937. https://doi.org/10.1016/j.est.2021.102937

[5] Mushfiqur R. Sarker, Hrvoje Pandžić, and Miguel A. Ortega-Vazquez. 2013. Electric vehicle battery swapping station: Business case and optimization model. In *2013 International Conference on Connected Vehicles and Expo (ICCVE)*. 289–294. https://doi.org/10.1109/ICCVE.2013.6799808