Allocation of Shared Energy Storage Units for Malaysian Residential Network with Rooftop PVs

Hasan Alawami*, Junainah Sardi, Chin Kim Gan
Faculty of Electrical Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia

*Corresponding author's email: m011910054@student.utem.edu.my

ABSTRACT: Realizing the high potential of PV systems, Malaysia has set a target of 20% of the country's electricity to be generated from renewable energy (RE) sources, mostly solar by 2030. Although, increment in photovoltaic (PV) generation has many advantages, its high penetration in traditional power grids leads to some technical challenges that are mainly due to the intermittent nature of solar. Meanwhile, energy storage which is believed to be able to solve the problem that arises from high PV penetration is still costly. To prepare Malaysia for achieving the RE target and solving the abovementioned problems, this research proposes a strategy to optimally site and size Shared Energy Storage (SES) units in pre-set Virtual Microgrid (VM) of Malaysian residential network with rooftop PVs. Genetic algorithm (GA) in MATLAB is used to optimize the objective function which considers major revenue streams for CES to justify the economic viability and operational feasibility of the VMs. The proposed framework is tested on IEEE 33-bus distribution system, and it generates a profit of 47.382 million MYR from the SES major revenue streams.

Keywords: *Rooftop PVs; Shared Energy Storage; Residential*

1. INTRODUCTION

The global warming issues encouraged the advancement on the technologies, government incentives, and technical and economic benefits of renewable energy resources. This has led to an increase of the worldwide capacity of rooftop and local PV installation. A report by the International Energy Agency [1] forecasts that the world's total renewable power capacity will grow by 50% around 2024 which is an increase of 1,200 gigawatts equivalent to the current total power capacity of the United States and PV accounts for 60% of the rise. The recent proliferation of distributed energy resources (DERs) is creating new options for the delivery of key electricity services to transmission and distribution network investments. rooftop solar photovoltaics (PVs) have the highest profile of these resources [2].

Increasing numbers of rooftop PV in the traditional distribution network may cause some technical issues. VM can provide an effective solution for the issues of high PV proliferation in distribution network. Where a VM can be considered as a group of small-scale prosumers single controlled entity [3-5]. Shared energy storage in residential network can be used to store PV energy during the day and feed back to the network during the peak demand period [6]. Also, due to the expensive cost of shared energy storage in the market especially one with a large size, VM design that is focused on maximizing the financial profits from shared energy storage deployment in Malaysia is needed. Therefore, this paper is conducted to optimally allocate shared energy storage unit in PV-rich residential VM that may benefited both parties' utility and prosumers in Malaysia.

2. METHODOLOGY

The aim of this paper is the allocation of Shared Energy Storage; where SES will be optimally sited and sized in each VM within a residential area with PV units under Malaysia's electricity framework. Noted that, methodology on the VM design is not presented here as this paper only focus on the shared ES allocation strategy. The allocation strategy deployed in this work is similar to the approach proposed in [7]. Contrast to work in [7], this study is concentrating on the shared energy storage allocation problem under Malaysian residential load pattern, PV profile and economic parameters. The allocation problem is nonlinear mixed integer problem with an objective function of maximizing the net profit value of shared energy storage deployment that incorporates major revenue streams of shared energy storage that are profits from the shared energy storage's peaking power generation (PG), energy arbitrage (AB), energy loss reduction (AL), T&D system upgrade deferral (TDB), reduction in CO2 emission (REC) and shared energy storage renting fees (RC). Meanwhile, the investment cost of the shared energy storage includes the capital cost C_{CES}, and the operation and maintenance costs (OM).

After that, a cost-benefit analysis that includes a new business model of shared energy storage units is conducted. Finally, the objective function which is the NPV of shared energy storage investment and constraints will be evaluated until the desired stopping criteria are met as follows:

$$F_{obj} = (PG + AB + LR + TDB + REC + RC) - (C_{CES} + OM) \quad (1)$$

Table 1 depicts the energy storage costs and economics data considered in this work. The load profile that represents typical Malaysian residential demand is taken from [8]. The PV profile of a sunny day were recorded for every 30 minutes from Solar Lab PVSG in the main campus of UTeM, Durian Tunggal, Melaka, Malaysia. The PV penetration level used in this work was 20%.

Table 1 Related Economic Parameters and Costs

Parameter (unit)	**Value**	**Parameter (unit)**	**Value**
SES cost (MYR/kWh)	565.26	Coal consumption rate for peak shaving (kg/kWh)	0.48
Power conversion system cost (MYR/kVA)	672.54	Coal consumption rate in routine period (kg/kWh)	0.27
SES annual maintenance cost (MYR (kW)	43.06	Investment cost of additional power (Mil MYR/MW)	6.33
Interest rate (%)	1.75	Fixed charge rate of costs conversion	0.13
Inflation rate (%)	2	T&D upgrade capacity (kW)	2000
Cost of gas turbines (MYR/kW)	387.16	Cost of reducing Co2 emission (MYR/ton)	70.93
Efficiency of SES	0.9	Self-discharge rate	0.1
Maximum depth of discharge	0.9	Annual demand growth (%)	1.3
Future replacement cost (MYR/kWh)	240.8		

3. Results and Discussion

The IEEE 33-bus test system was partitioned into 3 VMs as illustrated in Figure 2. Each VM has its own shared energy storage. The optimization result shows that to gain the maximum net profit value of the shared energy storage deployment over the 20-year planning horizon for the three-VM case, shared energy storage units with the rated power and energy size of 375 kWh, 2343 kWh, 1744 kWh need to be placed at buses 20, 13, and 29 respectively. The NPV recorded for the respected scenario is 47.382 million MYR. Detail costs and profits of the SES allocation within the planning horizon is shown in Table 2.

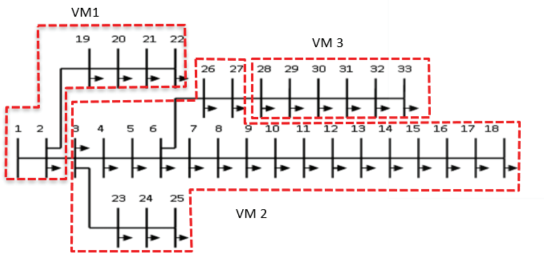

Figure 2. Partitioned IEEE 33-bus distribution network with 3 VMS

Table 2 Detail Cost Benefit Analysis

Parameter (unit in Million MYR)	**Value**
Energy loss reduction profits	0.3106
Energy arbitrage profit	0.47178
Peaking power generation profit	4.4284
T&D upgrade deferral	32.050
Reduction of CO2 emission profits	1.3992
Renting ES profits	18.344
ES cost	8.6525
Maintenance cost of ES	1.0059

4. CONCLUSION

In conclusion, this paper proposed an allocation strategy to optimally site and size one SES in each VM for Malaysian residential network with PV units by maximizing the NPV over a 20 year planning horizon. The result shows the optimal size and location of SES in each VM and the generated profits.

ACKNOWLEDGEMENT

Authors are grateful to Universiti Teknikal Malaysia Melaka for the financial support through Racer/2019/FKE-Ceria/F00402.

REFERENCES

[1] "International Energy Agency Market analysis and forecast from 2019 to 2024," 2019. https://www.iea.org/reports/renewables-2019.

[2] B. S. P. Burger, J. D. Jenkins, S. C. Huntington, and I. J. Pérez-arriaga, "Why Distributed?," IEEE Power Energy Mag., vol. Volume:17., no. april, pp. 16–24, 2019.

[3] J. Guo, G. Hug, and O. K. Tonguz, "Intelligent Partitioning in Distributed Optimization of Electric Power Systems," IEEE Trans. Smart Grid, vol. 7, no. 3, pp. 1249–1258, 2016.

[4] Z. Jingxiang, N. Huanna, and Z. Xiaoxue, "Island partition of distribution network with microgrid based on the energy at risk," IET Gener. Transm. Distrib., vol. 11, no. 4, pp. 830–837, 2017.

[5] Y. Chai, L. Guo, C. Wang, Z. Zhao, X. Du, and J. Pan, "Network Partition and Voltage Coordination Control for Distribution Networks With High Penetration of Distributed PV Units," IEEE Trans. Power Syst., vol. 33, no. 3, pp. 3396–3407, 2018.

[6] H. L. Willis. (2004). Power distribution planning reference book. CRC press.

[7] Junainah Sardi, N. Mithulananthan, Md M. Islam, Chin Kim Gan, Framework of virtual microgrids formation using community energy storage in residential networks with rooftop photovoltaic units, Journal of Energy Storage.

[8] Ibrahim, Khairul Anwar & Au, Mau & Gan, Chin &