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IEEE P2814: RECOMMENDED PRACTICES ON TECHNO-ECONOMICS TERMINOLOGY FOR HYBRID ENERGY AND STORAGE SYSTEMS

IEEE SYSTEMS, MAN, AND CYBERNETICS SOCIETY/ STANDARDS COMMITTEE (SMC/SC)

JANUARY 13, 2021

TIME: 11:00 PM (UTC)

Teleconference: Cisco Webex

IEEE

AGENDA

1. **Call to Order**
2. **Roll Call & Declaration of Affiliation**
3. **Approval of Agenda**
4. **IEEE Patent Policy:** https://mentor.ieee.org/myproject/Public/mytools/mob/slideset.ppt
5. **IEEE Copyright Policy:** https://standards.ieee.org/content/dam/ieee-standards/standards/web/documents/other/copyright-policy-WG-meetings.potx
6. **Approval of the minutes of the last meeting**
7. **Framework and methodology**
8. **AOB**
9. **Future Meetings**
10. **Meeting Adjourned**

Speak up now and respond to this Call for Potentially Essential Patents

If anyone in this meeting is personally aware of the holder of any patent claims that are potentially essential to implementation of the proposed standard(s) under consideration by this group and that are not already the subject of an Accepted Letter of Assurance, please respond at this time by providing relevant information to the WG Chair

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https://sagroups.ieee.org/2814/

SCOPE

This standard defines techno-economic terminologies used in the development, construction, and operation of renewable energy and electrical energy storage systems

STRUCTURE OF STANDARD

1. Overview (recommended practices), scope and purpose
2. Normative references (related standards)
3. Definitions (terms and nomenclature)
4. Need for the Recommended Practice, context of problems, outline of the recommended practice
5. Methodology
6. Examples of application of the methodology
7. Bibliography

Optimal Sizing of Battery Energy Storage System in Smart Microgrid Considering Virtual Energy Storage System and High Photovoltaic Penetration

Dongxiao Wang
Australia Energy Market Operator, Australia

C. Xie, D. Wang, C. S. Lai, R. Wu, L. L. Lai, "Optimal sizing of battery energy storage system in smart microgrid considering virtual energy storage system and high photovoltaic penetration", Journal of Cleaner Production, vol. 28, Jan 2021, https://doi.org/10.1016/j.jclepro.2020.125308

INTRODUCTION

High photovoltaic (PV) penetration

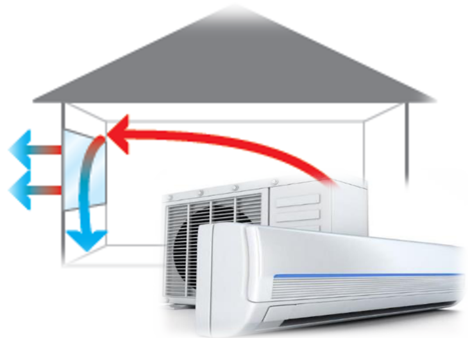
- The power grid face many challenges due to uncertainty of PV;

Battery energy storage system (BESS)

- The expensive cost of BESS;
- The size of BESS need to be optimized whilst the risk of system cost variability should be accessed considering system uncertainties;

Virtual energy storage system (VESS)

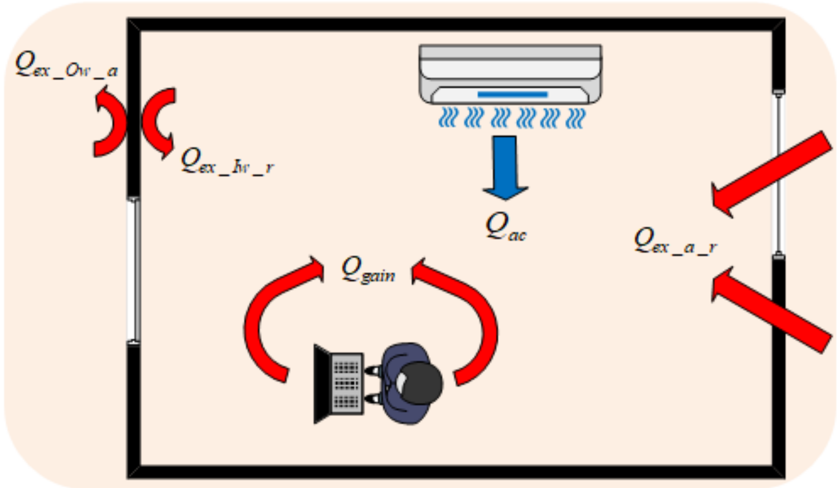
- High power consumption but the thermal buffering characteristics for air conditioning buildings;
- The system cost may be further reduced with VESS participation.



SYSTEM COMPONENTS MODELLING

➢ **VESS modelling:**

Indoor thermal process



$$E_{VES\_M} = \zeta \cdot \sum_{i=1}^{M} \left[M_{a\_i} \cdot C_{a\_i} \cdot (T_{r\_i}^{\max} - T_{r\_i}^{\min}) \right]$$

$$E_{VES}(t+1) = E_{VES}(t) + P_{VES}(t) \cdot \tau$$

$$E_{VES}(t) = \zeta \cdot \sum_{i=1}^{M} \left[M_{a\_i} \cdot C_{a\_i} \cdot (T_{r\_i}^{\max} - T_{r\_i}(t)) \right]$$

$$P_{VES}(t) = \frac{\zeta}{\tau} \cdot \sum_{i=1}^{M} \left[\frac{R_{eq\_i} + R_{wr\_i}}{R_{eq\_i} \cdot R_{wr\_i}} \cdot T_{r\_i}(t) - \frac{1}{R_{wr\_i}} \cdot T_{w\_i}(t) - \frac{1}{R_{eq\_i}} \cdot T_{amb\_i}(t) - \lambda_i + S_{ac\_i}(t) \cdot Q_{ac\_i}(t) \right]$$

$$VSOC(t) = \frac{E_{VES}(t)}{E_{VES\_M}} \cdot 100\%$$

SYSTEM COMPONENTS MODELLING

- **BESS modelling:**

$$E_{BESS}(t+1) = E_{BESS}(t)\cdot(1-\delta_{self\_d}) + P_{BESS,Chr}(t+1)\cdot\tau\cdot\eta_{BESS,Chr} - P_{BESS,Dis}(t+1)\cdot\tau/\eta_{BESS,Dis}$$

$$BSOC(t) = \frac{E_{BESS}(t)}{E_{BESS}^{rate}}\cdot 100\%$$

$$P_{BESS,Chr}^{\min} \le P_{BESS,Chr}(t) \le P_{BESS,Chr}^{\max}$$

$$E_{BESS}(t) = E_{BESS,Init}, \quad if\ t=1$$

$$BSOC^{\min} \le BSOC(t) \le BSOC^{\max}$$

$$P_{BESS,Dis}^{\min} \le P_{BESS,Dis}(t) \le P_{BESS,Dis}^{\max}$$

- **PV modelling:**

$$P_{PV}(t) = A_{PV}\cdot I_{PV}(t)\cdot\eta_{PV}$$

$$I_{PV}(t) = (I_B(t)+I_D(t))\cdot R_B + I_D(t)$$

$$\eta_{PV} = \eta_{ref}\cdot\left[1-\frac{0.9\cdot\beta_{tc}\cdot I_{PV}(t)}{I_{PVO}}\cdot(T_{CO}-T_{AO}) - \beta_{tc}\cdot(T_A(t)-T_{ref})\right]$$

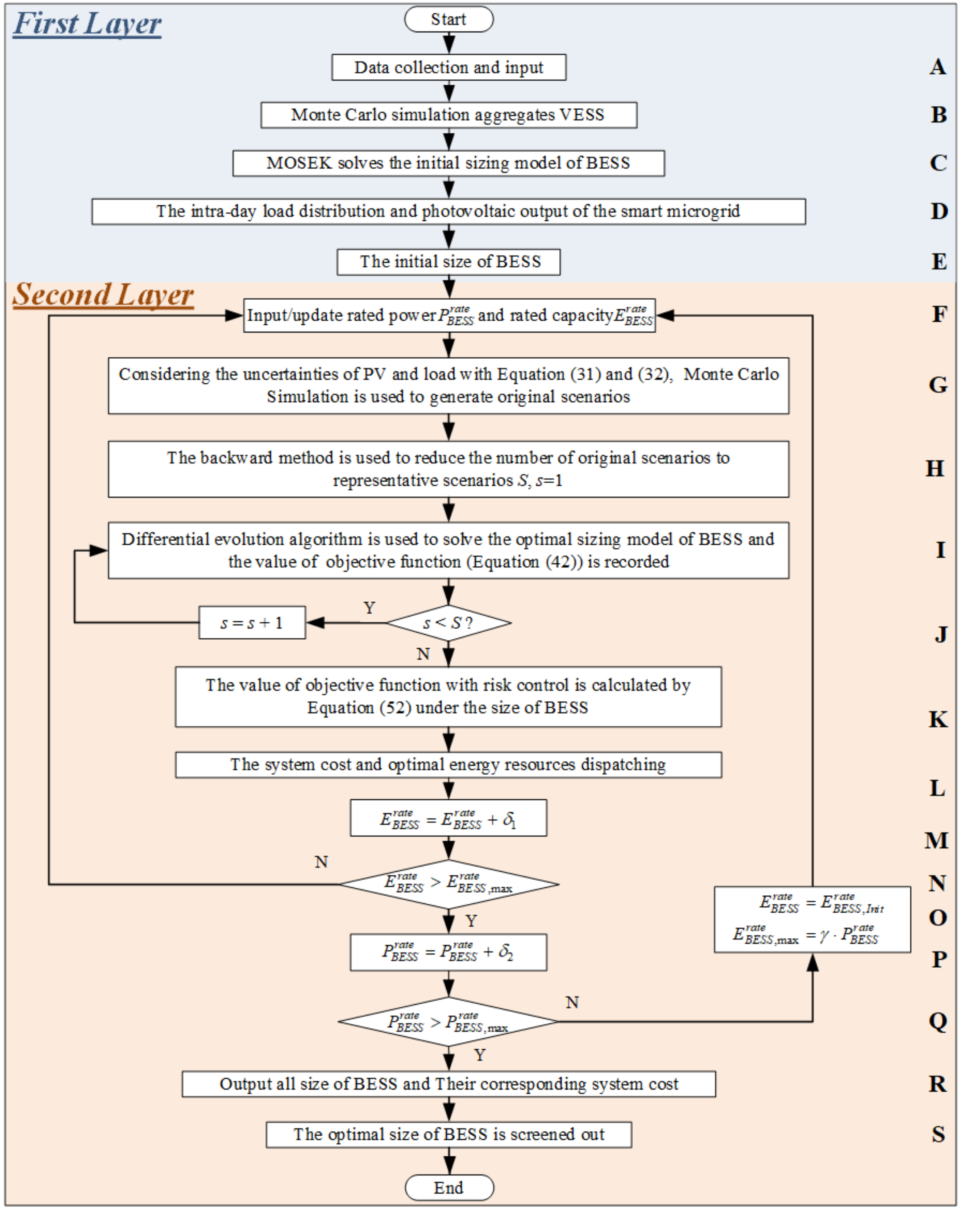
- **Uncertainties of PV power generation and load demand:**

$$f_{PV}(\Delta P;\alpha,\beta) = (\Delta P)^{\alpha-1}\cdot(1-\Delta P)^{\beta-1}\cdot N_{st}$$

$$f(\Delta L;\mu,\sigma_l^2) = \frac{1}{\sqrt{2\pi\sigma_l^2}}\exp\left[-\frac{(\Delta L-\mu)}{2\sigma_l^2}\right]$$

MATHEMATICAL MODEL FOR THE PROPOSED STRATEGY

- **First layer-BESS initial sizing model;**
- **Second layer - BESS optimal sizing model;**
- **Probabilistic version for the BESS optimal sizing model.**



MATHEMATICAL MODEL FOR THE PROPOSED STRATEGY

➢ **First layer-BESS initial sizing model:**

✓ Objective:

$$C_{Init} = \min \sum_{t=1}^{N} \left(P_{buy}(t) \cdot C_{buy}(t) - P_{sell}(t) \cdot C_{sell}(t) \right) \cdot \tau$$

Where,

$$\begin{cases} P_{sell}(t) = P_{PV}(t) - P_{Load}(t), & P_{PV}(t) > P_{Load}(t) \\ P_{buy}(t) = P_{Load}(t) - P_{PV}(t), & P_{PV}(t) < P_{Load}(t) \end{cases}$$

$$P_{Load}(t) = P_{Uncontro\_load}(t) + \sum_{i=1}^{M} P_{ac\_i}(t) \cdot S_{ac\_i}(t)$$

✓ The initial size of BESS is formulated as follows:

$$P_{BESS,Init}^{rate} = \max \left(P_{PV}(t) - P_{Load}(t) \right)$$

$$P_{BESS,\max}^{rate} = \max(P_{Load}(t))$$

$$E_{BESS,Init}^{rate} = \frac{\sum_{t=1}^{N} \left[P_{PV}(t) - P_{Load}(t) + \left| P_{PV}(t) - P_{Load}(t) \right| \right] \cdot \tau}{2 \cdot \eta_{BESS,Chr}}$$

✓ Constraints:

- Constraints of power balance
- Constraints of VESS
- Constraints of PV

MATHEMATICAL MODEL FOR THE PROPOSED STRATEGY

- **Second layer - BESS optimal sizing model:**

✓ Objective: $\min C = \min\left(C_{BESS} + C_{O\&M}\right)$

Where,

$$\begin{cases} C_{BESS} = A_{BESS}^{E} \cdot E_{BESS}^{rate} + A_{BESS}^{P} \cdot P_{BESS}^{rate} \\ C_{O\&M} = \min \sum_{T=1}^{T_{life}} \left[(C_O \cdot 365 + C_M) / K_{coef} \right] \end{cases}$$

$$\begin{cases} C_O = \min \sum_{t=1}^{N} \left[\left(P_{buy}(t) \cdot C_{buy}(t) - P_{sell}(t) \cdot C_{sell}(t) \right) \cdot \tau \right] \\ C_M = A_{BESS\_M}^{E} \cdot E_{BESS}^{rate} + A_{BESS\_M}^{P} \cdot P_{BESS}^{rate} \\ K_{coef} = \dfrac{r'(1+r')^T}{(1+r')^T - 1} \\ r' = \dfrac{r-e}{1+e} \end{cases}$$

✓ The net profit of BESS is formulated below:

$$\begin{cases} C_{BESS\_back} = \sum_{T=1}^{T_{life}} \left[\left(C_{Arbi} \cdot 365 - C_M \right) / K_{coef} \right] - C_{BESS} \\ C_{Arbi} = \sum_{t=1}^{N} C_{arbi}(t) \\ C_{arbi}(t) = \begin{cases} \left[P_{BESS,Dis}(t) \cdot C_{buy}(t) - P_{BESS,Chr}(t) \cdot C_{buy}(t) \right] \cdot \tau \text{ , } t \in \text{Non-photovoltaic charging period to BESS} \\ \left[P_{BESS,Chr}(t) \cdot C_{buy}(t) - P_{BESS,Chr}(t) \cdot C_{sell}(t) \right] \cdot \tau \text{ , } t \in \text{Photovoltaic charging period to BESS} \end{cases} \end{cases}$$

MATHEMATICAL MODEL FOR THE PROPOSED STRATEGY

- **Probabilistic version for the BESS optimal sizing model:**

  - ✓ Objective: $\min \; E(C) + \omega \cdot \sigma_C$

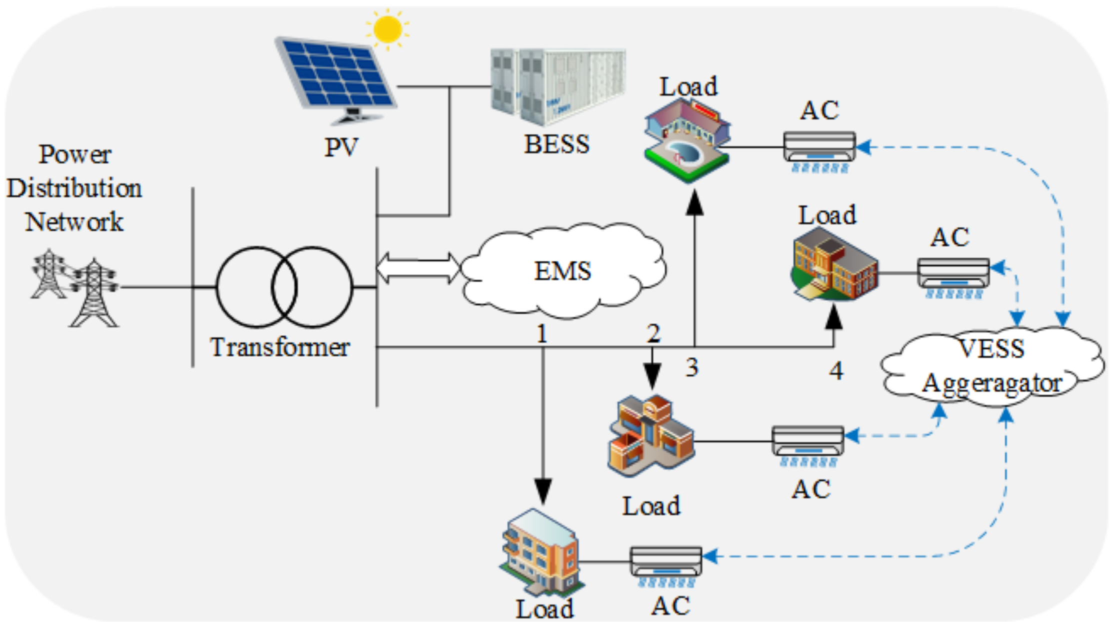
    Where,

    $$E(C) = \sum_{s=1}^{S} \Pr_s \cdot C_s$$

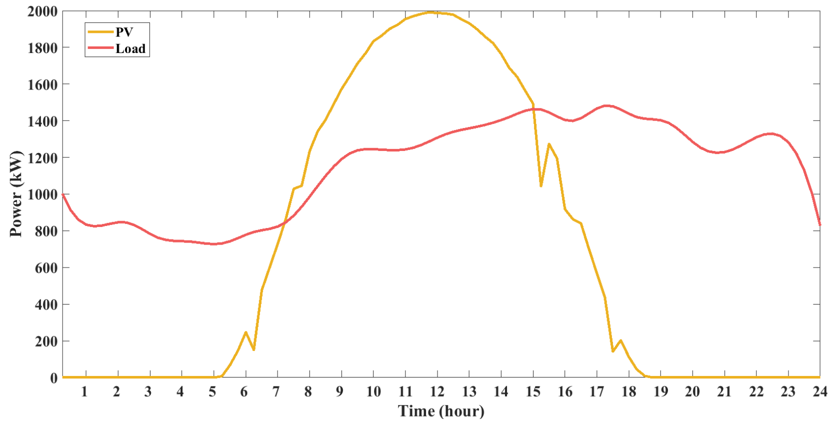
    $$\sigma_C = \sqrt{E(C^2) - E^2(C)} = \sqrt{\sum_{s=1}^{S} \Pr_s \cdot C_s^2 - \left(\sum_{s=1}^{S} \Pr_s \cdot C_s \right)^2}$$

  - ✓ Constraints:
    - Power balance
    - VESS
    - BESS
    - PV

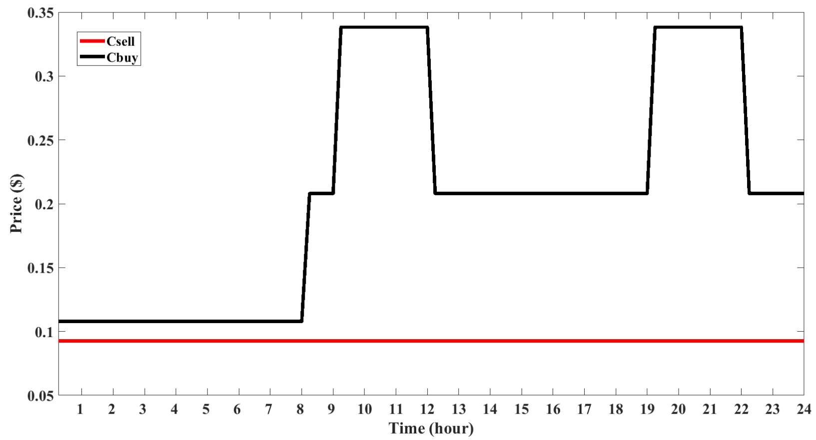
CASE STUDIES



The tested microgrid system



Typical load and photovoltaic profile

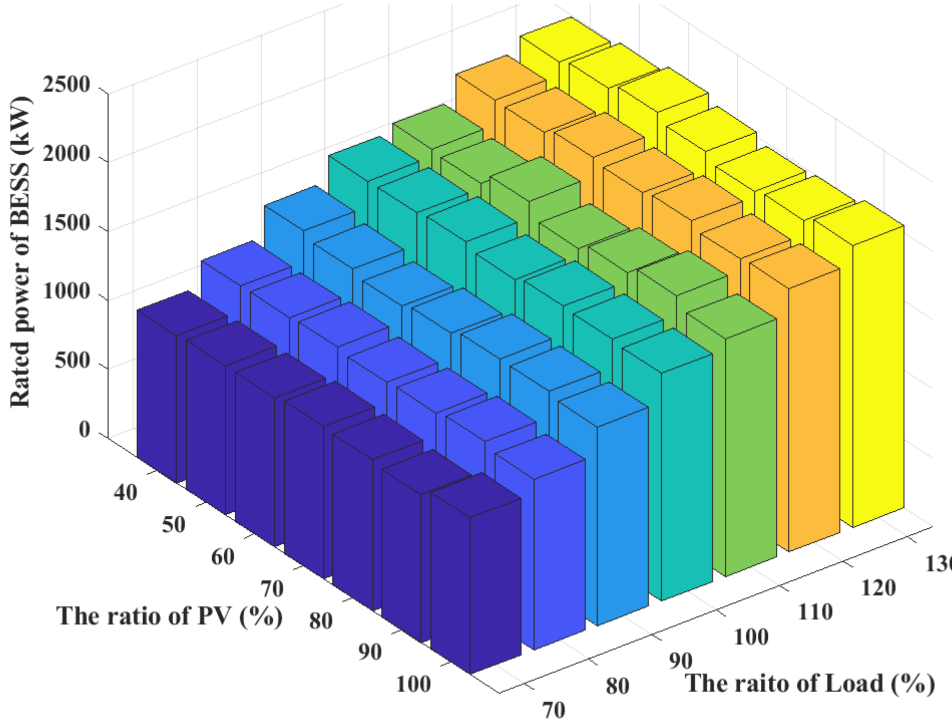


Time-of-use electricity price

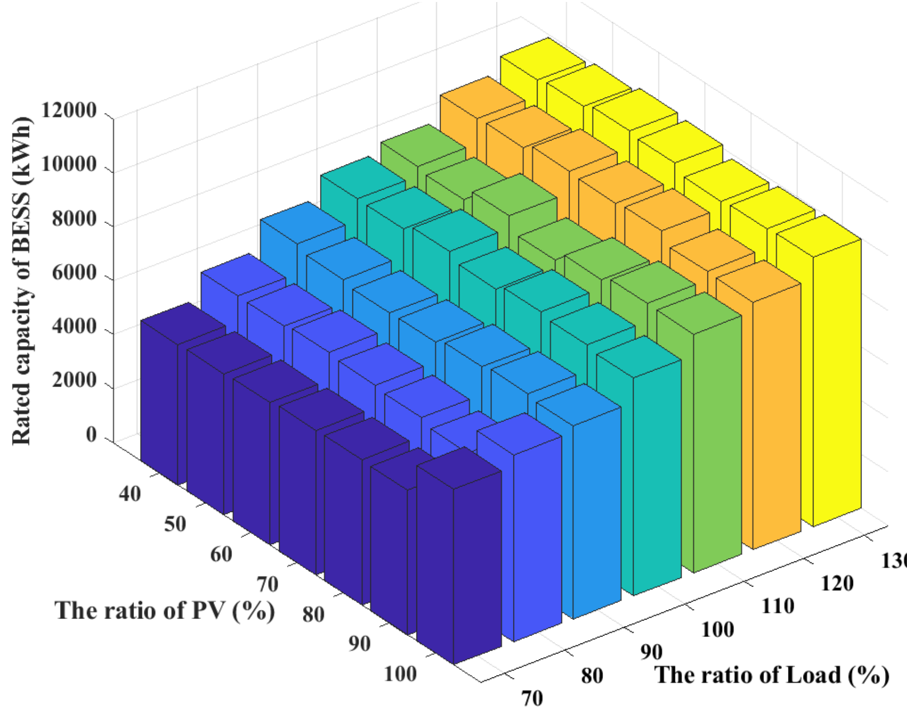
✓ Noted:

The PV system and BESS are owned by the microgrid system operator, further, the VESS are controlled by the aggregator to participate in the energy dispatching.

CASE STUDIES



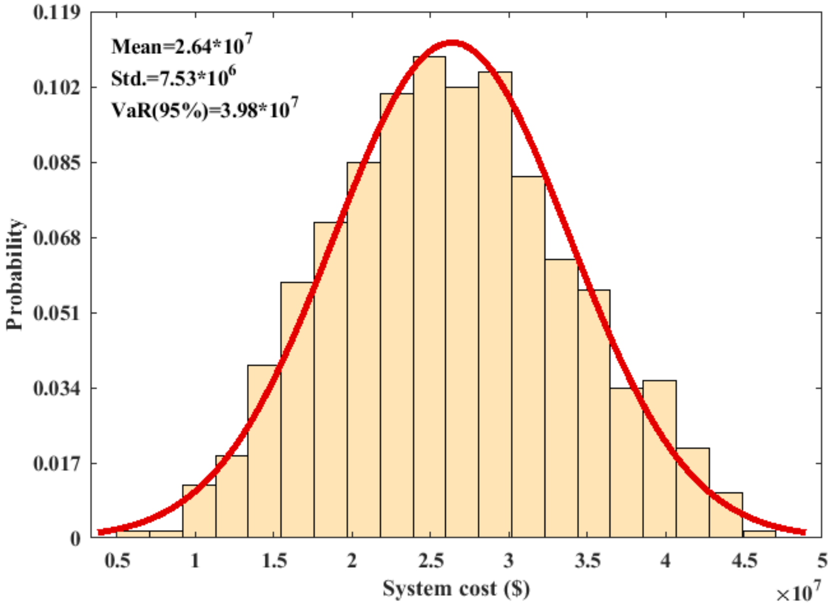
The sensitivity analysis of BESS rated power



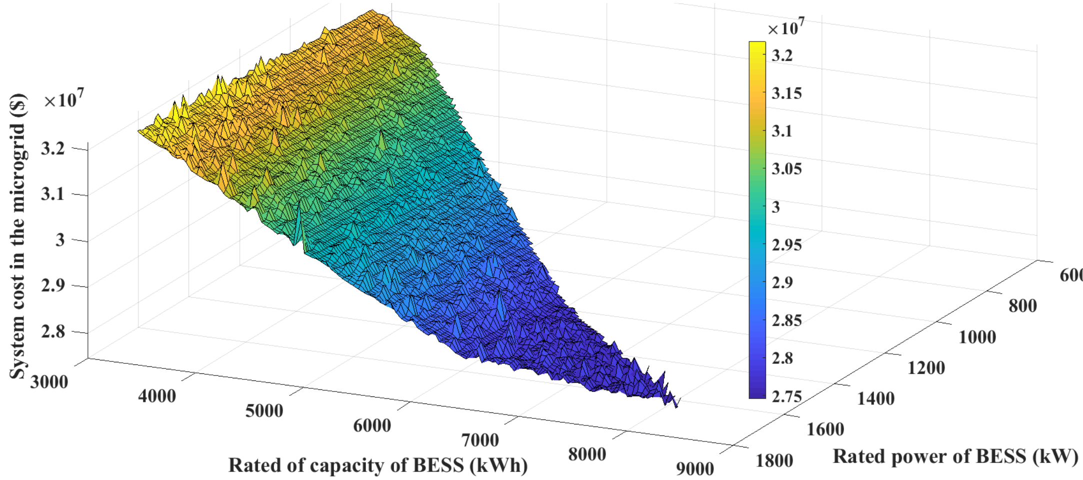
The sensitivity analysis of BESS rated capacity

✓ The investment cost of BESS can be reduced when the system load is decreased via demand response technologies.

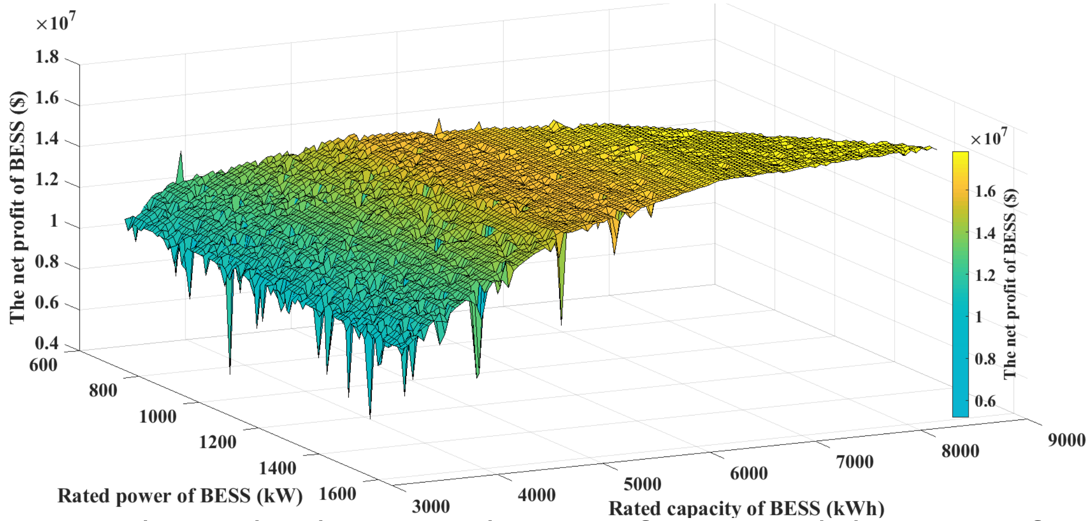
CASE STUDIES



Distribution of microgrid system cost during the entire lifecycle of BESS



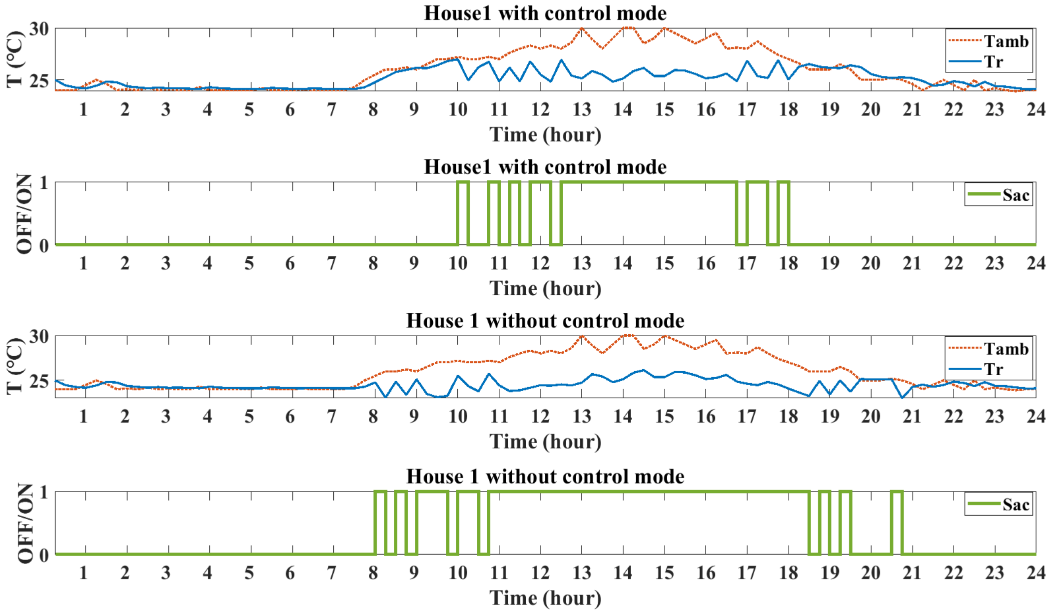
Relationship between the size of BESS and the total cost of the microgrid



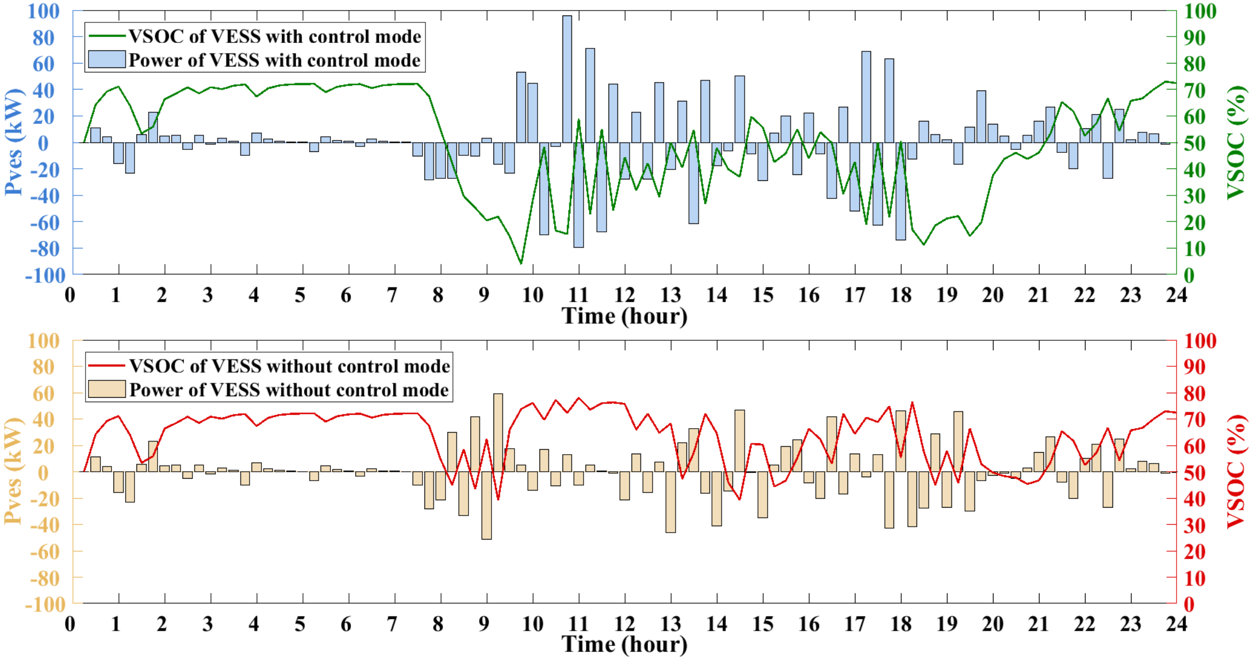
Relationship between the size of BESS and the net profit of BESS

CASE STUDIES

- ✓ VESS changes are largely affected by the ambient temperature;
- ✓ Compared with BESS, VESS has fast energy dissipation characteristics and allows deep discharge;



Optimal and random operation of the air-conditioned building



Operation status of VESS with and without control mode

- ✓ The system load can be reduced due to the thermal buffer involvement from VESS;
- ✓ The BESS investment cost is further reduced through the involvement of VESS.

CONCLUSION

- Employing a more accurate two-parameter thermal model with internal heating taken into account to establish the VESS model, which is further aggregated to participate system dispatch and control;
- A two-layer BESS optimal sizing strategy with the involvement of VESS and high PV penetration considering various system constraints, and system operation cost is minimized via optimally dispatching the photovoltaic system, battery energy storage system and virtual energy storage system;
- Analyzing the system cost risks in detail by incorporating mean-variance Markowitz theory based risk factors, the risk-based decision-making fully considers the impacts from system uncertainties which greatly influences system dispatch results;
- Sensitivity analysis reveals the optimal size of BESS is less impacted by PV generation change;
- With VaR(95%) the risk of system cost variability can be further reduced through VESS participation.

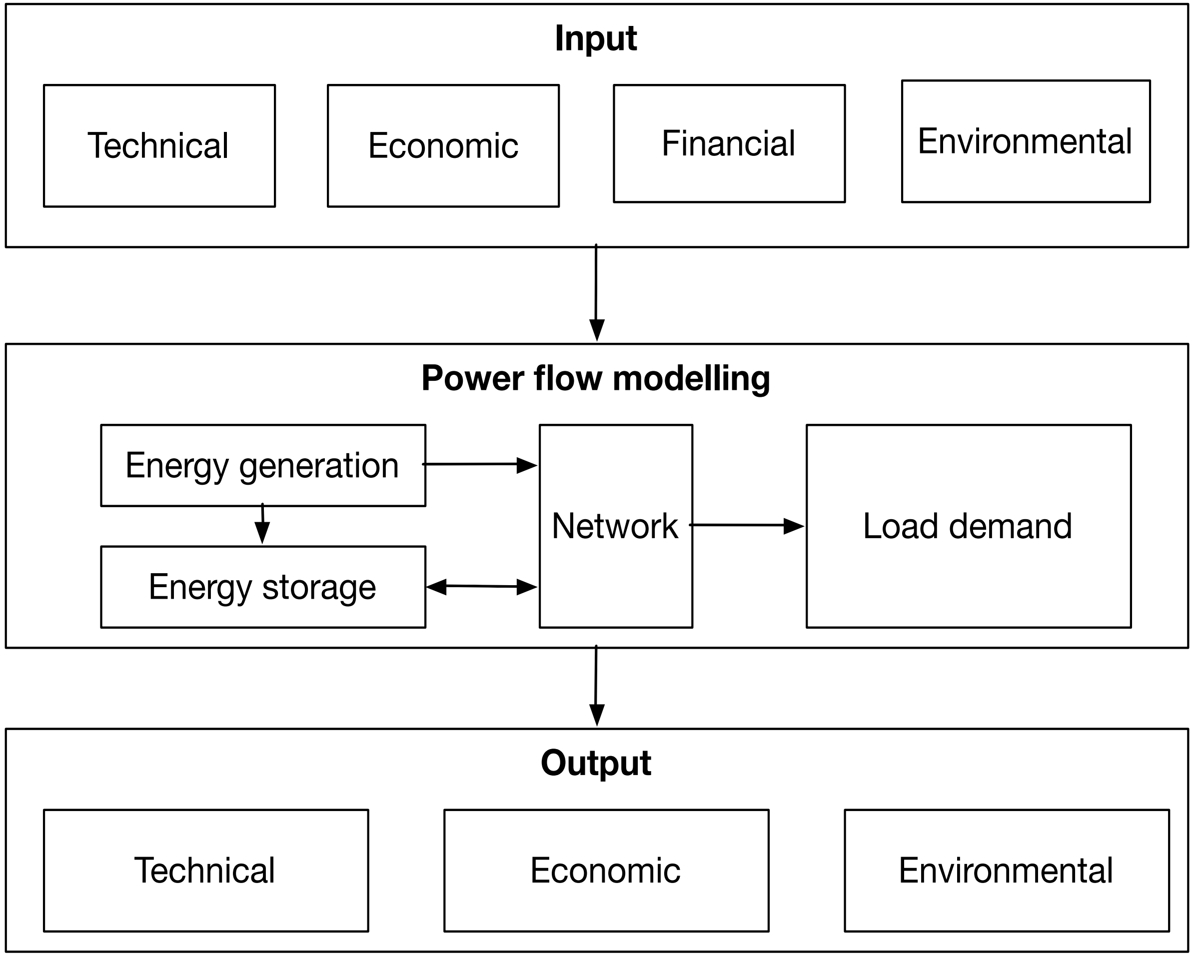
INPUT

- **Define unit of analysis: Storage or generator? Or combination of both?**
- **Define cost types (examples from literature, capital cost, operating cost, decommissioning cost)**
- **Define technical types (efficiency, power rating, energy rating)**
- **Library of energy storage options for study**
- **General financing conditions to be considered to calculate discount rate from cost of debt, cost of equity (examples from literature)**

METHODOLOGY

- **Recommended Practices for techno-economic analysis**
- **Timeframe for the analysis (recommended practices for different sampling interval in techno-economic studies e.g. context)**
- **Define the power flow modelling approach (distribution network) for techno-economic studies**

TEA FRAMEWORK FOR P2814



OUTPUT

- **Focus on techno-economic metrics**

- **Technical metrics**
  - Resilience,
  - Loss of load probability,
  - Power quality（voltage and load management）,
  - Reliability etc.

- **Economic metrics**
  - LCOE
  - NPV

CASE STUDIES

1. EV charging
2. Comparison of energy storage methods (e.g. generation integrated energy storage)
3. Virtual power plant
4. Controllable load and demand response programs, e.g. air conditioners and heat pumps
5. Multi-vector energy systems

- **Open for discussion**

TASKS

- **Data collection and confirming the methodology**
- **Initial Draft document**
- **Meeting (Webex, approx. every 1-2 months)**
- **Schedule of the next teleconference: March 2021, Time TBD**

P2814 STATUS

IMPORTANT DATES

PAR Request Date:14 Feb 2019

PAR Approval Date: 21 May 2019

PAR Expiration Date: 31 Dec 2023

THANK YOU

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