# Two-Layer Energy Sharing Strategy in Distribution Network with Hybrid Energy Storage System

**Xiao Han, Lingling Sun, Guozhong Liu, Li Kang, Fenglei Zheng, and Jing Qiu**

**Abstract** This paper addresses an energy sharing strategy in a two-layer microgrid with the renewable distributed generation and hybrid energy storage system considered to minimize the total energy bill purchased from the utility grid and reduce the peak time consumption from the utility grid. This approach considers the energy operation management of thermal energy loads and electrical energy loads, in which the thermal energy loads are supplied by electrical energy and gas energy. Moreover, this energy sharing model is designed to allow the operation with different types of end-user modes, and the participants are divided into different layers based on their characteristics. Furthermore, the modified trading method is based on the trading model of stock opening with the maximum transaction volume. The proposed two-layer model is tested in 18-bus IEEE system with the real historical data in the Australia energy market. With the proposed two-layer energy sharing strategy, the simulation results show that the two-layer energy sharing model provides economic profits to participants and encourages load schedule.

X. Han (✉) · J. Qiu
School of Electrical and Information Engineering, University of Sydney, Camperdown, NSW 2006, Australia
e-mail: xhan2702@uni.sydney.edu.au

J. Qiu
e-mail: qiujing0322@gmail.com

L. Sun (✉)
School of Electrical Engineering and Telecommunications, University of New South Wales, Kensington, NSW 2052, Australia
e-mail: lingling.sun@unsw.edu.au

G. Liu · L. Kang
School of Electrical Engineering and Intelligentization, Dongguan University of Technology, No. 1 Daxue Rd., 523808 Dongguan, China
e-mail: liugz@dgut.edu.cn

L. Kang
e-mail: kangl@dgut.edu.cn

F. Zheng
Dongguan Power Supply Bureau, 523808 Dongguan, China
e-mail: zhengfl@csg.cn



F. Shahnia and S. Deilami (eds.), *ICPES 2019*, Lecture Notes in Electrical Engineering 669, https://doi.org/10.1007/978-981-15-5374-5_1

**Keywords** Two-layer energy sharing strategy · Hybrid energy storage system · Energy market

## Abbreviations

| | |
|---|---|
| $\beta_n^{bat,ch}$ & $\beta_n^{bat,dch}$ | Charging and discharging coefficient of BESS |
| $\beta_n^{bat}$ | Coefficient of BESS degradation cost |
| $\beta_c^{th}$ & $\beta_l^{th}$ | Coefficients of the thermal energy capacity and loss |
| $\gamma_n^{bat,loss}$ | Coefficient of BESS loss |
| A | Price of electrical and gas energy |
| B | Benefit and profit |
| C | Cost |
| E | Energy |
| P | Power |
| t | Time |
| T | Temperature |
| bat | Battery energy storage system (BESS) |
| ch | Energy charging of BESS |
| dch | Energy discharging of BESS |
| ele | Electrical energy |
| rate | Rate value of variable |
| th | Thermal energy |
| $A_{n,t}^{buy}$, $A_{n,t}^{sell}$ | Planning buying and selling price |
| $\boldsymbol{A}_t^{buy}$ & $\boldsymbol{A}_t^{sell}$ | Sorted matrixes of buying price $A_{n,t}^{buy}$ and selling price $A_{n,t}^{sell}$ |
| $B_{n,t}^{ele}$ | Benefit from electrical energy sharing |
| $E_{n,}^{th,loss}$ | Loss energy of thermal energy |
| $E_{n,t}^{rdg}$ & $E_{n,t}^{dem}$ | DRG energy and demand energy for the n-th participant at time t |
| $E_{n,t}^{buy}$ & $E_{n,t}^{sell}$ | Planning buying and selling energy |
| $E_{n,t}^{t-b}$ & $E_{n,t}^{t-s}$ | Traded buying and selling energy for the n-th trading player at time t |
| $\boldsymbol{E}_t^{buy}$, $\boldsymbol{E}_t^{sell}$ | Sorted matrixes of buying energy $E_{n,t}^{buy}$ and selling energy $E_{n,t}^{sell}$ |
| $f_{A_{n,t}^{buy}}\left\{E_{n,t}^{buy}\right\}$ | Function to sort the buying energy $E_{n,t}^{buy}$ by the same with the same sorting sequence of the buying price $A_{n,t}^{buy}$ |
| $f'_{A_{n,t}^{buy}}\left\{\boldsymbol{E}_t^{\prime buy}\right\}$ | Function to sort the energy $\boldsymbol{E}_t^{\prime buy}$ with the inverse sequence of $f_{A_{n,t}^{buy}}\left\{E_{n,t}^{buy}\right\}$ |
| $M_t^{buy}$ & $M_t^{sell}$ | Amount energy of the buying and selling energy |
| $N_{n,lc}^{bat}$ | Charging numbers during the battery lifetime |
| $P_{n,t}^{waste}$ | Waste energy generated by RDG |
| $P_{n,t}^{dem}$ | Demand energy of the n-th participant at time t |

| | |
|---|---|
| $P_i$, $Q_i$, $V_i$ | Active power, reactive power and voltage in the i-th branch |
| $T_{amb}^{th}$ | Ambient temperature |

## 1 Introduction

With the development of the Renewable Distributed Generation (RDG) and the energy storage system, several existing works focus on the energy management strategy of distribution network with RDG and energy storage system [1]. The distributed energy storage system can mitigate the RDG fluctuation and increase the RDG penetration [2, 3]. Because of this significant role and the high investment cost of DESS in the distribution network, this paper focuses on the energy sharing strategy with Hybrid Energy Storage System (HESS).

Based on the increasing trend of the energy trading method applied in the energy market [4], the two-layer energy sharing model is developed on the energy trading method [5–7] and the energy management method of the energy storage system [3, 8, 9]. A real-time energy trading system is improved with rational aggregator in microgrids for the most currently energy market [5]. Another application of energy trading is proposed for the end-user and energy resources in the energy market [5]. Moreover, the energy sharing provider is proposed with the dynamic internal pricing and the demand response in microgrids [7]. Furthermore, a hierarchical energy management method is proposed to coordinate multiple groups of energy storage system [8]. Meanwhile, there is an optimal sizing model to provide the services of RDG fluctuation smoothing and the peak-time power supplying in the distributed network [3]. At last, A novel model of household energy management is applied with the energy storage devices for demand response [9]. In this paper, we are interested in the application of distributed network within the energy trading method, especially considering different end-users. Our motivation is to reduce the requirement of the capacity of the energy storage system, increase the utilization of RDG, and reduce the energy bill. To achieve these aims, HESS is operated in this model including the distributed Battery Energy Storage System (BESS) and the Thermal Energy Storage System (TESS), and the energy sharing model is modified on the energy trading method. In this paper, we discuss the two-layer energy sharing strategy with the consideration of the maximum transaction volume in the trading algorithm. The contributions of the two-layer energy sharing strategy are as follows.

- The proposed framework of the two-layer energy sharing model classifies different end-users into different communities based on the different characteristics, such as the RDG & load characteristics and geographical location.
- Based on the trading method of stock opening, the trading model is modified with the maximum transaction volume for this two-layer energy sharing model to achieve the aims of increasing RDG utilization, reducing energy bill, and saving HESS cost.

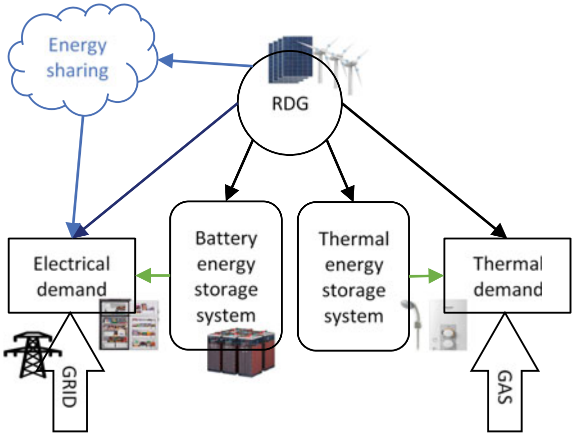



**Fig. 1** Frame structure of the energy sharing model for one participant

This frame structure of the proposed two-layer energy sharing strategy has been shown in Fig. 1. It is not independent of the traditional energy networks, and any kind end-users can be connected to. The rest of this paper is organized as follows. Section 2 introduces an overview of the proposed model. The model functions are presented in Sect. 3. Section 4 shows the case study simulated with the real-world data in the Australia electricity market,and conclusions are discussed in Section 5.

## 2 Energy Sharing Model Overview

In this paper, we propose a two-layer energy sharing strategy for the end-users in the distribution network. Users are classified into different communities based on their different characteristics, and a single end-user can be a community. In this two-layer energy sharing strategy, all participants are classed into two layers. Firstly, the demand is supplied by RDG, HESS, sharing with other participants and buying from the utility grid for each user in the first layer. Moreover, the participants in 1-layer are geographically adjacent and in the same sub-network. There are several groups in 1-layer and energy sharing is operated in each group. After the group-energy-sharing, the energy sharing between groups and other participants are in 2-layer. By this way, there is no network limitation in 1-layer, the energy sharing can be more efficient, and the utilization of RDG is maximized.

The model structure is shown in Fig. 2. It shows the operation in each group of 1-layer, and the energy sharing between groups and other participants in 2-layer. The 1-layer is operated in every community, in which the energy is shared with the participants who have the same load characteristics or are geographically close. After the 1-layer energy sharing, the remaining RDG or the shortage of demand is transferred to participate in the 2-layer energy sharing progressing. For each participant, the energy management model with the HESS operation could calculate

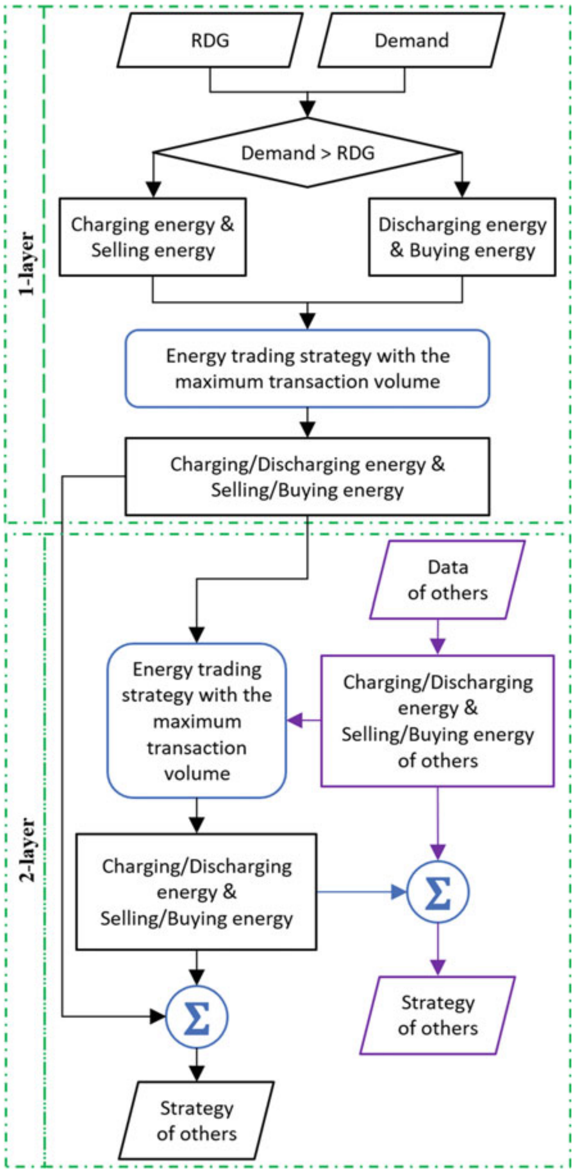



**Fig. 2** The flow chart of two-layer energy sharing model

the charging/discharging/selling/buying energy. According to the calculation, customers could share their selling/buying energy with other participants in the same layer based on the energy trading system. Moreover, the energy trading model is based on the trading method of stock opening, and the maximum transaction volume as the trading principle will increase the energy utilization of RDG and reduce the costs.

# 3 Model and Function

## 3.1 Energy Management Model

The energy storage system plays an important role in energy trading of the distribution network [10]. In this paper, the Battery Energy Storage System (BESS) and Thermal Energy Storage System (TESS) are considered for participants. The management strategy is based on the forecast data of RDG, demand and energy trading, in which the predictive data is referred by the method of the minimization optimization of empirical mean absolute percentage error [11].

The cost of BESS $C_{n,t}^{ele}$ is assumed to be the depreciation cost for every participant. The cost of TESS $C_{n,t}^{th}$ is the Operation and Management (O&M) cost in which the cost considers the thermal energy loss to the ambient. The HESS cost is the sum of costs of BESS and TESS, which the cost functions are expressed as,

$$C_{n,t}^{ele} = \beta_n^{bat} \Delta t \sum P_{n,t}^{ch,e} + P_{n,t}^{dch,e} + \gamma_n^{bat,loss} E_{n,t}^{bat} \tag{1}$$

$$\beta_n^{bat} = \frac{C_{n,inv}^{bat}}{E_{n,rate}^{bat} N_{n,lc}^{bat}} \tag{2}$$

$$C_{n,t}^{th} = \beta_n^{th} \sum P_{n,t}^{ch,th} + P_{n,t}^{dch,th} + A_{gas}^{buy,th} \sum E_{n,}^{th,loss} \tag{3}$$

$$E_n^{th,loss}\left(t_j - t_i\right) = \beta_c^{th}\left(\frac{T_n^{th}\left(t_j\right) - T_n^{th}(t_i)}{t_j - t_i}\right) + \beta_l^{th}\left(\frac{T_n^{th}\left(t_j\right) + T_n^{th}(t_i)}{2} - T_{amb}^{th}\right) \tag{4}$$

Based on the energy balance, the aim of the energy management model is to reduce the costs of BESS and TESS $\left(\mathrm{C}_{\mathrm{n,t}}^{\mathrm{th}}, \mathrm{C}_{\mathrm{n,t}}^{\mathrm{ele}}\right)$, increase the benefit of energy sharing $\left(\mathrm{B}_{\mathrm{n,t}}^{\mathrm{ele}}\right)$ and decrease the energy waste of RDG $\left(\mathrm{P}_{\mathrm{n,t}}^{\mathrm{waste}}\right)$, the objective function of the energy model is expressed as,

$$\underset{P_{n,t}^{th},\, P_{n,t}^{e},\, P_{n,t}^{waste}}{argmin} \left\{A_{grid}^{buy,e} P_{n,t}^{waste} + C_{n,t}^{th} + C_{n,t}^{ele} - B_{n,t}^{ele}\right\} \tag{5}$$

$$B_{n,t}^{ele} = \sum A_{grid}^{buy,e} P_{n,ele,t}^{rdg,e} + \sum A_{grid}^{buy,e} \frac{P_{n,t}^{dch,e}}{\beta_n^{dch,e}} + \sum \left(A_{grid}^{buy,e} - A_{n,t}^{buy,e}\right) P_{n,t}^{buy,e} + \sum A_{n,t}^{sell,e} P_{n,t}^{sell,e} \tag{6}$$

$$P_{n,t}^{rdg} + P_{n,t}^{dch,e} + P_{n,t}^{dch,th} + P_{n,t}^{buy,th} + P_{n,t}^{buy,e} = P_{n,t}^{dem,e} + P_{n,t}^{dem,th} + P_{n,t}^{ch,e} + P_{n,t}^{ch,th} + P_{n,t}^{sell,th} + P_{n,t}^{sell,e} + P_{n,t}^{waste} \tag{7}$$

$$\sum E_{n,t}^{ren} + E_{n,t}^{ch} + E_{n,t}^{buy} = \sum E_{n,t}^{dem} + E_{n,t}^{dch} + E_{n,t}^{sell} \tag{8}$$

$$P_{i+1}(t) = \sum_{h=i+2}^{N} R_h(t) \tag{9}$$

$$Q_{i+1}(t) = \sum_{h=i+2}^{N} Q_h(t) \tag{10}$$

$$V_{i+1}(t)^2 = V_i(t) - \frac{r_i P_i(t) + s_i Q_i(t)}{V_{i,0}} \tag{11}$$

$$V_{i,\min} \le V_i(t) \le V_{i,\max} \tag{12}$$

$$P_{i,\min} \le P_i(t) \le P_{i,\max} \tag{13}$$

$$G_i = \frac{f_{g,i} K_g \Gamma_0}{\rho_0} \sqrt{\frac{f_{g,i}\left(\rho_x^2 - \rho_y^2\right) D_{g,i}^5}{g F_i L_i \Gamma_i Z_g}} \tag{14}$$

$$f_{g,i} = \begin{cases} +1, \rho_x - \rho_y > 0 \\ -1, \rho_x - \rho_y < 0 \end{cases} \tag{15}$$

$$T_{n,\min} \le T_{n,th}(t) \le T_{n,\max} \tag{16}$$

$$S_{n,\min}^{BESS} \le S_{n,t}^{BESS} \le S_{n,\max}^{BESS} \tag{17}$$

$$S_{n,\min}^{TESS} \le S_{n,t}^{TESS} \le S_{n,\max}^{TESS} \tag{18}$$

where Eq. (6) denotes the benefit of energy sharing; Eqs. (7)–(8) denote the power balance; Eqs. (9)–(13) denote the power flow and the boundaries of the voltage and power; Eqs. (14)–(15) denote the gas power flow; Eqs. (16)–(18) denote the maximum and minimum values of temperature $\left(\mathrm{T_{n,th}}\right)$ and SOC $\left(S_{n,t}^{BESS}, S_{n,t}^{TESS}\right)$ of BESS and TESS.

## 3.2 Energy Trading

The energy sharing strategy is based on the call-action method with the maximum transaction volume. For the energy sharing mechanism in the same sharing layer, the sharing energy data is shown by the trading players based on the energy management strategy. The pricing model is not the main focus in this paper, the prices

$\left(A_{n,t}^{sell}, A_{n,t}^{buy}\right)$ are assumed to the forecast price based on the method of the minimization optimization of empirical mean absolute percentage error [11]. In this paper, there is a uniform trading price (clearing price) for every trading player. As the power energy is the homogeneous product in the current energy market, the price is the only factor for the energy sharing mechanism, and the trading principle is to achieve the maximum transaction volume. The trading price $\left(A_{n,t}^{trade}\right)$ is represented as

$$\begin{cases} A_{\min}^{trade} \le A_t^{trade} \le A_{\max}^{trade} \\ A_{\max}^{trade} = \max\left\{\max\left(A_{n,t}^{buy}\right), \max\left(A_{n,t}^{sell}\right)\right\} \\ A_{\min}^{trade} = \min\left\{\min\left(A_{n,t}^{buy}\right), \min\left(A_{n,t}^{sell}\right)\right\} \\ n \in [1, N] \end{cases} \tag{18}$$

$$A_t^{trade} \in \left\{argmax\left\{\min\left(\sum_{n=1}^{N} E_{n,t}^{buy}\gamma_{n,t}^{buy}, \sum_{n=1}^{N} E_{n,t}^{sell}\gamma_{n,t}^{sell}\right)\right\}\right\}, \tag{19}$$

$$\begin{cases} \gamma_{n,t}^{buy} = \begin{cases} 1, & A_{n,t}^{buy}(t) \ge A_{n,t}^{trade}(t) \\ 0, & others \end{cases} \\ \gamma_{n,t}^{sell} = \begin{cases} 1, & A_{n,t}^{sell}(t) \le A_{n,t}^{trade}(t) \\ 0, & others \end{cases} \end{cases} \tag{20}$$

where the Eqs. (18)–(20) denote the mathematical algorithm of the energy trading, in which $\gamma_n^{sell}, \gamma_n^{buy}$ denote the coefficients of selling/buying, they are binary variables. To achieve the principle of the maximum transaction volume, the trading amount with the same clearing price is processed as

$$\boldsymbol{A}_t^{buy} = descend\left\{A_{n,t}^{buy}\right\}, \boldsymbol{A}_t^{sell} = ascend\left\{A_{n,t}^{sell}\right\} \tag{21}$$

$$\boldsymbol{E}_t^{buy} = f_{A_{n,t}^{buy}}\left\{E_{n,t}^{buy}\right\}, \boldsymbol{E}_t^{sell} = f_{A_{n,t}^{sell}}\left\{E_{n,t}^{sell}\right\} \tag{22}$$

$$M_t^{buy} = \sum E_{n,t}^{buy}, M_t^{sell} = \sum E_{n,t}^{sell} \tag{23}$$

$$M_t^{trade} = \min\left\{M_t^{buy}, M_t^{sell}\right\} \tag{24}$$

$$\begin{gathered} m_t^{buy} = 1 + \underset{i}{\text{argmin}}\left\{M_t^{trade} - \sum_{n=1}^{i} \boldsymbol{E}_t^{buy}(n:i)\right\}, \\ if\ M_t^{trade} - \sum_{n=1}^{i} \boldsymbol{E}_t^{buy}(n:i) \ge 0, i \in [1, N] \end{gathered} \tag{25}$$

$$m_t^{sell} = 1 + \underset{j}{\text{argmin}} \left\{ \boldsymbol{M}_t^{trade} - \sum_{n=1}^{j} \boldsymbol{E}_t^{sell}(n:j) \right\}, \quad if\ M_t^{trade} - \sum_{n=1}^{j} \boldsymbol{E}_t^{sell}(n:j) \geq 0, j \in [1, N] \tag{26}$$

$$\boldsymbol{E}_t^{\prime buy}(m) = \begin{cases} \boldsymbol{E}_t^{buy}(m), \quad m \leq \left(m_t^{buy} - 1\right) \\ M_t^{trade} - \sum_{1}^{m_t^{buy}-1} \boldsymbol{E}_t^{buy}(1:m), \quad m = m_t^{buy} \\ 0, \quad m > m_t^{buy} \end{cases} \tag{27}$$

$$\boldsymbol{E}_t^{\prime sell}(m) = \begin{cases} \boldsymbol{E}_t^{sell}(m), \quad m \leq \left(m_t^{sell} - 1\right) \\ M_t^{trade} - \sum_{1}^{m_t^{sell}-1} \boldsymbol{E}_t^{sell}(1:m), \quad m = m_t^{sell} \\ 0, \quad m > m_t^{sell} \end{cases} \tag{28}$$

$$\boldsymbol{E}_t^{t-b} = f'_{A_{n,t}^{buy}}\left\{\boldsymbol{E}_t^{\prime buy}\right\}, \boldsymbol{E}_t^{t-s} = f'_{A_{n,t}^{buy}}\left\{\boldsymbol{E}_t^{\prime sell}\right\} \tag{29}$$

$$E_{n,t}^{t-b} = \boldsymbol{E}_t^{t-b}(n), E_{n,t}^{t-s} = \boldsymbol{E}_t^{t-s}(n) \tag{30}$$

where the Eqs. (21)–(22) denote the ordering based on the prices; the Eqs. (23)–(26) denote the total buying and selling transaction volume; the Eqs. (27)–(30) denote the selling or buying energy for each trading players. By the processing the equations, the trading energy for every trading player $\left(E_{n,t}^{t-b}, E_{n,t}^{t-s}\right)$ can be calculated.

## 4 Case Study

In this paper, the two-layer energy sharing strategy is proposed to possess end-users with different load characteristics and different HESS capacities in the distribution network. The participants 1–11 are the residential end-users, based on the geographical location they are classed into three communities (1–6, 7–9, 10–11) in the 1-layer. The participants 12–18 are the business and industry energy users, each of them is assumed to be one community and only progress in the 2-layer. The HESS capacities of participants 10–15 are zero, which is no HESS; the TESS capacities of participants 2 and 6–8 are the lowest value, which is the no extra TESS. The case study is operated in Matlab® on a PC with Intel Core i7-6600 CPU @ 2.80 GHZ with 8.00 GB RAM. All the data of the participants is the real historical data in the Australia national electricity market [12].

1. *Simulation in 1-layer*

With energy management model, the energy sharing strategy is operated for participants 1–11 in three communities. As shown in Fig. 3, the energy strategies for 11 participants are operated in 1-layer. The purple bar denotes the electrical buying

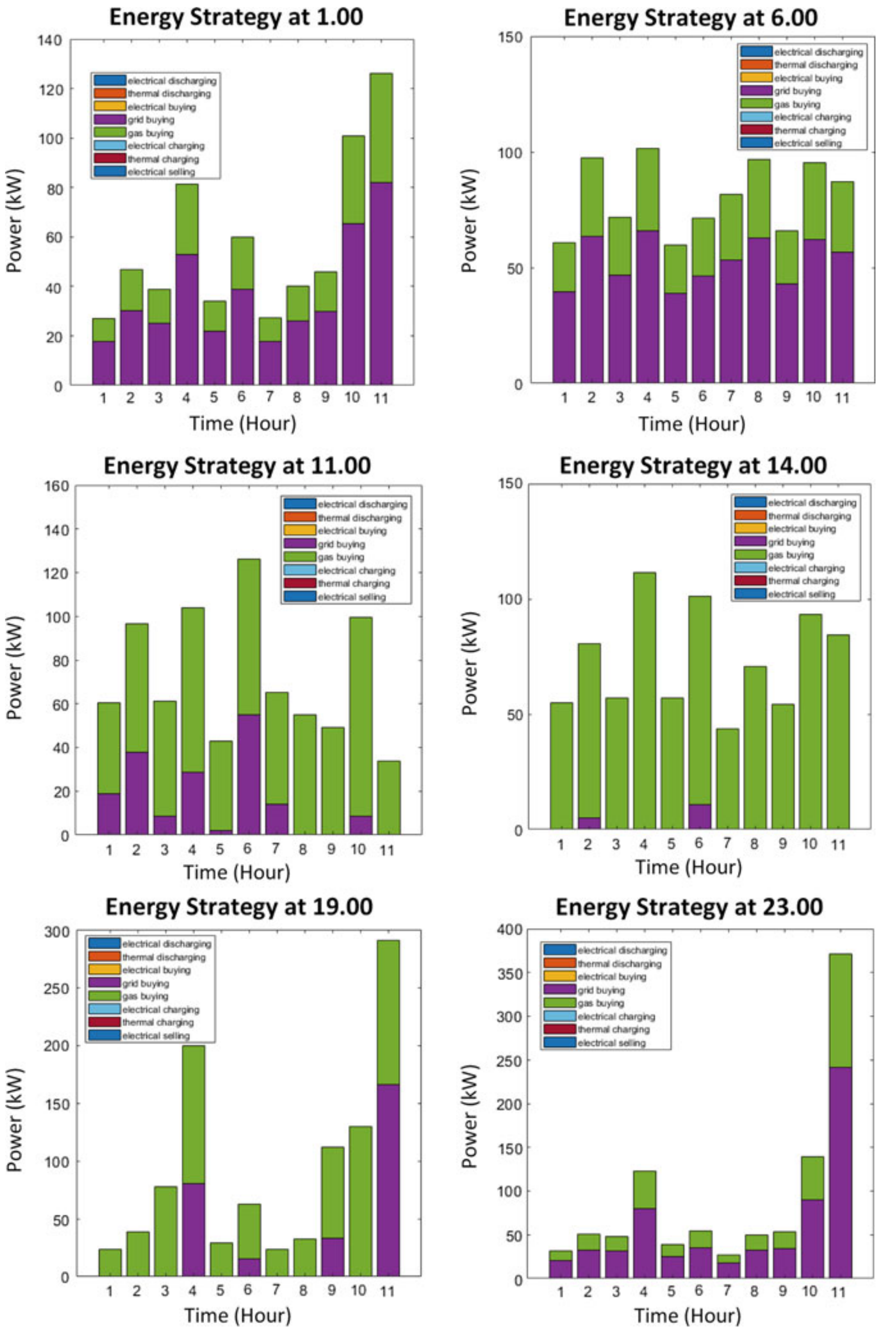



**Fig. 3** The simulation results of the energy strategies in 1-layer at time 1 am, 6 am, 11 am, 2 pm, 7 pm and 11 pm

energy from the utility grid, the green bar denotes the gas buying energy to supply the thermal demand. For the residential under-users, the investment costs of RDG and HESS is very high, the capacities of them are low, the supplying energy for electrical demand and thermal demand are main buying from the main grid. For the residential under-users, the investment costs of RDG and HESS is very high, the capacities of them are low, the supplying energy for electrical demand and thermal demand are main buying from the main grids. Figure 4 shows the hourly simulation results of three communities in 1-layers, this data is the transferring data for 2-layer.

2. *Simulation in Two-Layer Energy Sharing Strategy*

With the transferring data of three communities from 1-layer, the simulation results are calculated for the three communities and the participants 12–18. The energy sharing strategies in 2-layer of participants 12–18 are shown in Fig. 5. Because of the demand and generation characteristics of participants 12–18, the capacities of RDG and HESS are higher than the residential und-users in 1-layer, the energy charging is from 12.00 to 18.00, because that the PV panels generation is higher, and the energy sharing volume is much lower than the remaining energy, since the remaining energy is used as the HESS charging energy. Based on all the simulation data, the priority of energy management in this two-layer energy sharing strategy is shown in Fig. 6. There is the charging energy of HESS after energy sharing. By this way, the utilization of RDG can be provided, and the requirement of HESS is reduced.

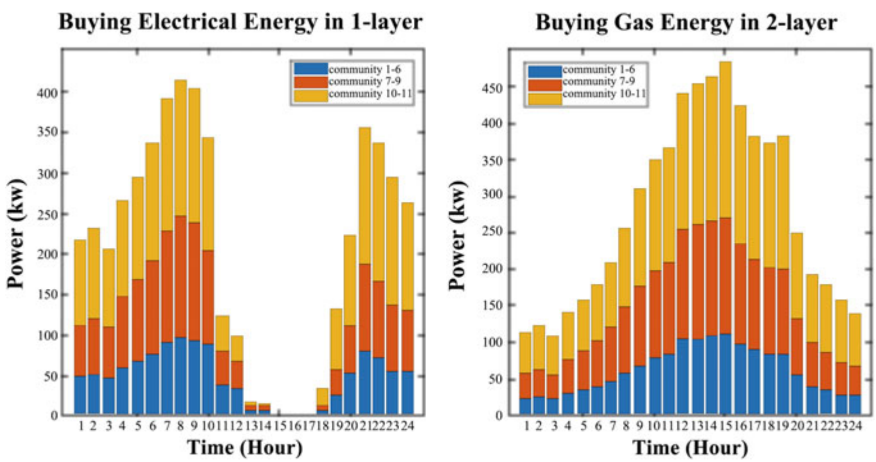



**Fig. 4** The energy data of 1-layer is transferred for 2-layer energy sharing of 24 h

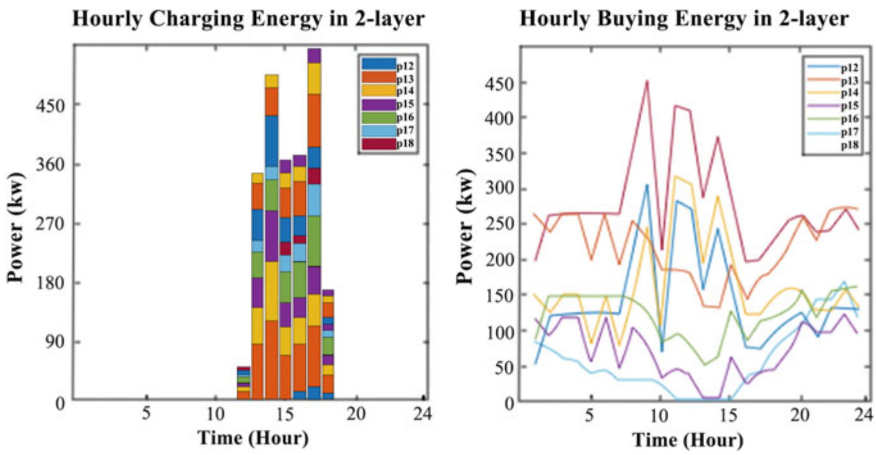
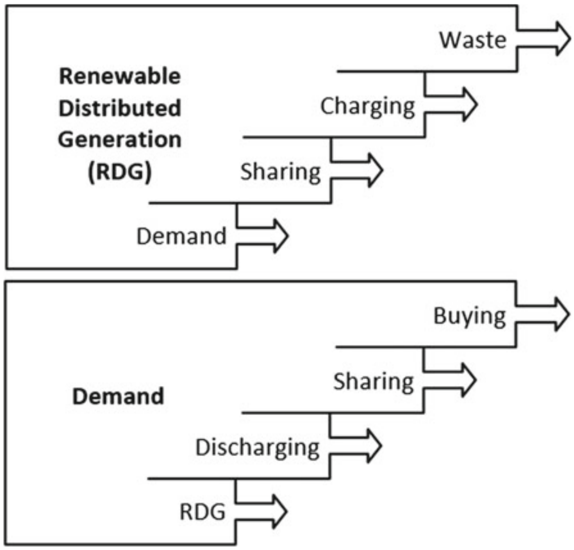



**Fig. 5** The hourly simulation results of 2-layer for participants 12–18

**Fig. 6** The energy management priority in this proposed two-layer energy sharing model




## 5 Conclusion

The two-layer energy sharing strategy is proposed to improve the utilization of RDG, reduce the energy cost of end-users, and decrease the investment of energy storage devices. Moreover, the HESS model is used in this paper, which includes BESS and TESS. The power flow and gas flow are considered in the energy management model under the energy nodal balance. Furthermore, the energy trading model with the maximum transaction volume is proposed as the energy sharing mechanism based on the stock trading method of stock opening. In the future, our work will focus on the trading player complete and the pricing model generalization works.

**Acknowledgements** This work was supported by the National Key Research and Development Program of China (2017YFB0903205) and was also supported by the ARC Research Hub for Integrated Energy Storage Solutions (IH180100020), FEIT Early Career Researcher and Newly Appointed Staff Development Scheme, The University of Sydney and Sir William Tyree Foundation-Distributed Power Generation Research Fund.

## References

1. Kang J, Yu R, Huang X, Maharjan S, Zhang Y, Hossain E (2017) Enabling localized peer-to-peer electricity trading among plug-in hybrid electric vehicles using consortium blockchains. IEEE Trans Industr Inf 13(6):3154–3164
2. Li Q, Choi SS, Yuan Y et al (2011) On the determination of battery energy storage capacity and short-term power dispatch of a wind farm. IEEE Trans Sustain Energy 2(2):148–158
3. Zhang F, Xu Z, Meng K (2016) Optimal sizing of substation-scale energy storage station considering seasonal variations in wind energy. IET Gener Transm Distrib 10(13):3241–3250
4. Castaneda J, Enslin J, Elizondo D, Abed N, Teleke S (2010) Application of statcom with energy storage for wind farm integration. In: Proceedings IEEE PES transmission and distribution conference and exposition, pp 1–6
5. Zhang C, Wang Q, Wang J, Pinson P, Morales JM, Østergaard J (2018) Real-time procurement strategies of a proactive distribution company with aggregator-based demand response. IEEE Trans Smart Grid 9(2):766–776
6. Nguyen DT, Le LB (2015) Risk-constrained profit maximization for microgrid aggregators with demand response. IEEE Trans Smart Grid 6(1):135–146
7. Zhang C, Xu Y, Dong ZY, Ma J (2017) Robust operation of microgrids via two-stage coordinated energy storage and direct load control. IEEE Trans Power Syst 32(4):2858–2868
8. Wang D, Meng K, Gao X, Qiu J, Lai LL, Dong ZY (2018) Coordinated dispatch of virtual energy storage systems in LV grids for voltage regulation. IEEE Trans Indust Inf 14(6):2452–2462
9. Wang Z, Gu C, Li F, Bale P, Sun H (2013) Active demand response using shared energy storage for household energy management. IEEE Trans Smart Grid 4(4):1888–1897
10. Castaneda J, Enslin J, Elizondo D, Abed N, Teleke S (2010) Application of statcom with energy storage for wind farm integration. In: Proceeding IEEE PES transmission and distribution conference and exposition, pp 1–6
11. Kong W, Dong ZY, Hill DJ, Luo F, Xu Y (2018) Short-term residential load forecasting based on resident behaviour learning. IEEE Trans Power Syst 33(1):1087–1088
12. AEMO: http://www.aemo.com.au