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ANALYZING DEMAND RESPONSE PROGRAM IN RESIDENTIAL ENERGY HUB OPERATION

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Abstract- This study involves evaluating the impact of a demand response program (DRP) on an extended residential energy hub (EH) operation that comprises a photovoltaic (PV) generator, a solar heat exchanger (SHE), and a battery energy storage system (BESS). Accordingly, a mathematical scheme is developed utilizing daily energy demands (including electricity, heating, and cooling) and time-varying energy prices to enhance energy efficiency and lower operating costs. Four scenarios are presented to examine how operational efficiency is influenced by solar energy technologies, BESS, and DRP. The intended problem has been programmed using the CPLEX solver within GAMS software. The overall findings reveal that the proposed model results in a notable decrease in operating costs. Moreover, the model seems appropriate for load traits in residential regions.

Keywords: Residential Energy Hub, Battery Energy Storage System, Solar, Demand Response Program, GAMS.

1. INTRODUCTION

Energy demands are primarily based on thermal and electrical sources. Therefore, combining heat and electricity is a major evolution toward improving system efficiency and reducing costs by taking into consideration multiple forms of energy rather than relying solely on one [1-3]. Monitoring and controlling residential energy consumption is crucial in the smart home to minimize operational costs and environmental pollution [4-5]. Mostly, the EH optimization model of a residential area is designed to reduce consumers' energy costs [6]. Recently, PV power generation systems and SHE have been widely developed due to environmental concerns [7-8]. In the last few years, some researchers have studied EH for different purposes and in the presence of various resources. The authors of [9] provide an operational model designed to optimize energy costs and pollution emissions for a residential home, utilizing PV and SHE instead of gas and electricity.

This structure of the EH is not very pleasant for residential areas due to the climatic conditions of some areas, it is necessary to consider cooling demand for indoor air-conditioning in residential buildings. In this regard, in [10] energy costs of a residential building have been optimized taking into account the electrical, heating, and cooling demands. Apart from the high initial investment, the main disadvantage of solar systems is their dependence on solar power, which is highly non-linear and varies at different times of the day and in different seasons [11-12]. Therefore, solar systems do not have the ability to coordinate with the load on demand. Hence, storage systems offer a significant advantage to solar systems in terms of increasing their efficiency and reliability [13-14]. For example, in [13], an electrical energy storage system and PV are considered in the scheduling problem to minimize investment costs as well as environmental pollution. Efficiency from an economic perspective has also improved in ref [14] and the cost of purchasing energy in the system has decreased. Also, in [15-16], thermal storage along with electrical storage has been used to reduce application costs and improve system efficiency.

The optimal management of a residential EH by considering a wind turbine (WT) as a renewable energy source (RES) is investigated in [17], in which the objective function contains the cost of energy exchanged with the distribution grid. In [18] objective is to achieve an optimal compromise between the efficiency and the resilience of a bi-level residential EH considering uncertainties of RESs. A multi-objective optimization problem is formulated in [19] for the allocation of energy resources in the residential hub energy and the preparation of scheduling plans for equipment using energy alongside conventional classified equipment. In this research, the overall objective is to minimize both energy costs and convenience deviations. DRPs are defined as a practical and effective solution to change consumers' electrical energy consumption according to their electricity demand pattern [20-23]. In this regard, the authors of [24] and [25] have considered DRP for the EH, which has a significant reduction in operating costs.

A study is conducted in this paper to evaluate the optimal management of the extended EH by considering the demands of electricity, heating, and cooling in the presence of BESS, solar energies (PV and SHE), and DRP. Minimizing the overall energy cost of the system is the main objective function of the problem proposed. Moreover, the various practical constraints of the system and resources are of paramount significance in this study. The results depict the performance-enhancing of the proposed methodology for optimizing the total cost of the system and scheduling the optimal efficiency of all equipment within the residential EH.

Section 2 outlines the detailed structure description of a residential EH and in the next section, the formulation of the problem is taken into account. Section 4, describes the proposed method and solving steps. In section 5, the simulation and the analyses of the scheduled method are demonstrated. Lastly, section 6 summarizes the findings of the present study and discusses the conclusion.

2. STRUCTURE OF ENERGY HUB FOR RESIDENTIAL LOADS

The overall EH structure is illustrated in Figure 1, in which energy storage, control, and conversion are used to connect various energy sources [26].

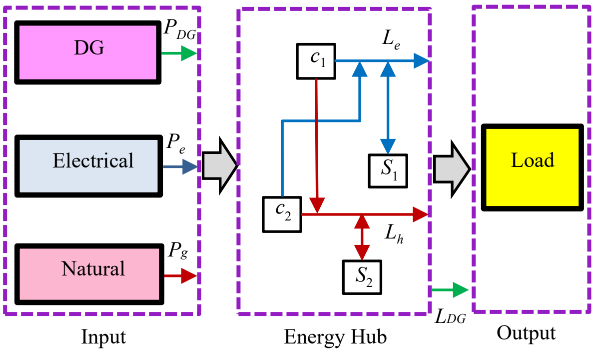

Figure 1. Energy hub topology

The EH model is mathematically expressed using the Equation (1):

$$\begin{bmatrix} L_1 \\ L_2 \\ \vdots \\ L_m \end{bmatrix} = \begin{bmatrix} c_{11} & c_{12} & \cdots & c_{1n} \\ c_{21} & c_{22} & \cdots & c_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ c_{m1} & c_{m2} & \cdots & c_{mn} \end{bmatrix} \begin{bmatrix} P_1 \\ P_2 \\ \vdots \\ P_n \end{bmatrix} \tag{1}$$

where, each factor of c indicates the relationship between input and output vectors. In other words, c_{ab} is the interconnecting component that illustrates the correlation between the ath input power and the bth output power; L_b, $b = 1, 2, 3\ldots, m$ and P_a, $a = 1, 2, 3\ldots, n$ are the output carriers and power inputs.

The model of extended EH for residential areas load is indicated in Figure 2. In general, the EH structure includes input energies such as gas and electricity named P_g and P_e. Also, output energies, which are the same as electrical, heating, and cooling demands, are defined by L_e, L_h, and L_c, respectively.

The extended EH model consists of transformers, microturbine (MT), gas boiler (GB), photovoltaic panel, SHE, and BESS. The proposed topology utilizes air-conditioners (AC) and absorption chillers (ACH) for the purpose of providing cooling to the residential area. Electricity is met by the MT, PV, and energy generated from the main grid. As it turns out, thermal energy is provided by SHE, GB, and MT. Also, cooling energy is provided by the ACH and AC. Thus, this is a flexible model in which conveys electricity, heating, and cooling energy can be easily shared between devices.

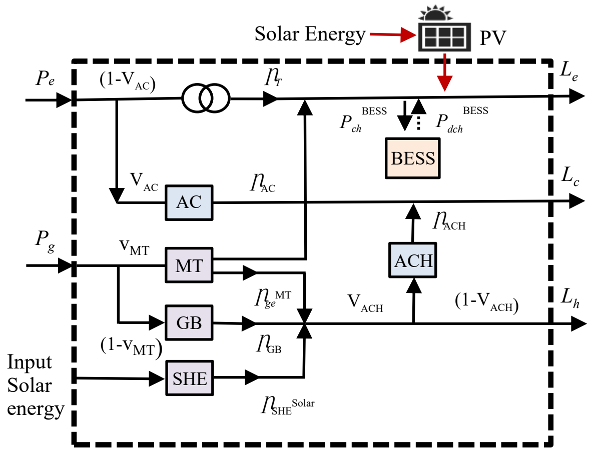

Figure 2. Extended energy hub model for residential demands

3. FORMULATION OF PROBLEM

3.1. Objective Function

There are two components to operating costs, which involve the consumption of electricity and heat on a daily basis, with the aim of minimizing the overall cost. Hence, a definition of the objective function can be found in the Equation (2).

$$\min \text{cost} = \sum_{t=1}^{24} (P_e(t).C_e(t) + P_g(t).C_g(t)) \tag{2}$$

In which $P_e(t)$ and $P_g(t)$ refer to electricity and gas received power as the inputs of EH at hour t. Additionally, $C_e(t)$ and $C_g(t)$ denote the prices of electricity and gas resources for hour t.

3.2. Constraints

3.2.1. Energy Balance Constraints

Achieving energy balance using Equations (3)-(5) is crucial.

$$\begin{aligned} L_e(t) &= P_e(t).(1 - v_{AC}(t)).\eta_T + P_g(t).v_{MT}(t).\eta_{ge}^{MT} \\ &+ P_{dch}^{BESS}(t) - P_{ch}^{BESS}(t) + P_{PV}(t) + Load^{DR}(t) \end{aligned} \tag{3}$$

$$\begin{aligned} L_h(t) &= [P_g(t).(v_{MT}(t)).\eta_{gh}^{MT} + (1 - v_{MT}(t)).\eta_{GB} + \\ & P_{SHE}(t)].(1 - v_{ACH}(t)) \end{aligned} \tag{4}$$

$$\begin{aligned} L_c(t) &= [P_e(t).(v_{AC}(t)).\eta_e^{AC} + [P_g(t).(v_{MT}(t)).\eta_{gh}^{MT} + \\ & + (1 - v_{MT}(t)).\eta_{GB} + P_{SHE}(t)].v_{ACH}(t)).\eta_h^{ACH} \end{aligned} \tag{5}$$

where, $v_{AC}(t)$, $v_{MT}(t)$, $v_{ACH}(t)$ represent how much power is dispatched of electricity, gas, and heat conversion, P_{ch}^{BESS} and P_{dch}^{BESS} are the BESS charging and discharging power at hour t, respectively. Moreover, $P_{pv}(t)$ signifies the power generated by the PV at hour t; $P_{SHE}(t)$ is the amount of thermal energy produced by the SHE at hour t. In addition, η_{ge}^{MT} and η_{gh}^{MT} are the efficiency indices of the MT in converting gas into electrical power and thermal energy; η_{GB}, η_T, η_h^{ACH}, and η_e^{AC} are the efficiency of GB, transformers, ACH, and AC, respectively.

3.2.2. Power Constraints

Energy purchased from electricity and gas networks can be limited by Equations (6-7), respectively.

$$0 \le P_e(t) \le P_e^{\max} \tag{6}$$

$$0 \le P_g(t) \le P_g^{\max} \tag{7}$$

where, $P_e^{\max}$ and $P_g^{\max}$ are the maximum amounts of electricity and gas that are permitted.

3.2.3. Conversion Constraints

The devices' conversion limits at hour t are described by v_{AC}, v_{MT}, and v_{ACH}. These are state variables that indicate how much input power is being directed from the relevant devices. Constraints related to state variables are defined according to Equations (8)-(10).

$$0 \le v_{AC}(t) \le 1 \tag{8}$$

$$0 \le v_{MT}(t) \le 1 \tag{9}$$

$$0 \le v_{ACH}(t) \le 1 \tag{10}$$

3.3. Battery Modeling

In Equations (11) and (12) the BESS charging and discharging formulation are provided. On the other side, during a specific period, the battery is not able to charge and discharge simultaneously. Thus, the constraint of Equation (13) is followed in which the binary variables of $u_b^{t,ch}$, also $u_b^{t,dch}$ are associated with the battery state of charge and discharge.

Moreover, the power limits of charging and discharging are described in Equations (14) and (15), respectively [27].

$$SOC_b^t = SOC_b^{t-1} + \eta_b^{ch} \times P_b^{t,ch} - \eta_b^{dch} \times P_b^{t,dch} \tag{11}$$

$$SOC_b^{\min} \le SOC_b^t \le SOC_b^{\max} \tag{12}$$

$$u_b^{t,ch} + u_b^{t,dch} \le 1 \tag{13}$$

$$P_b^{t,ch} \le P_{b,\max}^{ch} \times u_b^{t,ch} \tag{14}$$

$$P_b^{t,dch} \le P_{b,\max}^{dch} \times u_b^{t,dch} \tag{15}$$

3.4. DRP Modeling

The DRP applied in this study is a time-based model. It is intended to smooth the demand curve via an energy consumption shifting technique from on-peak to off-peak periods, thereby reducing the system operating costs. The time-based rate DRP is demonstrated in Figure 3 [28]. As modeled in Figure 3, by contributing to the DRP chosen, consumers may be able to shift only a particular percentage of loads to other hours.

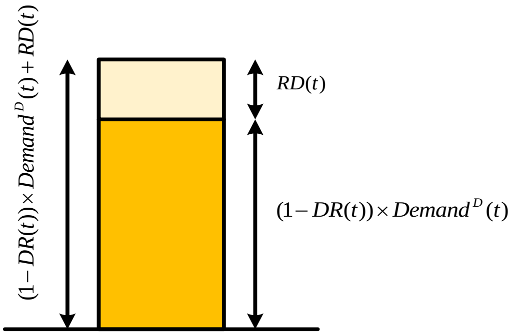

Figure 3. The demand model related to the proposed DRP

This concept is mathematically formulated in Equations (16) and (17):

$$Demand^{DRP}(t) = (1-DR(t)) \times Demand^D(t) + RD(t) \tag{16}$$

$$\begin{aligned} &Demand^D(t) - Demand^{DRP}(t) = \\ &= DR(t) \times Demand^D(t) - RD(t) \end{aligned} \tag{17}$$

According to Equations (18) to (21) the demand is not changed but shifted to another period of time. Equation (19) indicates that increasing demand must not exceed a particular proportion of the baseload. In addition, the percentage reduction or increase must be less than a specified amount determined by Equations (20) and (21). This study assumes a 20% percentage.

$$\sum_{t=1}^{T} RD(t) = \sum_{t=1}^{T} DR(t) \times Demand^D(t) \tag{18}$$

$$0 \le Demand^{in}(t) \le in(t) \times Demand^D(t) \tag{19}$$

$$DR(t) \le DR_{\max} \tag{20}$$

$$in(t) \le in_{\max} \tag{21}$$

In the above, $Demand^D(t)$ is the anticipated load at hour t, $DR_{\max}$ and $in_{\max}$ are the maximum percentage of demand that can be diminished or augmented. $RD(t)$ represents the demand reduction rate. $Demand^{in}(t)$ is the maximum amount of demand allowable. $in(t)$ is the proportion of the maximum amount of increasable demand. $Demand^{DRP}(t)$ is the demand after DRP. Moreover, $DR(t)$ refers to demand reduction value.

4. PROPOSED METHOD

The proposed model for EH is solved using the CPLEX solver of GAMS software. The model is represented simply and briefly as a flowchart in Figure 4.

5. SIMULATION

5.1. Scenarios

In order to assess solar energies, BESS, and DRP impacts and advantages, on the optimal management of EH, four case studies have been investigated, as Table 1.

Table 1. Summary of the understudied cases

Scenario	Base EH	Solar	BESS	DRP
1	✓			
2	✓	✓		
3	✓	✓	✓	
4	✓	✓	✓	✓

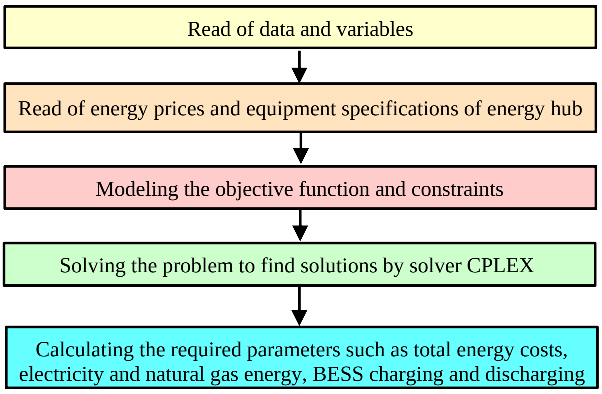

Figure 4. Problem solution steps in GAMS

5.2. Database

Figures 5 and 6 show demand curves for electrical, heating and cooling sections as well as PV and SHE output power, respectively. Moreover, Figure 7 shows the electricity and gas prices, where the gas price is set fixed. The parameters of efficiency are given in Table 2, also the amounts of $P_e^{\max}$ and $P_g^{\max}$ are considered 5 MW and 3 MW, respectively.

Table 2. Efficiency data

$_{ge}^{MT}$	$_{gh}^{MT}$	$_{GB}$	$_{T}$	$_{h}^{ACH}$	$_{e}^{AC}$
0.4	0.5	0.88	0.95	0.9	0.85

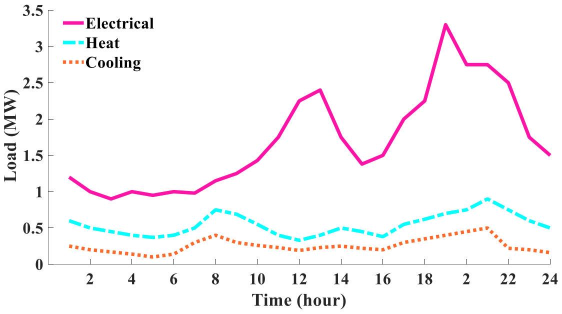

Figure 5. Electricity, heating, and cooling demand on a particular day

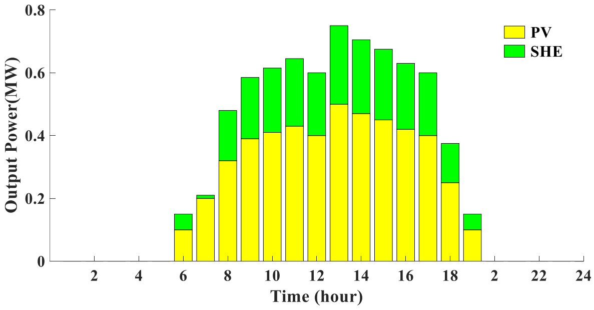

Figure 6. Power properties of SHE and PV on a particular day

5.3. Simulation Results of Scenarios

The electricity and gas input to the EH are shown in Figures 8-11 for 4 different scenarios. According to Figure 8, it can be said that the electrical energy has its highest amount of 2.25 MW during peak time (at 7 PM). Thus, the rest of the energy is supplied by MT, so it leads to high demand for natural gas.

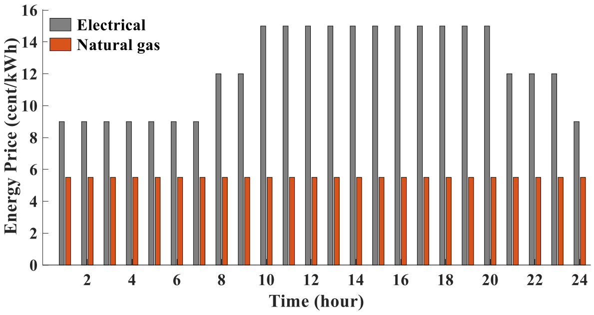

Figure 7. Price characteristics of electricity and gas

Its highest value is approximately 3 MW (at 9 PM). MT and GB operate in terms of parameters such as the hourly prices of electricity and gas, the ratio of energy needed for both electricity and heat demand as well as the effectiveness of the conversion process. For this reason, gas utilization steadily increases post-7 PM to cater to the demands of both heating and cooling.

According to the obtained curve in Figure 9, the amount of electricity and gas purchased in this scenario has decreased compared to one. Relative to the initial scenario, the demand for electrical power at 13 PM decreased from 1.48 MW to 1.23 MW, because at 13 PM, the highest potential and capacity of PV and SHE was reached. One can easily see that the consumption of natural gas from 6 AM to 19 PM is declined and in this way, environmental pollution is also reduced. It is obvious that the result is due to the generation of PV and SHE in this period. Consequently, it has been discovered that the inclusion of solar energy in EH systems result in a significant enhancement in their overall performance compared to scenario 1.

In scenario 3, due to the presence of BESS, the amount of energy purchased from the electricity network increased from 1 to 7 AM. That is because of the charging of BESS in this period, in which the electricity price is low. But on the contrary, the BESS provides power to the electrical load during high demand through discharging in which the electricity price is high, and that is why the total cost of energy is improved. Thus, it can be concluded that energy storage equipment holds a promising role in load balancing and load change.

As illustrated in Figure 11, due to the EH participation in the DRP, electrical demand decreased during peak hours and increased during low-load hours. As a result, the DRP has resulted in an increase in electricity purchases during low-cost hours, compared to case studies 1, 2, and even 3. In contrast, the amount of electricity purchased for the EH has decreased significantly during the high-price hours. Hence, DRP alleviated power consumption peak timeframes so that the electricity demand curve was significantly improved.

The EH operating cost for the four case studies is summarized in Table 3. Also, the cost savings of each item compared to the first item are presented in the same Table. According to Table 3, the fourth scenario has the lowest total energy cost. In this regard, the EH, which includes SHE, PV, BESS and DRP, yields more desirable results and efficiency rather than the other three scenarios.

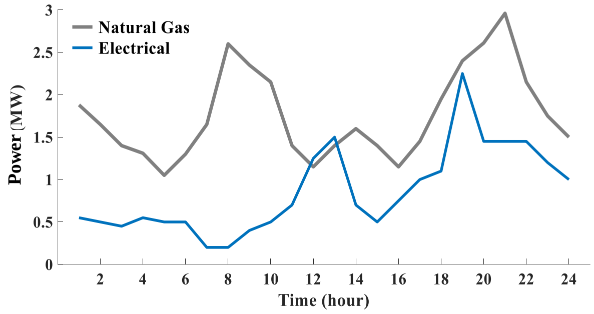

Figure 8. Electricity and gas power in scenario 1

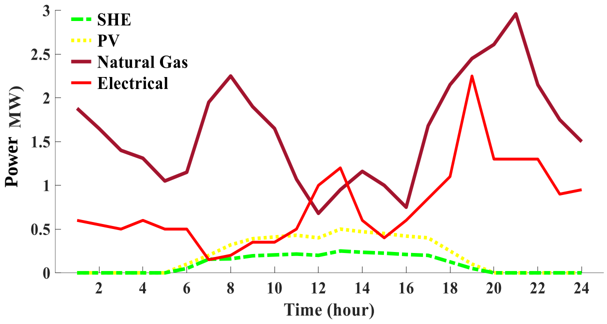

Figure 9. Electricity and gas power in scenario 2

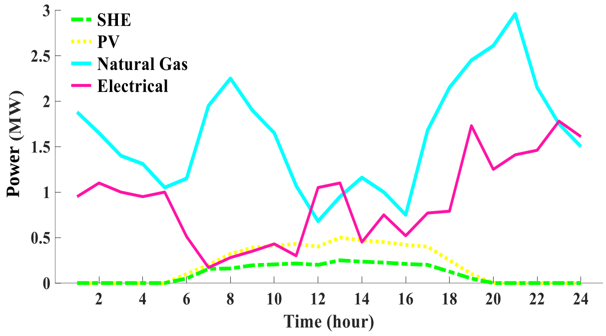

Figure 10. Electricity and gas power in scenario 3

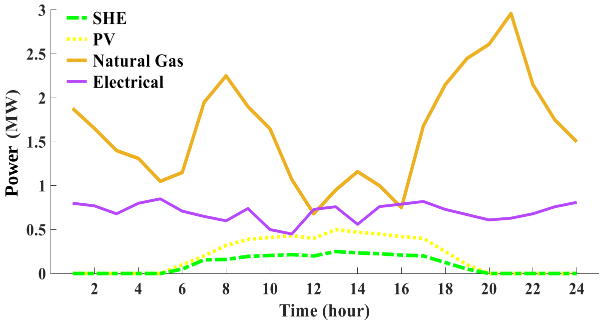

Figure 11. Electricity and gas power in scenario 4

Figure 12 shows the charge and discharge values of BESS for comparison scenarios 3 and 4, where the curve's positive and negative values signify BESS discharge and charge, respectively. In scenario 4, due to the consideration of the DRP and the demand shift from peak hours to low load hours, the BESS participation has decreased in this period compared to the previous scenario.

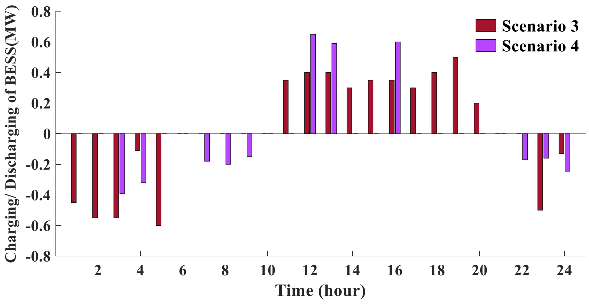

Figure 12. The BESS charger and discharger power

Table 3. Energy costs in 4 different scenarios

Scenario	1	2	3	4
Overall energy costs ($)	5813.164	5047.588	4801.706	4556.118
Total benefit ($)	--------	765.576	1011.458	1257.046

6. CONCLUSION

The present study evaluated an efficient scheduling technique for a residential EH. EH consists of electricity, heating, and cooling demands, and the electricity purchase is based on the time-varying price. The impact of solar energy technologies, BESS, and DRP on the operational costs of EH is demonstrated through a variety of scenarios. To examine how solar energy influences the optimal functioning of the EH, PV and SHE are considered. Solar resources decreased the operating cost by 13.169% compared to the EH base case (without BESS and DRP). In addition, the presence of BESS leads to a reduction in operating costs by 17.399%. Finally, with the participation of the EH in DRP, the electric demand curve became smoother, resulting in a reduction in operating costs by 21.624%. To conclude, the proposed EH could have a significant impact on operational efficiency based on its structure and components.

This study focuses only on the electrical section's DRP. Because its main objective is to compare the overall costs of the system after incorporating BESS and DRP into the system. However, by developing advanced technologies, it is easily feasible to utilize a variety of energy storage systems in all sectors. This will increase renewable energy penetration and help achieve the decarbonization target. In future work, we aim to design a multi-energy system that includes an integrated DRP (IDRP) and different stationary and mobile energy storages to improve its technical, economic, and environmental criteria.

REFERENCES

[1] M. Bilgili, F. Ekinci, A. Ozbek, T. Demirdelen, "Short Term Renewable Energy Strategic Vision in the World", International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 51, Vol. 14, No. 2, pp. 111-123, June 2022.

[2] M. Moazzami, L. Bagherzadeh, A. Barzandeh, H. Shahinzadeh, G.B. Gharehpetian, "Active Distribution System Expansion Planning Using Lion Pride Optimization Algorithm", International Journal of Renewable Energy Research (IJRER), Vol. 9, No. 3, pp. 1548-1559, September 2019.

[3] Z. El Idrissi, T. Haidi, F. Elmariami, A. Belfqih, "Optimal Coordination of DOCRS Using GA with Integration of DGS in Distribution Networks", International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 50, Vol. 14, No. 1, pp. 10-17, March 2022.

[4] M. Mohammadi, Y. Noorollahi, B. Mohammadi-ivatloo, M. Hosseinzadeh, H. Yousefi, S.T. Khorasani, "Optimal Management of Energy Hubs and Smart Energy Hubs - A Review", Renewable and Sustainable Energy Reviews, Vol. 89, pp. 33-50, February 2018.

[5] K. Zhang, B. Zhou, C. Li, N. Voropai, J. Li, W. Huang, T. Wang, "Dynamic Modeling and Coordinated Multi-Energy Management for a Sustainable Biogas-Dominated Energy Hub", Energy, Vol. 220, No. 119640, August 2021.

[6] M.S. Javadi, A.E. Nezhad, P.H. Nardelli, M. Gough, M. Lotfi, S. Santos, J.P. Catalao, "Self-Scheduling Model for Home Energy Management Systems Considering the End-Users Discomfort Index within Price-Based Demand Response Programs", Sustainable Cities and Society, Vol. 73, No. 102792, January 2021.

[7] L. Bagherzadeh, H. Shayeghi, "Optimal Allocation of Electric Vehicle Parking Lots and Renewable Energy Sources Simultaneously for Improving the Performance of Distribution System", The 24th Electrical Power Distribution Conference (EPDC), pp. 87-94, June 2019.

[8] S. Deng, Y. Zhang, Z. Ou, B. Huang, H. Liu, Q. Peng, Y. Shu, "Optimal Energy Dispatch of the Energy Hubs Considering Off-design Characteristics of Generation Units", The IOP Conference Series: Materials Science and Engineering, Vol. 782, No. 3, p. 032090, March 2020.

[9] S. Le Blond, R. Li, F. Li, Z. Wang, "Cost and Emission Savings from the Deployment of Variable Electricity Tariffs and Advanced Domestic Energy Hub Storage Management", The IEEE PES General Meeting| Conference the Exposition, pp. 1-5, July 2014.

[10] F. Brahman, S. Jadid, "Optimal Energy management of Hybrid CCHP and PV in a Residential Building", The 19th Conference on Electrical Power Distribution Networks (EPDC), pp. 19-24, May 2014.

[11] L. Bagherzadeh, H. Shahinzadeh, G.B. Gharehpetian, "Scheduling of Distributed Energy Resources in Active Distribution Networks Considering Combination of Techno-Economic and Environmental Objectives", International Power System Conference (PSC), pp. 687-695, December 2019.

[12] L. Bagherzadeh, H. Shayeghi, S. Pirouzi, M. Shafie-Khah, J.P. Catalao, "Coordinated Flexible Energy and Self-Healing Management According to the Multi-Agent System-Based Restoration Scheme in Active Distribution Network", IET Renewable Power Generation, Vol. 15, No. 8, pp. 1765-1777, January 2021.

[13] T. Ha, Y. Xue, K. Lin, Y. Zhang, V. Van Thang, T. Nguyen, "Optimal Operation of Energy Hub Based Microenergy Network with Integration of Renewables and Energy Storages", Journal of Modern Power Systems and Clean Energy, Vol. 8, No. 3, pp. 489-501, May 2020.

[14] T. Liu, D. Zhang, S. Wang, T. Wu, "Standardized Modelling and Economic Optimization of Multi-Carrier Energy Systems Considering Energy Storage and Demand Response", Energy Conversion and Management, Vol. 182, pp. 126-142, March 2019.

[15] M. Jadidbonab, B. Mohammadi-Ivatloo, M. Marzband, P. Siano, "Short-Term Self-Scheduling of Virtual Energy Hub Plant within Thermal Energy Market", IEEE Transactions on Industrial Electronics, Vol. 68, No. 4, pp. 3124-3136, April 2020.

[16] M. A. Mirzaei, M. Z. Oskouei, B. Mohammadi-Ivatloo, A. Loni, K. Zare, M. Marzband, M. Shafiee, "Integrated Energy Hub System Based on Power-to-Gas and Compressed Air Energy Storage Technologies in the Presence of Multiple Shiftable Loads", IET Gener. Transm. Distrib., Vol. 14, No. 13, pp. 2510-2519, September 2020.

[17] A.M. Moghaddam, H. Shayeghi, L. Bagherzadeh, S.J. Seyed-Shenava, "Assessing the Role of Wind Turbine in Residential Energy Hubs", The 28th Iranian Conference on Electrical Engineering (ICEE), pp. 1-6, August 2020.

[18] A. Raza, T.N. Malik, M.F.N. Khan, S. Ali, "Energy Management in Residential Buildings Using Energy Hub Approach", Building Simulation, Vol. 13, No. 2, pp. 363-386, April 2020.

[19] V. Halmschlager, R. Hofmann, "Assessing the Potential of Combined Production and Energy Management in Industrial Energy Hubs - Analysis of a Chipboard Production Plant", Energy, Vol. 120, p. 415, July 2021.

[20] S.A. Mansouri, A. Ahmarinejad, M. Ansarian, M.S. Javadi, J.P.S. Catalao, "Stochastic Planning and Operation of Energy Hubs Considering Demand Response Programs Using Bender's Decomposition Approach", Int. J. Electr. Power Energy Syst., Vol. 120, p. 106030, February 2020.

[21] Z. Yuan, S. He, A.A. Alizadeh, S. Nojavan, K. Jermsittiparsert, "Probabilistic Scheduling of Power-to-Gas Storage System in Renewable Energy Hub Integrated with Demand Response Program", J. Energy Storage, Vol. 29, p. 101393, April 2020.

[22] H. Hosseinnejad, S. Galvani, P. Alemi, "An Efficient Configuration for Energy Hub to Peak Reduction Considering Demand Response Using Metaheuristic Automatic Data Clustering", J. Electr. Comput. Eng. Innovations (JECEI), Vol. 8, No. 2, pp. 233-254, July 2020.

[23] S.A. Mansouri, A. Ahmarinejad, M.S. Javadi, J.P. Catalao, "Two-Stage Stochastic Framework for Energy Hubs Planning Considering Demand Response Programs", Energy, Vol. 206, p. 118124, November 2020.

[24] M. Azimi, A. Salami, "Optimal Operation of Integrated Energy Systems Considering Demand Response Program", J. Oper. Autom. Power Eng., Vol. 9, No. 1, pp. 60-67, January 2021.

[25] S.A. Mansouri, A. Ahmarinejad, M. Ansarian, M.S. Javadi, J.P.S. Catalao, "Stochastic Planning and Operation of Energy Hubs Considering Demand Response Programs Using Bender's Decomposition Approach", Int. J. Electr. Power Energy Syst., Vol. 120, p. 106030, February 2020.

[26] T. Ha, Y. Zhang, V.V. Thang, J. Huang, "Energy Hub Modeling to Minimize Residential Energy Costs

Considering Solar Energy and BESS”, J. Mod. Power Syst. Clean Energy, Vol. 5, No. 3, pp. 389-399, May 2017.

[27] L. Bagherzadeh, F. Khajvand, H. Shayeghi, “Optimal Allocation of Electric Vehicle Parking Lots to Improve Self-Healing Property of Smart Grid in Islanding Mode”, Iranian Conference on Renewable Energy and Distributed Generation (ICREDG 2019), pp. 1-6, Tehran, Iran, June 2019.

[28] L. Bagherzadeh, H. Shahinzadeh, H. Shayeghi, G.B. Gharehpetian, “A Short-Term Energy Management of Microgrids Considering Renewable Energy Resources, Micro-Compressed Air Energy Storage and DRPs”, International Journal of Renewable Energy Research (IJRER), Vol. 9, No. 4, pp. 1712-1723, December 2019.

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