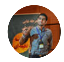
Resiliency-Oriented Planning of Smart City Energy Infrastructure, Considering Energy Hubs, Based on Prioritized Critical Loads

Conference Paper · February 2023

DOI: 10.1109/ICTEM56862.2023.10084210

3 authors:

Ahad Fallahsabet
K.N.Toosi University of Technology



Mahdi Nozarian
K. N. Toosi University of Technology

Alireza Fereidunian
K.N.Toosi University of Technology

Preprint, to be presented at the 8th International Conference on Technology and Energy Management (ICTEM) 8-9 February, 2023, Mazandaran University of Science and Technology, Babol, Iran

Resiliency-Oriented Planning of Smart City Energy Infrastructure, Considering Energy Hubs, Based on Prioritized Critical Loads

Ahad Fallahsabet
Faculty of Electrical Engineering
K.N.Toosi University of Technology
Tehran, Iran
a.fallahsabet@email.kntu.ac.ir

Mahdi Nozarian
Faculty of Electrical Engineering
K.N.Toosi University of Technology
Tehran, Iran
m.nozarian@email.kntu.ac.ir

Alireza Fereidunian
Faculty of Electrical Engineering
K.N.Toosi University of Technology
Tehran, Iran
fereidunian@eetd.kntu.ac.ir

***Abstract*— Mitigating the impact of high-impact disasters requires increasing the system resilience as an essential measure. The energy hub (EH), as an efficient framework of energy systems integration, could provide significant flexibility and robustness for energy systems in facing disasters. This manuscript proposes a resiliency-oriented planning model for smart city energy infrastructure, modeled as interconnected EHs. The proposed model aims at minimizing the customer interruption cost (CIC) and the cost of energy not supplied (CENS), to prioritize critical loads restoration. This study analyzes the effectiveness of the proposed model when the connection between the electricity distribution grid and the upstream grid is interrupted due to unpredicted conditions. The proposed MILP model is applied to the 33-bus distribution test system, to demonstrate the performance of the proposed framework. The numerical results demonstrate the effectiveness of the EHs-based planning model in realizing a resilient smart city energy infrastructure.**

Keywords—Resiliency, Energy hub, Smart city energy infrastructure, Critical load

I. Introduction

Electric power systems are susceptible to threats and risks, whereas some potential threats such as extreme climate changes or natural disasters are unavoidable. This can affect energy security, socio-economic measures, as well as the quality of life. Therefore, improving the resilience of the power grid in order to reduce the effects of natural disasters should be studied and evaluated [1].

The resilience of power system is the ability of power grid to predict, resist, adjust and recuperate from low-probability and high-impact occurrences. There are long-term and short-term methods to improve resilience. Long-term methods include infrastructure hardening and resilience planning, while short-term methods are applied in the periods before, during, and after the event [2]. From Ouyang's point of view, a resilient system is a system with absorption ability (the ability of the system to absorb the effects of disturbances and minimize these effects with the least effort), adaptability (the ability of the system to tolerate some unwanted conditions by applying changes in the system), and recovery ability and restoration (the ability of the network to quickly return to normal or improved operating mode) [3]. In recent years, integrated operation of different energy infrastructures has received a lot of attention due to improving flexibility, improving energy efficiency and decreasing operation cost. Integrated energy systems meet the requirements of customers for diverse kinds of energy. Considering that these systems support many consumers, maintaining the stability and resilience of these systems is very important to deal with emergency situations [4]. The optimal performance of multi-carrier energy systems can reach technical and financial advantages like improving system reliability and decreasing operation cost. But for the successful operation of systems, there is a need for an integrated management structure which manages the various elements of the system optimally. Development of the energy hub theory is a promising option for the optimal operation of multi-carrier energy systems and reaching a complete model of sustainable energy systems [5].

Since EH systems cover many customers, resilience criteria should be considered in their design. In [6], a mixed-integer non-linear programming formulation is presented to improve the resilience of multi-carrier energy systems integrated with electricity-gas systems. In the suggested model, the system operator can increase network resilience in emergency situations through automatic switching. The presented model, has confirmed the impact of power to gas technology and storage units on increasing system resilience.

Reference [7], presents a bi-level framework for resilience improvement of electricity-gas systems integrated with EHs by considering flexible loads, power to gas technologies, electric vehicles and gas storage systems. In this article, two different demand response programs are considered to increase the resiliency of the grid. [8] has presented a flexible model for microgrid configuration in the integrated electricity-gas network through optimal measuring, locating and operation of combined heat and power. The upstream network blackout, power lines outage and combined heat and power outage are modeled as the occurrence. In this article, under emergency situations, the network is divided into some microgrids. Also, the created microgrids can change their configuration under diverse disturbances. In this paper, the outcomes show that the end-buses of the network are the greatest sites for combined heat and power.

In [9], a two-stage model has been presented for EH planning by considering various uncertainties, in which the size of EH converters is done with the aim of improving resilience. In the suggested model, a robust optimization method for uncertainties is used, and the problem is expressed as a mixed-integer non-linear programming problem. The results of this research show that considering emergency conditions in the design of the EH reaches a substantial increase in its resilience.

Reference [10] presents a two-stage planning based on the resilience-oriented model to improve the resilience of the system against high-impact incidents. Also, in this study, an integrated model of electricity and gas is used regarding mutual interactions between electricity and thermal energy. Reference [11] introduces a stochastic approach to design an EH integrated with wind turbines and multi-carrier energy systems and states that EHs can provide significant benefits for energy services by providing flexibility. In this study, the reliability indices like the expected energy not supplied and loss of load expectation are considered. Also, this article increases the load reliability and decreases the cost of energy consumption.

Reference [12], has used the concept of EH to build a scenario-based model for optimal planning of electrical and thermal sources in a microgrid with integrated electrical and natural gas infrastructure. The intended microgrid of this study includes EHs, diesel generators, battery storage systems, and renewable sources. The EH itself includes transformers, combined heat and power units, boilers and heat storage. The aim of this study is to minimize the total cost. Reference [13], has presented an energy resilience modeling smart home that mainly uses solar energy and a storage system. In this study, the impact of different battery usage strategies on resilience for different generation and consumption patterns has been evaluated.

The [14], has investigated resilience and energy management in a multi-microgrid system, and in the suggested model of this study, each microgrid consists of four smaller microgrids. Small microgrids are integrated with renewable sources and electrical storage. Also, some diesel generators are alternative sources for the small microgrids. In this article, these small microgrids have integrated their sources and sizes to form a new and more complex microgrid that provides better resilience and management performance compared to single microgrids. In [15], a stochastic optimization structure for resilient planning of interconnected EHs considering peer-to-peer energy trading between EHs and storage unit during intense disturbances with the aim of reducing load shedding is provided. In this research, the problem of optimization in normal and resilient operating modes has been formulated by considering the uncertainties of renewable sources and the duration of the occurrence. In [16], a resilient design against cyber-attack in a microgrid to prevent the loss of critical loads with the aim of minimizing the microgrid planning cost has been introduced. Also, the proposed microgrid planning model is expressed as a mixed-integer programming problem.

According to the previous literature review, the EHs-based planning and operation proposed models neglected the interconnection effect of EHs in improving resilience based on prioritizing critical loads. Further, to the best of the authors' knowledge, the development of an MILP model for resilience-oriented planning of smart city energy infrastructure, including interconnected EHs, is not addressed.

As stated in [17], "Urban energy systems can thus be seen as sets of EHs" in this manuscript, the smart city energy infrastructure is considered a set of critical, industrial, commercial, residential, and agricultural EHs, which are designed according to their loads prioritization to realize a resilient urban energy.

The key contributions of this study are summarized as follows:

- Proposing a resiliency-oriented planning model for smart city energy infrastructure to prioritize critical loads restoration,
- Presenting a model for smart city energy infrastructure as a system of interconnected EHs,
- Developing an MILP formulation for the above-mentioned problem.

The different parts of this article are as follows; In part (II), the modeling of the objective function of the problem, different components of the network and the governing constraints on the network in the problem of microgrid planning have been discussed. In section (III), the under study network and evaluation of simulation results in three scenarios have been investigated, and in section (IV) the results of this study have been summarized.

II. Problem Formulation

In this study, a microgrid including EHs has been studied. Equation (1) shows the general model of EHs [18].

$$\begin{bmatrix} L_\alpha \\ \vdots \\ L_\beta \end{bmatrix} = \begin{bmatrix} C_{\alpha\alpha} & \cdots & C_{\beta\alpha} \\ \vdots & \ddots & \vdots \\ C_{\alpha\beta} & \cdots & C_{\beta\beta} \end{bmatrix} \begin{bmatrix} P_\alpha \\ \vdots \\ P_\beta \end{bmatrix} \tag{1}$$

In equation (1), L is the vector of loads supplied by the EH and P is introduced as the input energy carrier vector of the EH. The load and the input energy carrier are connected to each other by matrix C. Fig. 1, depicts the conceptual block diagram for the problem and the suggested method. As mentioned in Fig. 1, the studied EH includes the combined heat and power, boiler and electrical storage which receives electrical energy and natural gas as input. In this section, the modeling of the problem including the objective function and the governing constraints on the network components and EHs is investigated.

A. Objective function

In this part, the objective function of the problem and its components are stated.

$$Minimize: \quad TINVC + TOPC \tag{2}$$

According to equation (2), the objective function includes total investment cost (TINVC) and total operation cost (TOPC). TOPC includes customer interruption cost (CIC) and cost of energy not supplied (CENS) as resiliency criteria and the costs associated to purchasing natural gas from network [20, 22]. Equations (3)-(6) are the components of the objective function in this research.

$$TINVC = \sum_{ch} INVC_{ch}\, I_{ch}\, P_{ch} + \sum_{w} INVC_{w}\, I_{w}\, P_{w} + \sum_{bo} INVC_{bo}\, I_{bo}\, P_{bo} + \sum_{s} INVC_{s}\, I_{s}\, P_{s} + \sum_{Dg} \mathrm{INVC_{Dg}\, I_{Dg}\, P_{Dg}} + \sum_{pv} INVC_{pv}\, I_{pv}\, P_{pv} \tag{3}$$

$$TOPC = \sum_{h} PG_{g}(h)\, \rho_{g}(h) + CIC + CENS \tag{4}$$

$$CENS = \sum_{h}\sum_{b} LSI(h.b)\, P_{el}(h.b)\, \rho_{e}(h) \tag{5}$$

$$CIC = \sum_{b} (P_{e}(b)\, (\sum_{k} \lambda(b.k)\, C_{odt}(b.k)) \tag{6}$$

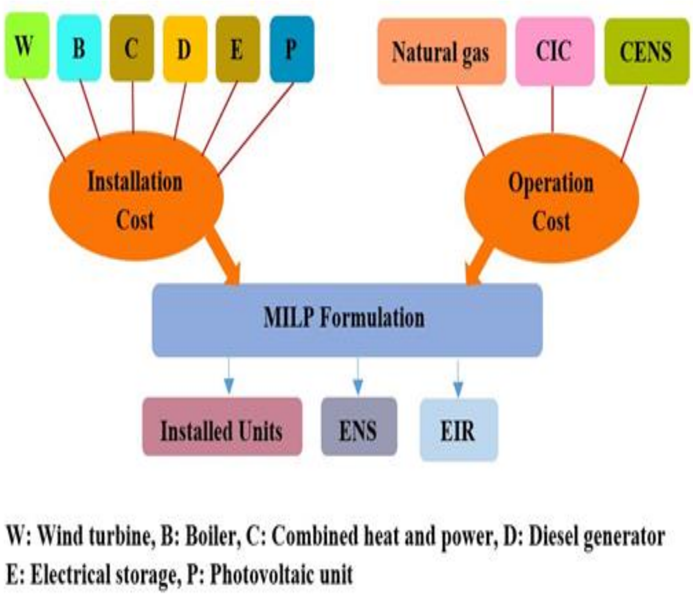


Figure 1. conceptual block diagram for the problem

B. Constraints

1) Electricity network

Equations (7)-(12) express the limitations of alternating current power flow in the electrical network [19, 21].

$$\sum_{Dg} P_{Dg}(h.Dg) + \sum_{w} P_{w}(h.w) + \sum_{pv} P_{pv}(h.pv) + \sum_{s} P_{s}(h.s) + \sum_{ch} P_{ch}(h.ch) - \big(1 - LSI(h.b)\big)\, P_{el}(h.b) = \sum_{c} P_{L}(h.b.c). \forall h. \forall b \tag{7}$$

$$\sum_{Dg} Q_{Dg}(h.Dg) + \sum_{w} Q_{w}(h.w) + \sum_{pv} Q_{pv}(h.pv) + \sum_{s} \mathrm{Q_{s}(h.s)} - \big(1 - LSI(h.b)\big)\, Q_{el}(h.b) = \sum_{c} Q_{L}(h.b.c). \forall h. \forall b \tag{8}$$

$$P_{L}(b.c.h) = G(b.c)\big(V(b.h) + V(c.h)\big) + B(b.c)\big(\delta(b.h) - \delta(c.h)\big). \forall b. \forall c. \forall h \tag{9}$$

$$Q_{L}(b.c.h) = B(b.c)\big(V(b.h) + V(c.h)\big) + G(b.c)\big(\delta(b.h) - \delta(c.h)\big). \forall b. \forall c. \forall h \tag{10}$$

$$(P_{L}(b.c.h))^2 + (Q_{L}(b.c.h))^2 \le (S_{L}^{max}(b.c.h))^2 \tag{11}$$

$$(\mathrm{PG_e}(t))^2 + (\mathrm{QG_e}(t))^2 \le (\mathrm{SG_e^{max}}(t))^2 \tag{12}$$

Constraints (7) and (8) refer to the limits of active and reactive power and state that the electrical active load existing at each load point, like reactive power, in addition to the ability to be supplied by the national network in normal mode, has this possibility to be supplied through diesel generator, wind, solar, combined heat and power and electrical storage units. Constraints (9, 10) refer to the linear formulation of active and reactive power passing through the grid lines, and constraints (11, 12) refer to the apparent power passing through the lines and the apparent power exchanged with the network.

2) Natural gas network

Equations (13)-(16) express the limitations of gas network.

$$P_{gas}(b.c.h) = GHV f(b.c.h) \tag{13}$$

$$P_{gas}(b.h) = \sum_{c} P_{gas}(b.c.h) \tag{14}$$

$$PG(h) = \sum_{b=2} P_{gas}(b.h) \tag{15}$$

$$\sum_{ch} P_{chp}(ch.h) + \sum_{bo} P_{bo}(bo.h) = \sum_{b} P_{hb}(b.h). \forall h \tag{16}$$

The gas supply network is responsible for gas distribution between thermal load points and electrical load points in order to supply the required gas. The consumers of this gas are boilers and combined heat and power unit. in this study, combined heat and power units are considered as the interface between gas and electricity networks. The gas supply network of this study is an approximation of the model presented in reference [20]. Also, the gas transmission power along the gas pipeline depends on the characteristics of the pipeline, the flow rate of the gas passing through the pipeline and the fluid passing through the pipe. Equation (13) is used to convert the flow rate of gas passing through the pipeline (f) to the power of gas transferred in the gas pipeline (P_{gas}). In each hour, the balance of natural gas power transferred to each bus through the gas transmission lines connected to that bus is expressed by equation (14). Equation (15) shows the amount of natural gas planned (PG_h) for purchase on the next day, which is equal to the total gas consumption in all buses. Finally, the equation (16) refers to the supply of heat loads (P_{hb}) by combined heat and power units and boilers in case of installation.

Furthermore, the proposed planning framework aims to improve energy not supplied (ENS) and energy index of reliability (EIR) as described in following [24].

$$ENS = \sum_{h} \sum_{b} LSI(h.b)\, P_{el}(h.b) \quad (17)$$

$$EIR = 1 - \frac{ENS}{\sum_h \sum_b \; P_{el}(h.b)} \quad (18)$$

The details of linearization of natural gas network constrains is mentioned in [20].

3) *Diesel Generator units*

The general model of diesel generator units is adapted from [22].

4) *Renewable energy units*

The general model of generation of wind units is stated in reference [20].

5) *Combined heat and power units*

The electrical and thermal power of the units of combined heat and power are modeled in reference [20].

6) *Thermal boilers*

The modeling of thermal boilers is mentioned in reference [20].

7) *Electrical storage units*

Reference [19] has discussed the limitations of electrical storage units.

III. Implementation and Results

In this section, the simulation results of the presented model in the studied network are evaluated. The proposed model is developed with the presence of distributed energy resources and EHs. so, a cyber-attack occurs in the upstream network and the connection with the upstream network is interrupted. in this research, the resilience of the smart city energy infrastructure in order to provide energy for the required loads has been done. For this purpose, three cases have been evaluated in this study. In case one, no measures are taken in the network, in case two, the effects of distributed energy resources in different busses and in case three, the proposed methods based on interconnected EHs have been evaluated.

A. *Implementation*

The under study network according to Fig. 2, is a 33-bus distribution test system. In Fig. 2 critical, industrial, commercial and residential loads are supplied with red, orange, green and blue EHs, respectively. The desired network information is stated in reference [17]. The price of electricity and natural gas, the characteristics of the equipment in the EH, solar radiation, wind speed and the specification of natural gas lines are mentioned in reference [20-23]. The amount of network load per hour and storage units is stated in reference [19]. The objective function and constraints are modeled in the form of mixed-integer linear programming in GAMS software using the CPLEX solver.

Case (1): Upstream grid interruption, without any preparation
Case (2): Upstream grid interruption, Preparation based on DG allocation common method
Case (3): Upstream grid interruption, Preparation based on proposed framework

B. *Results*

1) *Case (1): Without any preparation*

In this case, the connection with the upstream network has been disconnected and no action has been taken to supply the desired loads. Therefore, in this case, according to what is stated in Table I, CIC, CENS and ENS have increased due to the lack of installation of distributed energy resources units and EHs. In next cases, with the help of distributed energy sources like solar units, wind units and electrical storages, efforts are made to improve the CIC, CENS and ENS.

2) *Case (2): Preparation based on DG allocation method*

The difference between this case and case (1) is the addition of diesel generator units in different buses of the studied network, and the results of the simulation are shown in Table II. According to Table II, the presence of diesel generator units that have been installed in all 33 buses of the studied network has reduced the CIC, CENS, operation cost and ENS. Also, the EIR has improved.

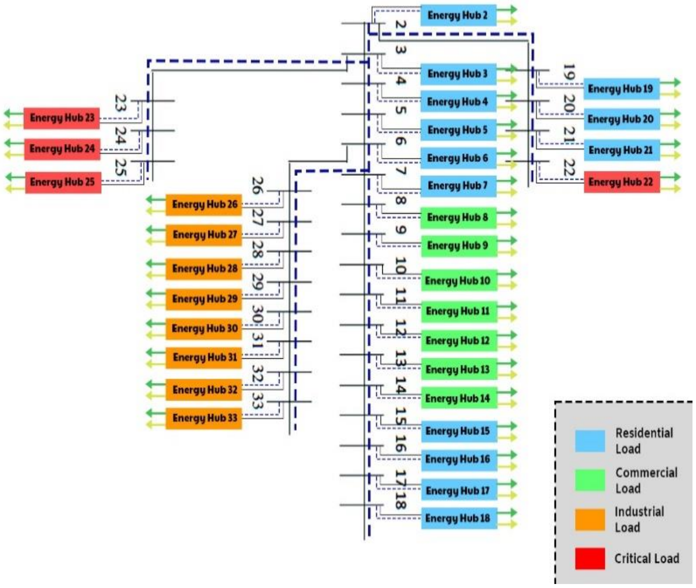


Fig. 2. Smart city energy infrastructure including interconnected EHs

TABLE I. SIMULATION RESULTS FOR CASE (1)

Cost	($)
TINVC	0
TOPC	2440620.145
CIC	1410112.489
CENS	1030507.656
Indices	-
ENS	122703.334
EIR	0

TABLE II. SIMULATION RESULTS FOR CASE (2)

Cost	($)
TINVC	6624000
TOPC	1881382.538
CIC	881576.645
CENS	805266.813
Installed units	**Number**
Diesel generator	32
Indices	-
ENS	96312.301
EIR	0.236

3) Case (3): Preparation based on proposed framework

In this case, the problem of microgrid planning including presence of EHs connected to each other has been evaluated. The results of optimal planning of the studied microgrid in the presence of EHs are shown in Table III. According to Table III, the presence of EHs has caused a significant reduction in CIC, CENS, ENS and operation cost. Also, EIR has increased significantly in this scenario. Fig. 3 shows the equipment installed on the buses in case (3). In bus 25, which is one of the critical buses of the studied network, all the desired equipment has been installed in this bus.

TABLE III. SIMULATION RESULTS FOR CASE (3)

Cost	($)
TINVC	90296000
TOPC	261571.617
CIC	5568.746
CENS	18438.901
Installed units	**Number**
Combined and heat power unit	32
Diesel generator	32
Electrical storage	32
Boiler unit	10
Photovoltaic unit	0
Wind unit	2
Indices	-
ENS	1500.6
EIR	0.988

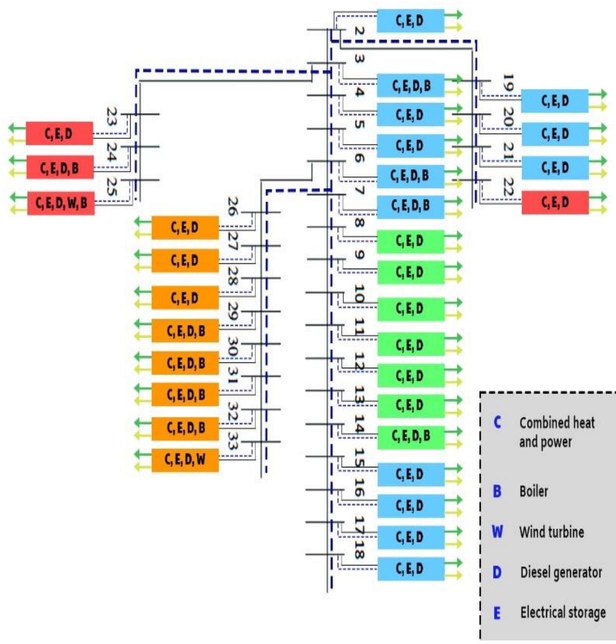


Fig. 3. Designed resilient smart city energy infrastructure based on proposed framework in Case (3)

According to Fig. 4, in case (3) that EHs are installed on the network, ENS has decreased significantly compared to the previous cases.

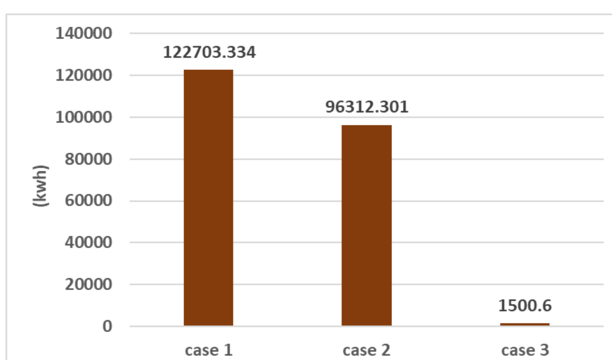


Fig. 4. Comparison of ENS in three cases

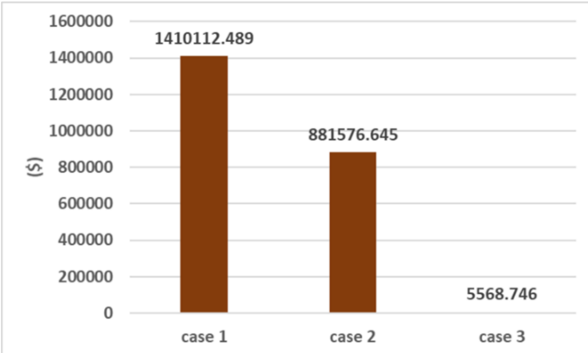


Fig. 5. Comparison of CIC in three cases

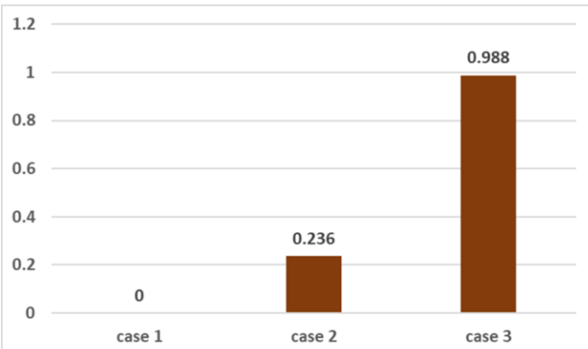


Fig. 6. comparison of EIR in three cases

In Fig. 5, CIC in case (3) is equal to 5568.746 ($), which has decreased significantly compared to case (1) and case (2). In Fig. 6, EIR is compared in three cases. It can be seen that in case (3), EIR has increased significantly.

IV. CONCLUSION

In recent years, occurrence of natural disasters like storms, earthquakes, and climate changes caused by global warming has caused irreparable damage to power systems. This article, introduces a resiliency-oriented planning model for smart city energy infrastructure. This study, evaluates the effectiveness of the proposed model when the connection between the electricity distribution grid and the upstream grid is interrupted due to unpredicted conditions. Also, the MILP model is tested on a 33-bus distribution test system to show the performance of the suggested model. Based on the results of the simulation, the presence of EHs has a significant effect on reducing CIC, CENS, ENS and the operation cost. In addition, the EIR has increased significantly in the presence of EHs.

REFERENCES

[1] E. Galvan, P. Mandal, Y. Sang, "Networked microgrids with roof-top solar PV and battery energy storage to improve distribution grids resilience to natural disasters", International Journal of Electrical Power & Energy Systems, 2020, Vol. 123, 106239.
[2] E. -I. E. Stasinos, D. N. Trakas, N. D. Hatziargyriou, "Microgrids for power system resilience enhancement," in iEnergy, vol. 1, no. 2, pp. 158-169, June 2022.
[3] M. Ouyang, L. Duenas-Osorio, "Multi-dimensional hurricane resilience assessment of electric power systems", Structural Safety, 2014, Vol. 48, pp.15-24.
[4] J. He, Z. Yuan, X. Yang, W. Huang, Y. Tu and Y. Li, "Reliability Modeling and Evaluation of Urban Multi-Energy Systems: A Review of the State of the Art and Future Challenges," in IEEE Access, vol. 8, pp. 98887-98909, 2020.
[5] P.Mancarella, "MES (multi-energy systems): An overview of concepts and evaluation models. Energy, 2014, Vol. 65, pp.1-17.
[6] S. E. Hosseini, A. Ahmarinejad, M. Tabrizian, M. A. Bidgoli, "Resilience enhancement of integrated electricity-gas-heating networks through automatic switching in the presence of energy storage systems", Journal of Energy Storage, 2022, Vol. 47, 103662.
[7] E. A. Javadi, M. Joorabian, H. Barati, "A sustainable framework for resilience enhancement of integrated energy systems in the presence of energy storage systems and fast-acting flexible loads", Journal of Energy Storage, 2022, Vol. 49, 104099.
[8] R. Hemmati, H. Mehrjerdi, S. M. Nosratabadi, "Resilience-oriented adaptable microgrid formation in integrated electricity-gas system with deployment of multiple energy hubs", Sustainable Cities and Society, 2021, Vol. 71, 102946.
[9] A. Z. G. Seyyedi, M. J. Armand, E. Akbari, J. Moosanezhad, F. Khorasani, M. Raeisinia, "A non-linear resilient-oriented planning of the energy hub with integration of energy storage systems and flexible loads", Journal of Energy Storage, 2022, Vol. 51, 104397.
[10] S. S. Gharehveran, S.Ghassemzadeh, N. Rostami, "Two-Stage Resilience-Constrained Planning of Coupled Multi-Energy Microgrids in the Presence of Battery Energy Storages", Sustainable Cities and Society, 2022, 103952.
[11] A. Dolatabadi, B. Mohammadi-ivatloo, M. Abapour and S. Tohidi, "Optimal Stochastic Design of Wind Integrated Energy Hub," in IEEE Transactions on Industrial Informatics, vol. 13, no. 5, pp. 2379-2388, Oct. 2017.
[12] M. H. Shams, M. Shahabi, M. Kia, A. Heidari, M. Lotfi, M. Shafie-Khah, J. P. Catalão, "Optimal operation of electrical and thermal resources in microgrids with energy hubs considering uncertainties", Energy, Vol. 187, 115949, 2019.
[13] H. Ghasemieh, B. R. Haverkort, M. R. Jongerden and A. Remke, "Energy Resilience Modelling for Smart Houses," 2015 45th Annual IEEE/IFIP International Conference on Dependable Systems and Networks, 2015, pp. 275-286.
[14] H. Mehrjerdi, "Resilience Improvement With Zero Load Curtailment by Multi-Microgrid Based on System of Systems," in IEEE Access, vol. 8, pp. 198494-198502, 2020.
[15] S. Rezaei, A. Ghasemi, "Stochastic scheduling of resilient interconnected energy hubs considering peer-to-peer energy trading and energy storages", Journal of Energy Storage, 2022, Vol. 50, 104665.
[16] M. Azimian, V. Amir, S. Javadi, S. Mohseni, A. C. Brent, "Resilience-Oriented Planning of Multi-Carrier Microgrids under Cyber-Attacks. Sustainable Cities and Society", 2022, Vol. 79, 103709.
[17] M. La Scala, S. Bruno, C. A. Nucci, S. Lamonaca, U. Stecchi, "From smart grids to smart cities: new challenges in optimizing energy grids", John Wiley & Sons, 2021, Vol. 2.
[18] M. Nozarian, A. Fereidunian, "smart city as an smart energy hub: A Bibliographic, Analytic and Structural Review", Iranian Electric Industry Journal of Quality and Productivity, Vol. 9, No. 4, November 2020, pp. 63-83.
[19] A. Karimi, F. Aminifar, A. Fereidunian, H. Lesani, H. "Energy storage allocation in wind integrated distribution networks: An MILP-Based approach", Renewable energy, 2019, Vol. 134, pp. 1042-1055.
[20] M. Nozarian, A. Fereidunian, "Analysis of Emergent Behavior of Reliability in the System of Systems Including Energy Hubs", Journal of Modeling in Engineering", 2021, 19(66).
[21] M. Nozarian, A. H. Nikoofard, A. Fereidunian, "Efficient MILP formulations for AC optimal power flow to reduce computational effort", International Transactions on Electrical Energy Systems, 2020, 30(8), e12434.
[22] SM. Mohammadi-Hosseininejad, A. Fereidunian, H. Lesani, M. H. Gavgani, "Enhancement of self-healing property of smart grid in islanding mode using electric vehicles and direct load control", Smart Grid Conference (SGC), 2014, pp. 1-6.
[23] A. Karimi, Z. Ranjbar, A. Fereidunian, H. Lesani, "A stochastic approach to optimal sizing of energy storage systems in a microgrid", Smart Grids Conference (SGC), 2016, pp. 1-8.
[24] E. Akhavan-Rezai, M.R., Haghifam, and A. Fereidunian, "Data-driven reliability modeling, based on data mining in distribution network fault statistics", 2009 IEEE Bucharest PowerTech , 2009, pp. 1-6.