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Author(s): Tahmasebi, Dorna; Sheikh, Morteza; Dabbaghjamanesh, Morteza; Jin, Tao; Kavousi-Fard, Abdollah; Karimi, Mazaher

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Year: 2024

Version: Accepted manuscript

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Please cite the original version:

Tahmasebi, D., Sheikh, M., Dabbaghjamanesh, M., Jin, T., Kavousi-Fard, A., & Karimi, M. (2024). A security-preserving framework for sustainable distributed energy transition: Case of smart city. *Renewable Energy Focus*, 51, 100631. <https://doi.org/10.1016/j.ref.2024.100631>

A Security-Preserving Framework for Sustainable Distributed Energy Transition: Case of Smart City

Dorna Tahmasebi¹, Morteza Sheikh², Morteza Dabbaghjamanesh³, Tao Jin⁴, Abdollah Kavousi-Fard^{*1}, Mazaher Karimi⁵

1- Electrical Engineering Department, Shiraz University of Technology, Shiraz, Iran. (kavusi@sutech.ac.ir)

2- Fars Regional Electric Company

3- R&D Department, Electric Reliability Council of Texas, Taylor, TX 76574. (morteza.d@ieee.org)

4-Department of Electrical Engineering, Fuzhou University, Fuzhou, Fujian China 350116. (jintly@fzu.edu.cn)

5- School of Technology and Innovations, University of Vaasa, Wolffintie 34, 65200 Vaasa, Finland.

(mazaher.karimi@uwasa.fi)

Abstract—The proliferation of smart devices that complement the energy system in order to make it easier to change the appearance of unique and autonomous energy systems and make them more manageable, causes the biggest problems in energy management in smart cities. With these promising results, storing data exchange between the smart city and its components of renewable sources and storage will reduce the risk of cyber-attacks in the energy system. To solve these problems, this paper proposes a reliable and privacy-preserving distributed model for the transition to smart cities, emphasizing the integration of renewable energy sources such as wind, solar, and tidal power into the urban energy ecosystem. For this purpose, a distributed model-based two-dimensional multiplicative method (PDMM) and a design-based model have been developed as a fast method to solve energy problems in smart cities. The results will show that PDMM performs well in large-scale optimization problems. To protect data privacy, the method of secure data exchange is based on a modified acyclic graph based on blockchain. Detailed numerical results demonstrate the performance of the proposed method based on the dynamic force curve. The results prove that the proposed model was able to get to an optimal and true consensus among agents with very low error values.

Index Terms— Blockchain, Energy transition, Renewable energy, Smart city, Transportation.

NOMENCLATURE

Constants

α_{PV} : Loss efficacy of PV.

$C_{V2G}^{t,e}, C_{V2S}^{t,e}, C_{S2G}^{t,s}, C_{G2S}^{t,s}$: Price for V2G, V2S and S2G.

η_C, η_D : Charging and discharging efficiencies, respectively.

$E_{V,min}^e, E_{V,max}^e$: Min/max capacity of the EVs' batteries, respectively.

$ET^{s,u}, ED^{s,u}$: Energy for traveling to the subway station s in the u^{th} urban path and discharging energy.

P_L^t : Smart distribution grid demand.

$P_{ch,min}^e, P_{ch,max}^e$ Min/max EVs' charging rate.

$P_{dis,min}^e, P_{dis,max}^e$ Min/max EVs' discharging rate.

π_{grid} Energy transaction price.

ω_W^t Wind speed

G Solar irradiation

ρ_w Water density

A Turbine blade area

ϕ Wind density

A_{TV} Rotor blade area

$T_{TV}^{cut-in}, T_{TV}^n$: Cut-in and rated tidal current speeds.

P_{TV}^n : rated power of tidal.

Variables

$F_T, f_{tr}, f_{MG}, f_{SDN}$: Total, transportation, microgrid, and smart distribution network costs, respectively.

$f_{V2G}, f_{V2S}, f_{dg}, f_{S2G} + f_{S2V}$: Energy transaction costs of V2G and V2S, EVs degradation cost and S2G and S2V.

$E_{V2G}^{t,e}, E_{V2S}^{t,e}, E_V^{t,e}$: EV energy over V2G, V2S and energy exchange

$D_{new}^{t,s}, D_{old}^{t,s}$:	Metro consumption afterward and beforehand of change.
f_{EV}, f_S :	Energy costs of EV and subway station.
$P_{V2G}^{t,e}, P_{G2V}^{t,e}$:	V2G and G2V energy transactions.
$PC_{V2S}^{t,e,u}, Pd_{V2S}^{t,e,u}$:	Charging/discharging power during E2S, respectively.
$PC_{V2G}^{t,e,u}, Pd_{V2G}^{t,e,u}$:	Charging/discharging power during V2G, respectively.
$P_{LG}^t, P_{MG}^t, P_{tr}^t$:	Power generation, power generated in microgrid, and power transaction in transportation, respectively.
$P_{S2G}^{t,s}, P_{G2S}^{t,s}$:	Power transaction between transportation and grid.
$P_{PV}^t, P_{WPG}^t, P_{TV}^t, P_{ES}^t$:	PV, WT, tidal battery units' power.
S_i^{Batt}	EH energy at t .
$\delta_{ch}^{t,e,u}, \delta_{dis}^{t,e,u}, \delta^{t,e,u}$	EV status.

I. INTRODUCTION

A. Motivation and Outlook

The smart city is a concept that emerged to manage cities in an environmentally friendly, sustainable, safe, and flexible environment. With the development of communication infrastructure, autonomous enterprises in the smart city will focus on the importance of energy consumption and environmental sustainability, focusing on energy, water, transportation, etc. They can manage the delivery of urban services such as smart cities consisting of various elements such as smart grids, transportation systems, and microgrids (MG) and their laws, policies, and goals. Because these components are part of an integrated system, decisions changing in one component can affect other components. Moreover, smart city units can compete to achieve their goals in a liberalized environment. Therefore, even though the smart city is an integrated system, parts of the smart city do not want to share all the information shared with other institutions. Therefore, it is important to protect the privacy of smart cities [2], [3]. This problem inspired us to propose a privacy-preserving approach for

smart cities. In this context, fundamental problems such as i) limitations of the security system, ii) rapid integration with real-time distributed algorithms, and iii) creating an efficient path for energy transfer between different parts of smart cities still remain unresolved. This paper presents a comprehensive, secure, and privacy-preserving approach to energy transformation in smart cities.

B. Brief Survey on Related Works

Energy conversion in large and technological systems is a complex task. The development of technology in smart cities, various energy sources, smart transportation vehicles, user services, etc. led to its creation. For example, In summary, authors in [28] emphasized a flexible platform for active system management, which emphasizes effective energy consumption, better infrastructure management, and sustainable urban expansion, generally supporting the larger goals of smart city development. Also, in the paper [29], the goal is to control power system outages and improve resilience during extreme weather events by developing and implementing a flexibility platform. The platform's goal is to offer a strong reaction system for weather-related disturbances, guaranteeing power supply continuity and mitigating the effects on impacted populations. In conclusion, the flexible platform for handling disruptions and guaranteeing resilience in the face of harsh weather contributes to the goals of smart cities by boosting emergency response times, strengthening infrastructure dependability, and incorporating cutting-edge technology for improved system management. Therefore, energy conversion is an important decision-making problem that requires good representation and efficient use. Typically, a smart city may include a smart distributed network (SDN), a network connection such as a microgrid, and a smart grid.

1) Intelligent Transportation System

Electric vehicles (EV) and metros have made great progress in the transportation system in recent years. The optimal performance of electric vehicles using vehicle-to-grid (V2G) has been discussed in previous studies [4] and [5]. The urban train schedule was developed in [6] based on the arrival/departure time and the renewable energy consumption of the energy brake. Additionally, the combination of energy storage and powertrain (using a braking system) is also discussed in [7]. Energy-efficient applications with modern

technologies and different operating modes, such as V2G and motor-to-meter (V2S), bring new challenges to the performance of public transport systems. However, the relationship between EVs and measuring devices has rarely been explored in the literature. For example, in [8] an optimal performance scheme is presented for EV cooperatives and meters considering energy storage devices. Additionally, [9] studied efficient energy management systems in a smart grid consisting of renewable energy, electric vehicles, and railways. The high cost of energy storage in the transportation system can be solved by using the braking system in piston trains.

2) *Microgrid*

Microgrids (MGs) are low-voltage distribution networks and generally consist of renewable energy generation, energy storage devices, and electrical loads. The MG energy management problem has been extensively discussed in various ways, such as MG energy planning [10], MG energy distribution [2], and microgrids [11]. Authors in [30] presented a new approach to microgrid restoration after a blackout, emphasizing important load prioritization. The suggested course of action attempts to minimize downtime and optimize the recovery process while effectively restoring power to critical services and infrastructure. However, the main function of MG users, the transition of MG and smart city to a system under a reliable network, was not addressed in previous studies.

3) *Energy Transition*

Recent studies have shown energy transitions between different parts of smart cities. For example, [12] described energy transition systems, distributed generation (DGs), heating and energy storage devices for high-end users. A power conversion system for power conversion between commercial and bulk power is proposed in [13]. A comparative study of electrical energy and heating energy input of cogeneration, heating and combined heat and power plants (CHPs) is discussed in [14]. However, due to the lack of reliable and privacy-saving energy transition methods required for energy transitions, this research aims to realize them.

4) *Privacy-Preserving and Security*

The rise of smart cities over the past decade has complicated the communications infrastructure. Despite all the advantages of the communication system, risks associated with the presentation of information are possible. A lot of research has been done on this. One possible solution is blockchain as a decentralized and secure platform. Practical methods can be divided into [15]: i) decentralized, ii) distributed and iii) graph-based crypto. In decentralized management, information exchange occurs between multiple units and related lines without any central institution. For example, a decentralized system of energy and energy trading systems is proposed in [16]. The distributed transmission method defines a set of protocols for transferring information between agents from system to system [17]. A method to prevent increasing security against cyber-attacks is presented in [18]. In the current study, a new method based on cryptographic algorithms was developed to prevent data exchange between different regions of smart cities. Moreover, storing useful information is important in modern systems. For this purpose, a distributed algorithm can be used to decompose the optimization problem and its associated constraints into multiple independent expressions. In this regard, many algorithms decomposition, and adjustment multiplication method (ADMM) [2] are based on the principle of auxiliary problem (APP) power system. However, some disadvantages make these algorithms unsuitable for energy conversion in smart cities: i) low convergence speed, ii) instability in large optimization problems, and iii) sensitivity to supporting parameters. To solve these problems, this paper proposes a design-based distribution optimization algorithm, the first double multiplicative method (PDMM), previously proposed in [22]. It is worth remembering that its main purpose is to provide an efficient and accurate way of trading energy in energy units, which should carry out all types of energy management related to the transfer of energy to other activities. In other words, the decentralized system should be able to distribute the energy activities and energy management for each part of the energy in the smart city, which can be one of the main concerns according to the method proposed by [22]. In fact, this article tries to focus on the development of PDMM based on the management of distributed energy compatible with the structure of the urban energy system, which can eliminate the above concerns raised by the results. In the acyclic

scheme presented in [23], the hash address is defined as a digital code. always to communicate. As the network/personnel on the site increases, unauthorized access becomes possible and can weaken the system against attacks. This article addresses this problem by explaining the control mechanism. In the mode shown, each unit sends/receives data based on the speed address associated with a different switch. The authentication key is randomly determined for each communication line. The key to identifying each data is therefore independent of other blocks and will change from time to time. The identity key created is called a quick address. Each data is assigned a unique address to prevent the data transmission process. All previous statements show that the two fundamental problems of the smart city can be calculated as a suitable model for energy transfer between different parts that can be addressed in the smart city. It is also important to provide a reliable security tool for data transfer. Table I provides an overview of recent research publications in this field.

C. *Contributions*

The above discussion shows that the urban energy system consists of many components, each of which solves energy management in different ways. This can be used to verify that the correct distribution system is provided for efficient use of urban energy management. Another important problem can be shown in the exchange of information between the sun of the smart city and against malicious cyber-attacks. To solve this problem, the city's energy system must have reliable equipment that allows units to transmit data efficiently. Therefore, it is very important to find ways to combine the two aspects of energy distribution and data management. This research aims to increase privacy and security for positive change in smart cities. To achieve this, an efficient power conversion system was first developed between the transmission system, smart distribution network (SDN), and microgrid. The transportation network takes into account smart modes of transportation, including subways and electric vehicles (EVs). Metros and electric vehicles can operate in different energy transmission modes: vehicle-to-grid (V2G), vehicle-to-metering (V2S), and meter-to-grid (S2G). Additionally, the energy conversion of the braking system has been changed to eliminate the cost of

energy storage devices. The microgrid model considers a mix of renewable energy sources, including wind power generation, photovoltaic (PV) electricity, hydro turbines, and energy storage. In addition, the costs of purchasing electricity/providing electricity from the grid are also taken into account. The answer given is mixed integer *linear* programming (MILP), which guarantees a real-world solution. Given that each energy segment of the smart city needs to send required data to the central management unit with the aim of achieving the optimal energy schedule based on the centralized optimization algorithm. Over the past few years, This approach has sparked thought-provoking questions among researchers. Indeed, centralized energy management may presumably make to emerge significant challenges for energy management including 1) Big data, 2) High-converging time 3) Low resiliency 4) Vulnerable central security architecture. Paper [29] most likely addresses the creation and application of a platform intended to improve power systems' resilience in the face of extreme weather conditions. Presumably, the platform's primary goal is to enable flexible outage management so that power systems can remain stable and operational even in challenging circumstances. As a result, the study proposes a substantial advance in distributed energy management: using all the independent energy resources of a smart city in a coordinated framework. Nevertheless, the potential of data alteration due to hacks plagues such an energy management structure. This issue may be addressed through blockchain technology, but it is limited due to high energy consumption. To protect privacy and improve algorithm convergence, this paper develops a PDMM-based optimization algorithm to find the optimal variable in the power switching problem containing a large number of variables. Therefore, to improve the security of the proposed power exchange system, a mesh network communication method based on an acyclic scheme was developed. All in all, the main novelties of this article are:

- It proposes an actual synergy mechanism amongst dissimilar segments of the smart city consisting of the underground metro and EVs, a microgrid that consists of renewable power generations (i.e., wind power, PV, tidal power, and electrical energy storage), and a smart grid.
- To cooperate toward common tasks among the different sections of smart cities, providing a comprehensive distributed structure based on the PDMM approach for the energy transition in smart cities is

developed.

- To preserve information related to each section of the smart city, a modified directed acyclic graph mechanism-based blockchain framework is suggested.

TABLE I
THE LITERATURE REVIEW COMPARISON

Reference	Transportation	Distribution/ PDMM	Microgrid	Security/ DAG
[6,22]	✓	✗	✓	✗
[17,13]	✗	✓	✗	✓
[1,12,20]	✗	✗	✗	✓
[19]	✓	✗	✓	✓
[2]	✗	✗	✓	✓
[15]	✓	✓	✗	✗
Proposed Model	✓	✓	✓	✓

D. Paper organization

The article structure is as below:

- Section II provides the mathematical formulation of the proposed energy transition problem in detail.
- The designed blockchain framework is described in Section III.
- Section IV presents the PDMM-based problem solution algorithm.
- Numerical results are discussed in Section V. Sections VI, VII concludes the paper.

II. PROBLEM DESCRIPTION

Looking over literature, it seems that the energy resources in a smart city can be divided into fossil fuels, renewable production units and mobile energy sources such as electric motors and meters (braking systems) that can exchange energy through parking lots. . . In this article, we categorize smart city energy according to the production model, which includes electric vehicles and subways, known as mobile energy vehicles, suitable for the city's smart white transportation system. It is worth noting that the proposed transportation system can exchange upper-line energy through EV parking and subway. In addition, microgrid-based renewable generation has been put into operation as a unit that carries out load requirements

and energy transmission to the upper electrical grid in the island region and integrates the grid system. The main goal is to reduce operating costs by providing life-saving devices at different points of the smart city. This article details the energy management problem of smart cities, which consists of smart distribution network (SDN), transportation networks, and microgrids. The total energy transfer rate is defined as:

$$F_T = f_{tr} + f_{MG} + f_{SDN} \quad (1)$$

where F_T , f_{tr} , f_{MG} , and f_{SDN} represent the total costs, transportation network cost, microgrid cost, and SDN cost, respectively. The first term represents the cost of the transportation system, which is composed by subway and electric vehicles (EVs).

A. SDN Cost

The cost of energy transition in the SDN is computed as follows:

$$f_{SDN} = \sum_{t=1}^T [P_{LG}^t - P_{MG}^t - P_{tr}^t] \times \pi_{grid} \quad (2)$$

where P_{LG}^t represents the power consumed in the SDN, power consumption/generated in the MG, electrical power transition in the transportation network, and price of the electrical power, respectively. The electrical power transition in the transportation network is given by [23]:

$$P_{tr}^t = \sum_{s=1}^S [P_{S2G}^{t,s} + P_{G2S}^{t,s} + \sum_{e=1}^E [P_{V2G}^{t,e} + P_{G2V}^{t,e} + \sum_{s=1}^S [P_{E2S}^{t,e,s} + P_{S2E}^{t,e,s}]]] \quad (3)$$

where $P_{S2G}^{t,s}$, $P_{G2S}^{t,s}$, $P_{V2G}^{t,e}$, $P_{G2V}^{t,e}$ represent the injected power to the grid by the subway, absorbed power by the subway, injected power by the EVs to the grid, the absorbed power by EVs, power transited from subway to EV, and transferred power by the subway to the EVs, respectively. The total number of subway stations and EV fleets are respectively shown by S and E , while the scripts s and e represent the number of subway stations and the EV fleets.

In the smart city, it is essential to provide a balance between generation and supply:

$$P_L^t = P_{LG}^t - P_{MG}^t - P_{tr}^t \quad (4)$$

B. Transportation System Cost

In this paper, the transition of energy between the smart city and the transportation system has been considered. To this end, different types of energy transition, i.e., V2G, V2S, S2G, S2V, and V2S have been considered.

It is worthwhile to note that the EVs can charge/discharge in the parking lots located in the subway stations and smart grid.

The cost of the transportation system is given as:

$$f_{tr} = f_{EV} + f_S \quad (5)$$

As shown in (5), the cost of the transportation system consists of two terms, including EVs energy exchange with the subway, and grid f_{EV} , the subway energy exchange with the grid and EV f_S . In the following, each of these terms is explained in detail.

1) EV costs

The first term in (5), f_{EV} , is defined as:

$$f_{EV} = f_{V2G} + f_{V2S} + f_{dg} \quad (6)$$

where f_{V2G} , f_{V2S} , and f_{dg} are the cost of energy transition between the EV and grid, the cost of energy transition between the grid and EVs, and EV degradation cost, respectively. All these terms are given as:

$$f_{V2G} = \sum_{t=1}^T \sum_{e=1}^E C_{V2G}^{t,e} P_{V2G}^{t,e} \quad (7a)$$

$$f_{V2S} = \sum_{t=1}^T \sum_{e=1}^E C_{V2S}^{t,e} P_{V2S}^{t,e} \quad (7b)$$

$$f_{dg} = C_{dg} \sum_{t=1}^T \sum_{u=1}^U \sum_{s=1}^S \vartheta (Pd_{V2G}^{t,u,s} + Pd_{V2S}^{t,u,s}) \quad (7c)$$

Equations (6) and (7c) are cited that The EVs' overall cost through the V2G and V2S energy transactions is shown in (6) and consists of three main terms, wherein the first term represents the V2G energy transaction, the second term expresses V2S energy exchange and the third term shows the EVs' battery degradation cost

model. It means that the battery model proposed in this paper can cover the concern on the limited lifecycle. The bidding prices of V2G and V2S are shown by $C_{V2G}^{t,e}$ and $C_{V2S}^{t,e}$, respectively, while the power exchange in the V2G and V2S modes are $P_{V2G}^{t,e}$ and $P_{V2S}^{t,e}$, respectively. The degradation cost of the EV is depicted by C_{dg} and the discharging powers during V2G and V2S are respectively illustrated by $Pd_{V2G}^{t,u,S}$ and $Pd_{V2S}^{t,u,S}$. Besides, subscripts u shows the urban path in the transportation network. The abovementioned costs of energy transitions of EVs are limited by [8]:

$$E_{V2G}^{t+1,e} = E_{V2G}^{t,e} + \eta_C P C_{V2G}^{t,e,u} - \eta_D P d_{V2G}^{t,e,u} \quad (8a)$$

$$E_{V2S}^{t+1,e} = E_{V2S}^{t,e} + \sum_{s=1}^S \left[\sum_{u=1}^U \left(\eta_C P C_{V2S}^{t+1,e,u} - \eta_D P d_{V2S}^{t+1,e,u} \right) - \sum_{s=1}^S \left[\sum_{u=1}^U \delta^{t+1,s,u} (ET^{s,u} - ED^{s,u}) \right] \right] \quad (8b)$$

$$E_V^{t,e} = E_{V2G}^{t,e} + E_{V2S}^{t,e} \quad (8c)$$

$$P_{V2G}^{t,e} = E_{V2G}^{t+1,e} - E_{V2G}^{t,e} \quad (8d)$$

$$P_{V2S}^{t,e} = E_{V2S}^{t+1,e} - E_{V2S}^{t,e} \quad (8e)$$

$$\delta_{ch}^{t,e,u} + \delta_{dis}^{t,e,u} = \delta^{t,e,u} \quad (8f)$$

$$\delta_{ch}^{t,e,u} P_{ch,min}^e \leq P_{V2G}^{t,e,u} \leq \delta_{ch}^{t,e,u} P_{ch,max}^e \quad (8g)$$

$$\delta_{dis}^{t,e,u} P_{dis,min}^e \leq P d_{V2G}^{t,e,u} \leq \delta_{dis}^{t,e,u} P_{dis,max}^e \quad (8h)$$

$$E_{V,min}^e \leq E_V^{t,e} \leq E_{V,max}^e \quad (8j)$$

$$E_V^{t+1,e} = E_V^{t,e} + \eta_C P c^{t,e} - \eta_D P d^{t,e} \quad (8k)$$

$$P c^{t,e} = P c_{V2G}^{t,e} + P c_{V2S}^{t,e} \quad (8l)$$

$$P d^{t,e} = P d_{V2G}^{t,e} + P d_{V2S}^{t,e} \quad (8m)$$

where $E_{V2G}^{t,e}$, $P C_{V2G}^{t,e} / P C_{V2S}^{t,e}$, η_C / η_D , and $P d_{V2G}^{t,e,u} / P d_{V2S}^{t,e,u}$ represent the capacity of EVs in V2G mode, charging power of EVs in V2G/V2S mode, charging/discharging efficiency of EV battery, and discharging power of

EVs in V2G/V2S mode, respectively. $\delta^{t,e,u}$ is a binary variable (showing the urban path), while $ET^{s,u}$ and $ED^{s,u}$ respectively depict the required energy for traveling to the subway station s in the u^{th} urban path and discharging energy to go to the subway station s in the u^{th} urban path. In addition, the total energy transition in EVs is shown by $E_V^{t,e}$, while binary variables that show the charging and discharging of the EVs are depicted by $\delta_{ch}^{t,e,u}$ and $\delta_{dis}^{t,e,u}$, respectively.

2) Subway

The subway cost is composed of two terms including f_{S2G} and f_{S2V} , being described as:

$$f_S = f_{S2G} + f_{S2V} \quad (9)$$

The first term f_{S2G} is obtained as [23]:

$$f_{S2G} = \sum_{t=1}^T \sum_{s=1}^S C_{S2G}^{t,s} P_{S2G}^{t,s} - \sum_{t=1}^T \sum_{s=1}^S C_{G2S}^{t,s} P_{G2S}^{t,s} \quad (10)$$

where $C_{S2G}^{t,s}$ shows the bidding price by the subway for the energy exchange with the grid, while the power transition from the subway to the grid and from the grid to the subway are depicted by $P_{S2G}^{t,s}$ and $P_{G2S}^{t,s}$, respectively. The cost of purchased energy by the subway from the grid is given by $C_{G2S}^{t,s}$.

The reshaped demand of the subways before the proposed energy transition program is limited as:

$$D_{new}^{t,s} = D_{old}^{t,s} - P_{G2S}^{t,s} \quad (11)$$

where the reshaped subway's demand is shown by $D_{new}^{t,s}$, while the subway's demand before the change is given as $D_{old}^{t,s}$.

Besides, the power transition between the subway and the grid is limited by the maximum value of the subway braking power, P_{SB}^{max} , as:

$$P_{S2G}^{t,s} \leq P_{SB}^{max} \quad (12)$$

The second term of subway energy transition cost, f_{S2V} , is:

$$f_{S2V} = \sum_{s=1}^S \sum_{e=1}^E (P_{C_{V2S}}^{t,e,s} - P_{D_{V2S}}^{t,e,s}) C_{S2V}^e \quad (13)$$

The amount of power exchange between the subway and the EVs is restricted as:

$$P_{V2S}^{t,s} \leq P_{SB}^{max} \quad (14)$$

Consequently, the subway's demand after the implementation of the proposed energy transition is limited by:

$$D_{new}^{t,s} = D_{old}^{t,s} - \sum_{u=1}^U \sum_{e=1}^E P_{V2S}^{t,e,s} \quad (15)$$

C. Microgrid Cost

MGs can be an interconnected network of smart cities with their private operators. The considered MG in this paper includes energy-based distributed generation (DG) units, i.e., wind power generation (WPG), tidal turbine (TV) and photovoltaic (PV) systems, and also energy storage (ES) devices. The cost of the MG is computed as:

$$f_{MG} = \sum_{t=1}^T P_{PV}^t C_{PV}^t + \sum_{t=1}^T P_{WPG}^t C_{WPG}^t + \sum_{t=1}^T P_{TV}^t C_{TV}^t + \sum_{t=1}^T P_{ES}^t C_{ES}^t \quad (16)$$

The power generated by the PV, TV, and WPG are shown by P_{PV}^t , P_{TV}^t , and P_{WPG}^t , respectively, while the cost of PV, TV and wind generators are depicted by C_{PV}^t , C_{TV}^t , and C_{WPG}^t , respectively. Furthermore, the charging/discharging power and cost of the ES are represented by P_{ES}^t and C_{ES}^t , respectively.

The power balance in the MG is P_{MG}^t :

$$P_{MG}^t = P_{PV}^t + P_{WPG}^t + P_{TV}^t + P_{ES}^t \quad (17)$$

The power generated by PV is dependent on the solar irradiation and can be expressed as:

$$P_{PV}^t = \frac{1 - P_{PV-loss}^t}{G} (N_G^t \times \alpha_{PV}) \quad (18)$$

The power generated by WPG is also defined as:

$$P_{WPG}^t = \frac{1}{2} \phi A (\omega_W^t)^3 \quad (19)$$

where ω_W^t , ϕ , and A represent the wind speed, wind density, and area of rotor blades, respectively.

The output power of the storage system (ES) is updated at each time interval as:

$$P_{ES}^{t+1} = P_{ES}^t + P_{c_{ES}}^t - P_{d_{ES}}^t \quad (20)$$

where $P_{c_{ES}}^t/P_{d_{ES}}^t$ shows the charging/discharging power of ES. The output power of the TV is obtained at each time interval t , as:

$$P_{TV}^t = \begin{cases} 0 & 0 \leq T_{TV}^t \leq T_{TV}^n \\ \frac{1}{2} \rho_w A_{TV} (T_{TV}^t)^3 & T_{TV}^{cut-in} \leq T_{TV}^t \leq T_{TV}^n \end{cases} \quad (21)$$

where T_{TV}^t , T_{TV}^n , T_{TV}^{cut-in} , and P_{TV}^n represent the tidal current, nominal tidal current, cut-in tidal current, and nominal tidal turbine-generated power, respectively. Furthermore, ρ_w and A_{TV} depict the seawater density and swept area of the tidal turbine blade, respectively. Generally speaking, Equation (1) is introduced as the underlying goal followed by a smart city energy trading system. Needless to say, the energy management associated with each energy segment of a smart city can be brought costly if not inspired by a true and secure energy-trading framework. As a matter of fact, employing truly the whole energy capacity of smart city can help to eliminate this issue. In virtue of such a proposed trading mechanism, each segment of smart city can dazzlingly fulfill its targeting economic propose by the distinctive energy exchanging platform to other segments. Hence, being inspired by the aforementioned argument, the entire energy-trading framework of smart city is organized by equations (1), (2), (5), (16) and the relevant constraints pertaining to the total function, the SDN, transportation, and microgram in smart city, respectively.

III. BLOCKCHAIN MODEL

The blockchain is a modern technology to increase security in multi-agent systems with different actors. Since modern energy systems consist of different institutions with their own rules, policies and goals, blockchain has received a lot of attention in recent years due to its security potential. In an energy system, electricity and demand are treated as load (also called employee). Each of these components is a block of

data and communicates confidential data. data verification is performed according to the hash address. Hashing address is a simple and effective technique that provides a unique key to identify sender/receiver data for each node. Employees can access information using the authentication key generated by encryption technology. An acyclic diagram (DAG) can solve these problems by providing the possibility of broadcasting public and business information to all operators in the power system [23]. Even if this problem occurs, the blocking system for circular systems cannot prevent cyber-attacks and unauthorized access to data is possible. Although in acyclic design the structure consists only of received/transmitted business data, the ability to receive and review data in the sales phase is still preserved for the following reasons: i) low sampling frequency, ii) complementarity of quick addresses for sales. Order of the data series. This page addresses the above issues with the display control system. In the mode shown, each unit sends/receives data based on the speed address associated with a different switch. The authentication key is randomly determined for each communication line. The key to identifying each data is therefore independent of other blocks and will change from time to time. The unique ID created is called a unique address (AHD). AHD is divided into each data transmission mode block. The proposed data storage system is shown in Figure 1. AHD is a unique address recognition system for sending/receiving data. In the blockchain-based network in this article, the data block first receives the encrypted data. Then the data block is opened for the first time using the AHD corresponding to the $t-1$ floor. According to AHD, a data block provides a unique address and a cryptocurrency for time slot t . In this method, the balance of the data after and before analysis is considered as a verification list. The application demonstrates the data transfer method presented in Algorithm 1.

A. The proposed approach: advantages and disadvantages

The arguments over such a trend have interested investigators to suggest the DAG. In this method, the information of the systems' nodes based on the private, public and transaction forms are produced and exchanged, individually, over the private blockchain, public blockchain and transaction blockchain, respectively. In the private blockchain, the nodes related to an agent can only broadcast their detailed data to each other such that that information will not be accessed by other agents of the system. The public

information of system through the public blockchain is available for all agents of systems. Each agent can hourly broadcast its transaction information to another agent within each hour. Such an acyclic, decentralized framework has decreased the successful probability of cyber-attacks in smart city. As cons of such an approach, the possibility of data cyber-attacks particularly by the transaction blockchain can be still a matter of debate. Because of the interdependency of the HAs among the consecutive data blocks, the chance of injecting false data within the monitoring system can be increased within a certain time period compared with the security framework proposed in the literature review. This issue can be repelled by AHD method.

Algorithm 1: Data transmission based on AHD

Sending process:

Step1: Send data from each block

1-1: Initialization of the time, data blocks generation,

1-2: AHD-based encrypted data

1-3: send the data from the data block

Receiving process

Step 2: Receive encrypted data

2-1: Set time $t = t + 1$

2-2: receive data

2-3: decrypt data using AHD-based ID key

Step3: Secure data exchange

3-1: Cryptocurrency using merkle root between previous hashing address and current hashing address

Step4: Data Corrupted

4-1: compare the encrypted data in previous and current time intervals

4-2: if resulted data is equal

Set $t = t + 1$

Send validation report

Extended the blockchain

Otherwise

Report cyber attack

End

End

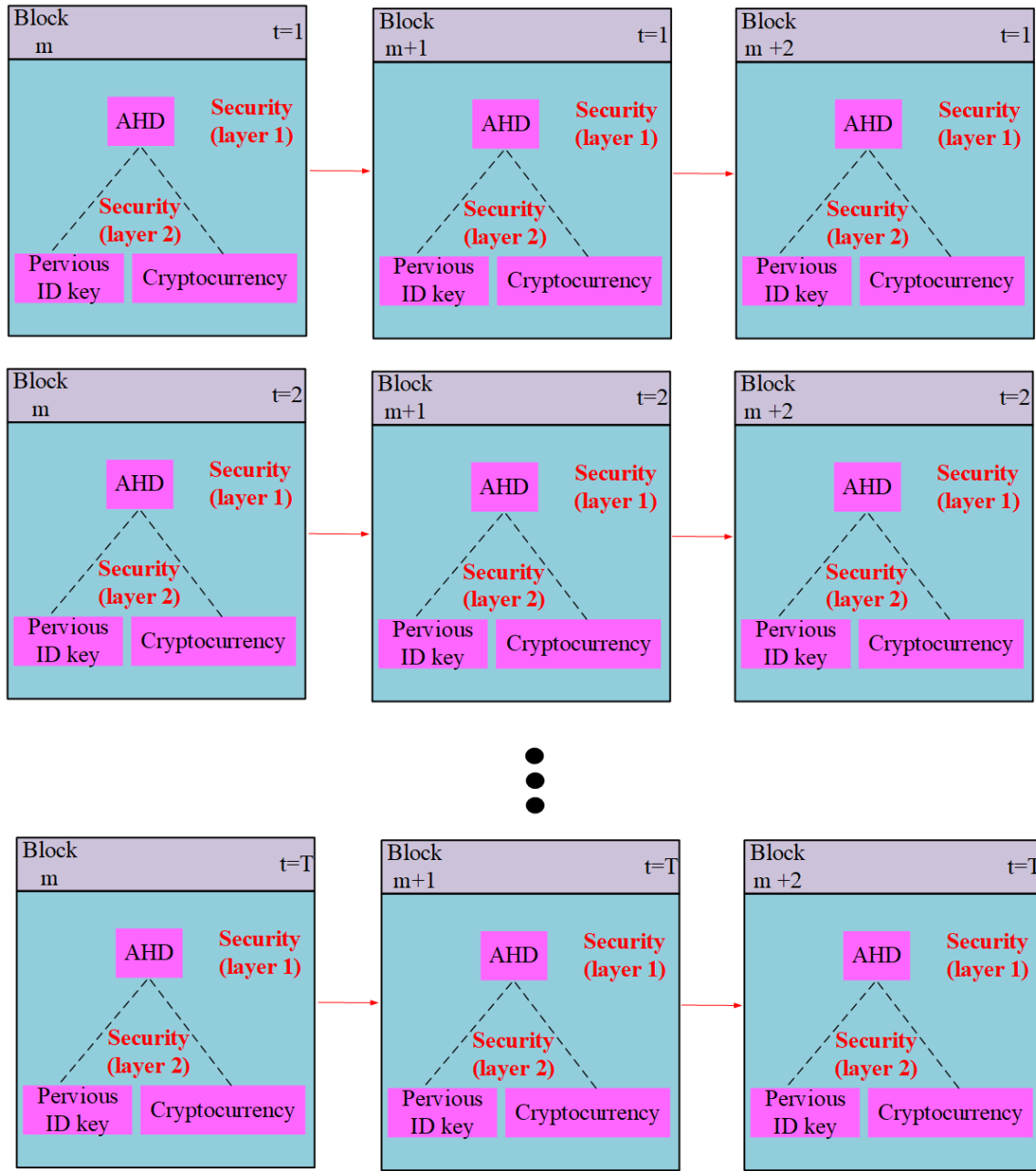


Fig. 1. Data blocks configuration.

Using this method, as shown in Algorithm 1, can guarantee data security during information exchange in the block. Additionally, incorrect or corrupt data may be detected using data processing on the host site. In [18], the laundry address is created based on the combination of numbers (0-9) and letters (A-F) into 32 sequential words [24]. The proposed energy transition scheme based on the electricity grid is shown in Figure 2. As you can see, there are many actors in smart cities, including smart grid, microgrid and smart transportation system. Blockchain is also available for microgrids, transport systems and SDN. Private networks allow parts of

smart cities to share private information with high security. As a result, the block was responsible for providing a reliable environment that transmitted energy conversion information to different points of the smart city.

IV. DISTRIBUTED CONTROL USING A PDMM-BASED STRUCTURE

To solve the proposed energy transition problem in a distributed manner, this paper develops a PDMM algorithm. Generally, distributed optimization algorithms such as ADMM are algorithms with high computational costs that aim to preserve the privacy of different agents or reduce the required communication links [25].

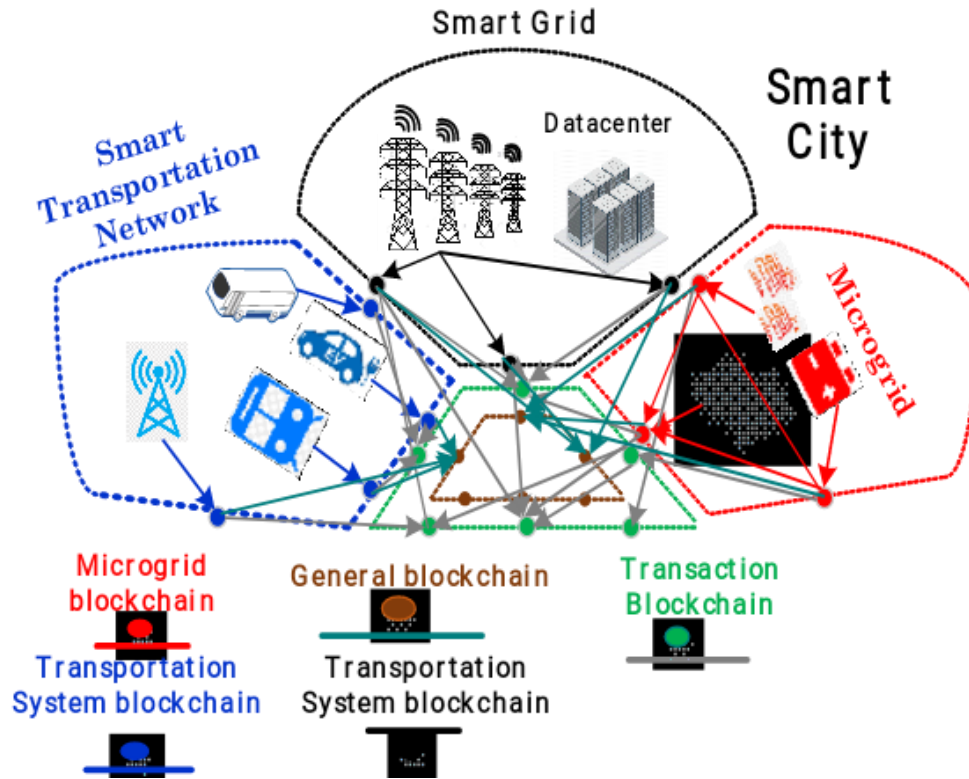


Fig. 2. Smart city and corresponding components.

To address these issues, this paper develops a PDMM-based algorithm. The PDMM is a graph-based distribution optimization algorithm, which was originally presented in [22].

A. General Form of PDMM

For distributed optimization across a graph, we present the primal-dual method of multipliers (PDMM). Specifically, we maximize the product of convex functions specified over a graph with a linear equality constraint on each edge. An augmented primal-dual Lagrangian function is created during the design of the new method, and it seamlessly captures the graph topology. It is demonstrated that a saddle point of the created function offers the best way to solve the initial issue. Distributed averaging experiments are also used to study other characteristics of PDMM, such as convergence rates versus various parameter values and robustness to transmission failure. Consider a graph consisting of i^{th} different node and each node $i \in R^{n \times n}$. In this graph-based optimization algorithm, x^i and $f^{gr}(x^i)$ denote the inputs and node functions corresponding to all nodes. Each node represents the agent, therefore, each agent is connected to the neighbor node(s) through a path $x_{ij} \in \Lambda^{i \times j}$ with edge function $\pi_{ij}x_i + \pi_{ji}x_j = \beta_{ij}$, as shown in Fig 3. The general form of the optimization problem considering an edge function is:

$$\underset{x}{\operatorname{argmin}} \sum_{i=v}^V f_i(x_i) \quad (22a)$$

s. t.

$$\pi_{ik}x_i + \pi_{ki}x_k = \beta_{ik} \quad (22b)$$

In the graph-based optimization algorithms, the different objective functions x_i and x_j reform as the vectors $\vec{x}_i$ and $\vec{x}_j$. Each node in the PDMM is described as $(\vec{x}_i, \vec{\gamma}_i)$, where $\vec{\gamma}_i$ is a dual variable. The PDMM is an iterative based algorithm and performs based on the updating the states. The iteration continues until the optimum solutions is reached to the equilibrium among all agents. The general procedure of the PDMM is given in Algorithm 2.

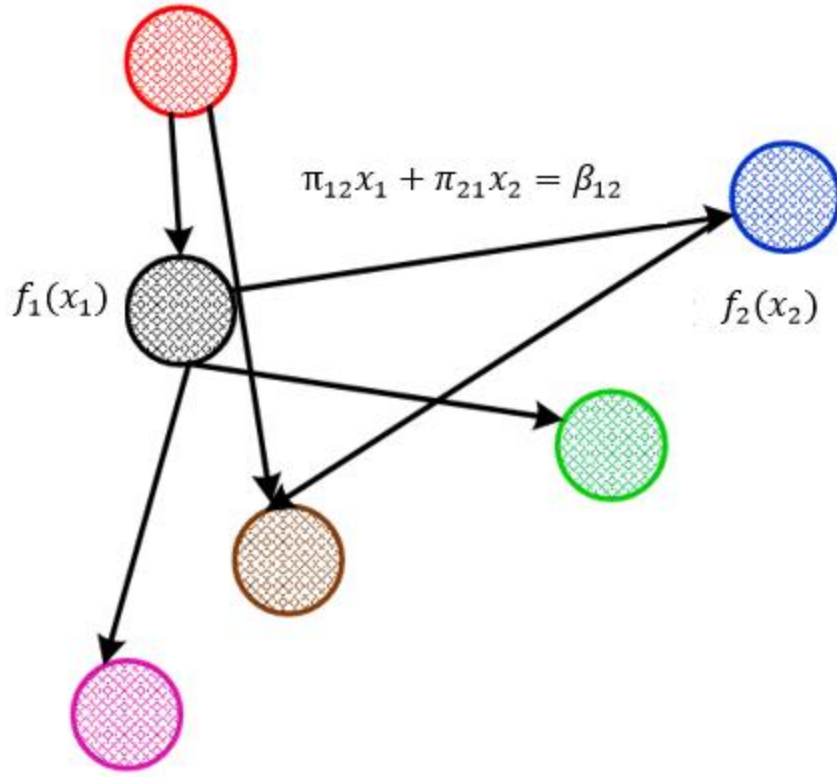


Fig. 3. PDMM over a graph.

Algorithm 2: General form of the PDMM

Input: constant parameters, constraints, and objective functions

Output: optimal decision variables

1: Initialization $\vec{x}_i, \vec{\gamma}_i, \forall i = 1, \dots, N^{obj}$ (N^{obj} number of objective functions)

2: Set $it = 0$

3: while $|\vec{\gamma}_{ik}^{it+1} - \vec{\gamma}_{ik}^{it}| < \epsilon$

4: $it = it + 1$

 for $i=1$

 Compute (23a) & (23b)

 end

End

As can be seen in Algorithm 2, the procedure of the PDMM is started using the initial value of the states $\vec{x}_i$ and $\vec{\gamma}_i$.

Then, at each iteration (shown by i), these values are updated based on:

$$x_i^{it+1} = \underset{x_i}{\operatorname{argmin}} \left\{ f_i(\vec{x}_i) + \frac{1}{2} \sum_{k=1}^{N^k} \left\| \pi_{ik} \vec{x}_i + \pi_{ki} \vec{x}_k - \beta_{ik} \right\|_{\varphi_{ik}}^2 - \vec{x}_i^T \left[\sum_{k=1}^{N^k} \pi_{ik}^T \vec{\gamma}_{ki} \right] \right\} \quad (23a)$$

$$\vec{\gamma}_{ik}^{it+1} = \vec{\gamma}_{ik}^{it} + z_{ik}^{-1} (\beta_{ik} - \pi_{ik} \vec{x}_i^{it} - \pi_{ki} \vec{x}_k^{it+1}) \quad (23b)$$

The $\vec{x}_i$ and $\vec{\gamma}_i$ are updated until the difference between $\vec{\gamma}_{ik}^{it+1}$ and $\vec{\gamma}_{ik}^{it}$ would be less than a small constant value ϵ .

B. PDMM-based Energy transition

To obtain the optimal values of the energy transition of the SDN, transportation system, and microgrid, considering $P_{en}^t = \{P_{LG}^t, P_{MG}^t, P_{tr}^t\}$, the following procedure should be carried out:

$$\vec{P}_{en,i,t}^{it+1} = \underset{P_{en,i,t}}{\operatorname{argmin}} \left\{ f_i(\vec{P}_{en,i,t}) + \frac{1}{2} \sum_{k=1}^{N^k} \left[\|\pi_{ik} \vec{P}_{en,i,t} + \pi_{ki} \vec{P}_{en,i,t}^{it} - \beta_{ik}\|_{\varphi_{ik}}^2 - \vec{P}_{en,i,t}^T \left[\sum_{k=1}^{N^k} \pi_{ik}^T \vec{\gamma}_{ki}^T \right] \right] \right\} \quad (24a)$$

$$\vec{\gamma}_{ik}^{it+1} = \vec{\gamma}_{ik}^{it} + z_{ik}^{-1} (\beta_{ik} - \pi_{ik} \vec{P}_{en,i,t}^{it} - \pi_{ki} \vec{P}_{en,i,t}^{it}) \quad (24b)$$

The energy transition of the smart city $\vec{P}_{en,i,t}$ is given by:

$$\vec{P}_{en,i,t} = \left\{ \vec{P}_{en,i,t=1}^{tr:P_m \rightarrow P_1}, \vec{P}_{en,i,t=2}^{tr:P_m \rightarrow P_1}, \dots, \vec{P}_{en,i,t=T}^{tr:P_m \rightarrow P_1}, \vec{P}_{en,i,t=1}^{tr:P_m \rightarrow P_2}, \dots, \vec{P}_{en,i,t=T}^{tr:P_m \rightarrow P_2}, \dots, \vec{P}_{en,i,t=1}^{tr:P_m \rightarrow P_n} \right\}_{1 \times (T \times P_m)} \quad (25a)$$

$$\pi_{ik} \vec{P}_{en,i,t} = \{ \vec{P}_{en,i,t=1}, \vec{P}_{en,i,t=2}, \dots, \vec{P}_{en,i,t=T} \}_{1 \times T} \quad (25b)$$

$$\vec{P}_{en,min} \leq \vec{P}_{en,i,t} \leq \vec{P}_{en,max} \quad (25c)$$

where $\vec{P}_{en,i,t=1}^{tr:P_m \rightarrow P_n}$ shows the energy transition between agents P_m and P_n . All to all, focusing on procedure of the PDMM method elucidated in equation (24a), $\vec{P}_{en,i,t}$ is only considered as optimal decision variable of problem and trading power among agents, which should be determined for each agent in each time. On the other hand, it assumes that the energy price is input parameter and is determined by the decision-making algorithm in the day-ahead energy market for all agent. Therefore, the bargaining based cooperative energy trading is settled down based on the energy market price and power exchanging among agents. Also, it is important to mention that the wide-spreading use of smart devices with the aim of being more flexible the power system emerges the sundry energy systems within smart city which can increase in high scalable in future. Hence. There is needed an effective distributed method to handle the energy management considering

many energy segments of smart city. Hence, based on the descriptions proven by [22], the proposed PDMM approach is capable of converging the energy trading among many agents in a true and optimal way. On the other hand, it is proven in literature works that the blockchain technology could enumerate the many nodes of network to get into the data security. Considering relationship between the blockchain and DAG concepts, it seems that the proposed security method is appropriate for the smart city. In conclusion, it seems to be inevitable that the proposed secured energy-trading mechanism take the sufficient ability to develop for the high-scale case study.

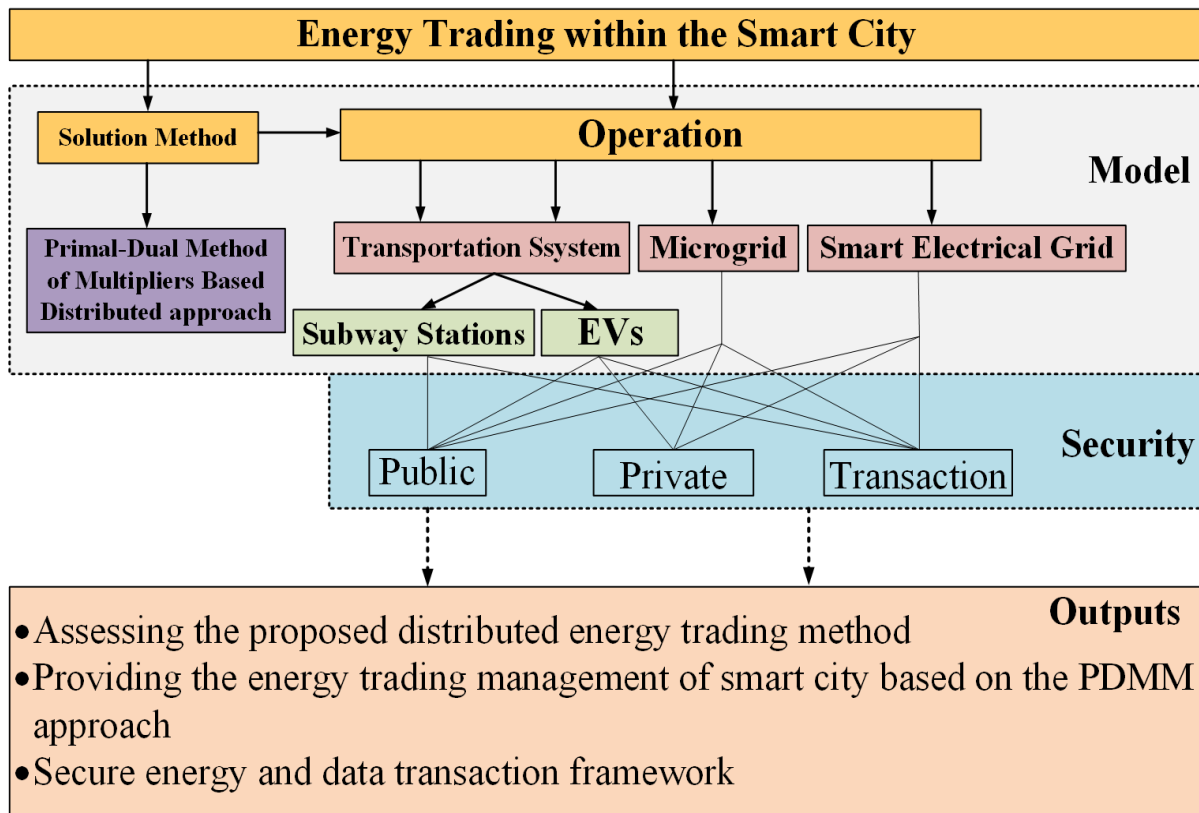


Fig. 4. The overall methodology of the work

In the above figure, the methodology of the whole work is represented. As can be seen, the studied model is divided into three main parts including the model and security, the consequences followed by this paper.

V. NUMERICAL RESULTS

This section discusses the results of the proposed energy transition framework. As mentioned before, in the proposed framework, the SDN, microgrid, and intelligent transportation system have been considered. The microgrid consists of WPG, PV, and ES. The output power of the WPG and PV systems are modeled based on the wind speed and solar irradiation [26]. In this paper, EVs are charged/discharged in the parking lot connected to the SDN or subway stations. In the case of the EVs connected to the SDN, the decision variables of the EVs are determined by the operator of the SDN, while the optimal decision variables of the EVs in the subway stations are determined by the transportation network operators. For both types of EVs in this study (charging/discharging in the SDN or transportation system), it is crucial to provide the initial information of EVs, e.g., access time, charge/discharge restrictions, arrival/departure time, etc. Table II depicts the detailed information of the EV fleets in the smart city. The cost of EVs is adopted from the [27]. The EVs can exchange the power with the subway's stations between subway departures. In this study, the transportation system consists of six subway stations with the capability of trading power with the smart grid and EVs. Also, two different paths with different lengths and traffic congestion have been considered in the transportation network. The electrical network parameters and constraints used in this paper are given in [8], [5], [12]. The subway stations (six subway stations have been considered) should supply the electrical demand for transportation and also can save energy using braking energy. As mentioned before, the operators of the transportation system, microgrid, and SDN are independent, while these systems perform as an interconnected system. The simulations are implemented in GAMS and MATLAB. The CPLEX solver solves the proposed mixed integer linear problem (MILP).

A. Discussion: Energy Transition

Figure 5 shows the transportation system with SDN $t = 3$. As can be seen in this figure, 400 iterations are required to establish a balance between the smart grid and the transportation system. In the first iteration (shown as High), the smart grid is the energy buyer and the transmission network is the energy supplier. However, the practical implementation of SDN was not completed in the first iteration. In other words, the

process continues until the host and delivery are replaced and the smart and functional units of the city become functional. The energy trade between the microgrid and the smart grid at time $t = 10$ is shown in Figure 6. It is clear that in the first iteration, the smart grid buys energy and the microgrid sells it, and there is effective energy trading between the microgrid and the smart grid. network smart network is zero.

TABLE II
EVs FLEET PARAMETERS

Fleet Num.	Number of EVs	Access Time (hr.)	$E_{V,min}^e$ (kWh)	$E_{V,max}^e$ (kWh)	Pc_{max}^e / Pd_{max}^e	Pc_{min}^e / Pd_{min}^e
1	41	(7,8), (13,14), (14,16)	219	1644	292	7.3
2	64	(7,10), (12,14), (17,19)	263	1973	496	7.3
3	53	(7,10), (12,14), (17-19)	251	1902	386	7.3
4	32	(12,14), (16,18)	208	1610	234	7.3
5	55	(7,10), (12,14), (17,19)	251	1902	386	7.3
6	41	(7,9), (12,14), (16-18)	219	1644	292	7.3

It means that zero energy at $t = 10$ is the optimal energy transition for both microgrid and smart grid. The primal-dual error is also leading to the zero value based on Fig. 7. That is, the energy is not traded at $t = 10$ between the microgrid and the smart grid. The total cost variation of the smart city energy transition at each iteration of PDMM-based algorithm is shown in Fig. 8. It is obvious that the costs are restricted by the constraints. The optimal total cost after 400 iterations is 4.45 B\$ and the maximum value is 4.7 B\$. Fig. 9 shows the energy transition between the smart grid and the transportation system throughout a 24-hour time period. As can be seen, the transportation system profits by selling power to the energy system in the 23-time slot. Only at $t = 3$, the transportation system is an energy buyer in trading with the smart grid.

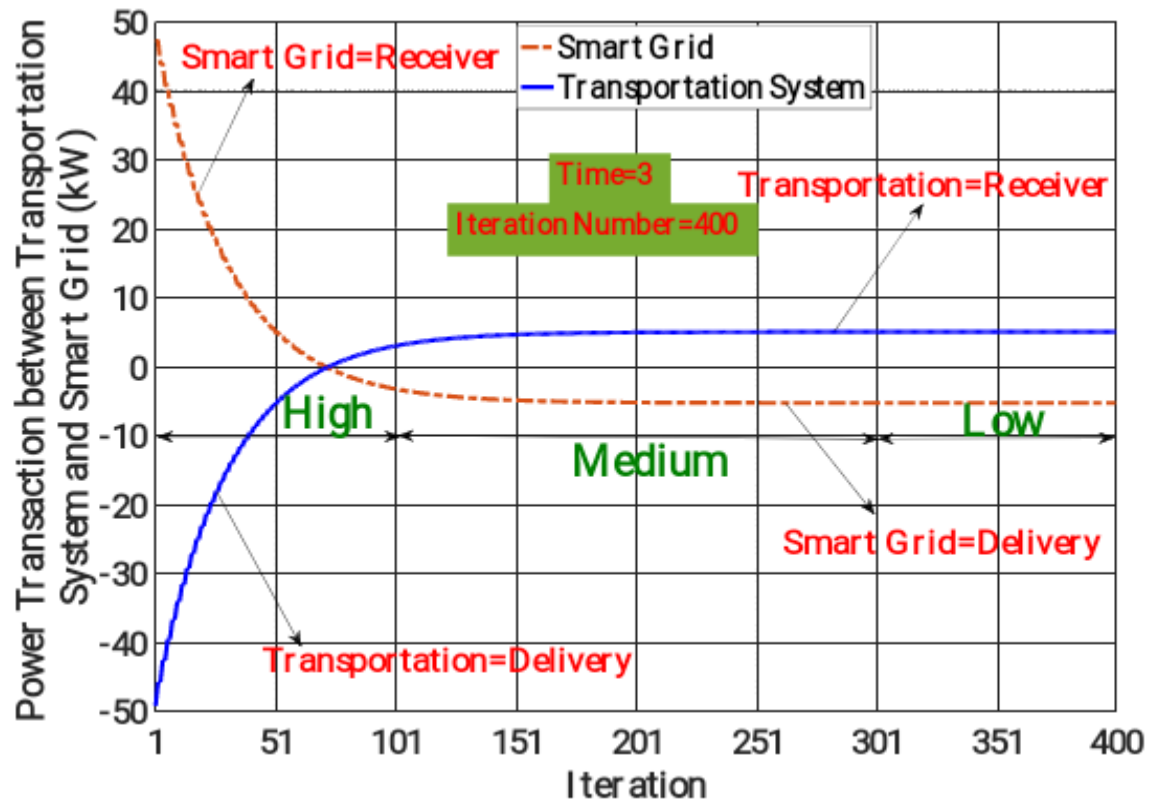


Fig. 5. Energy trading between smart grid and transportation system at $t = 3$.

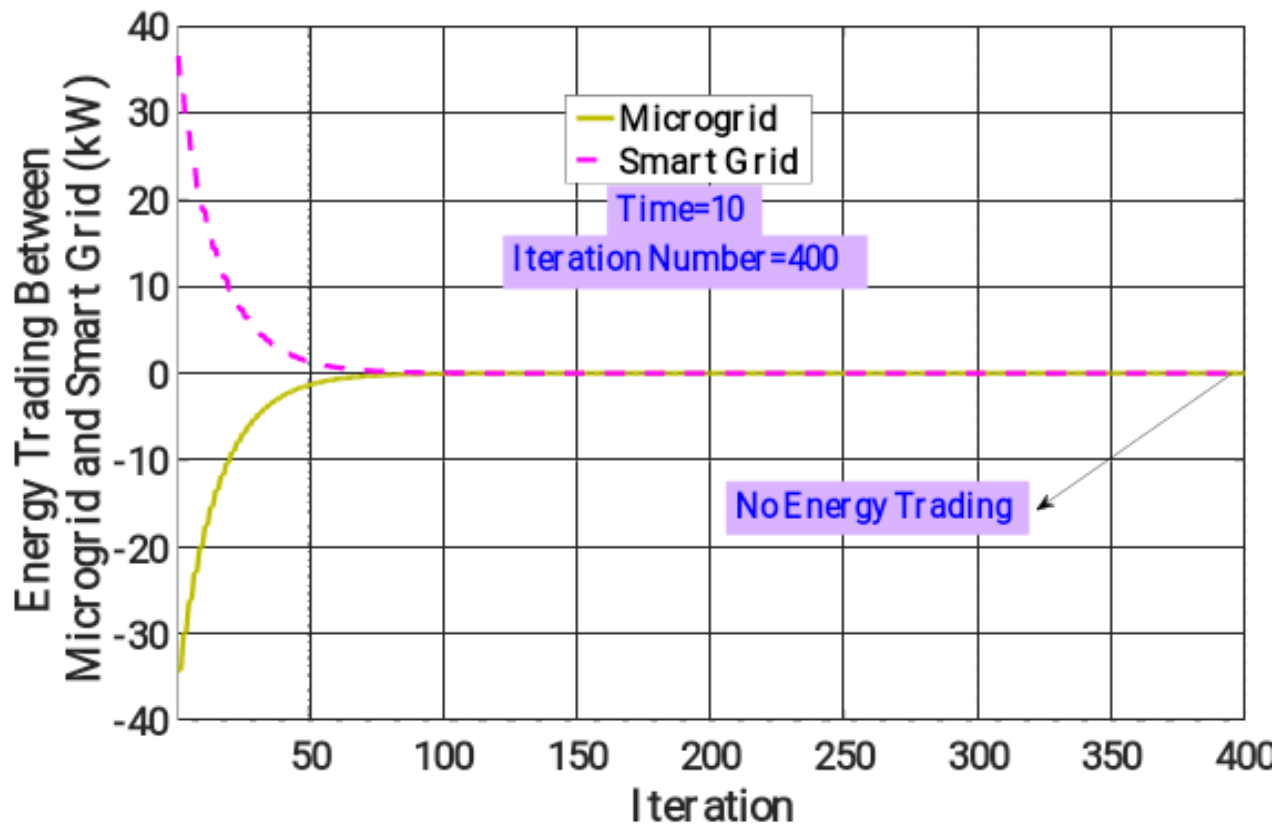


Fig. 6. Energy trading between smart grid and microgrid at $t = 10$.

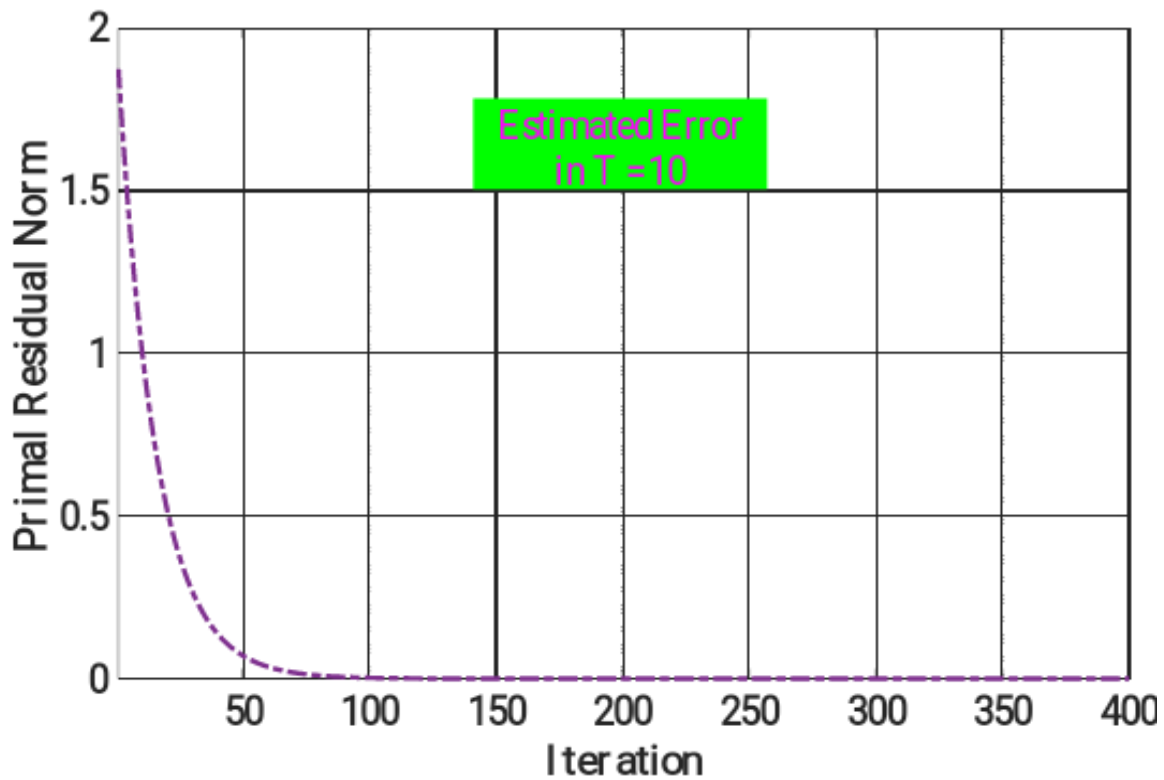


Fig. 7. Primal residual norm error for energy trading between microgrid and smart grid.

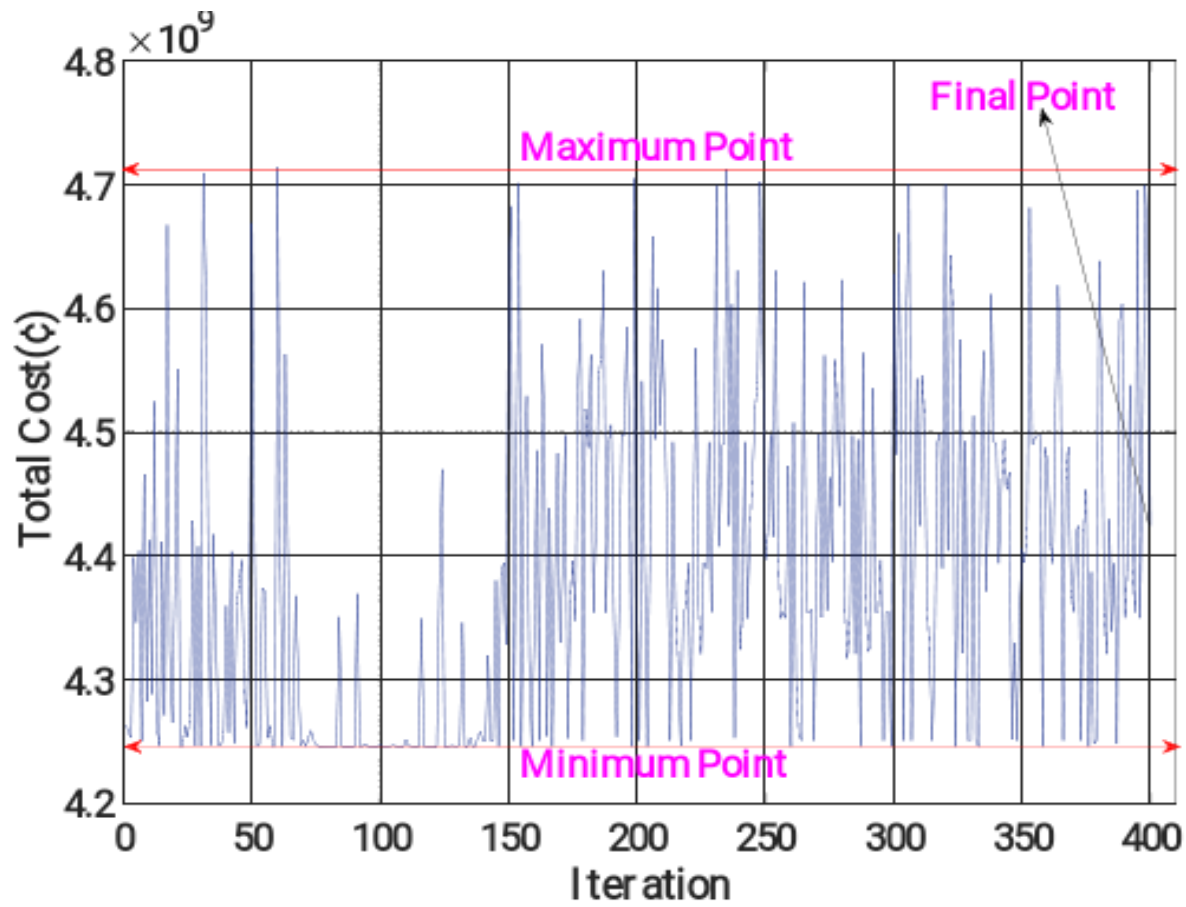


Fig. 8. Total cost variation of smart city energy transition at each iteration of PDMM-based algorithm.

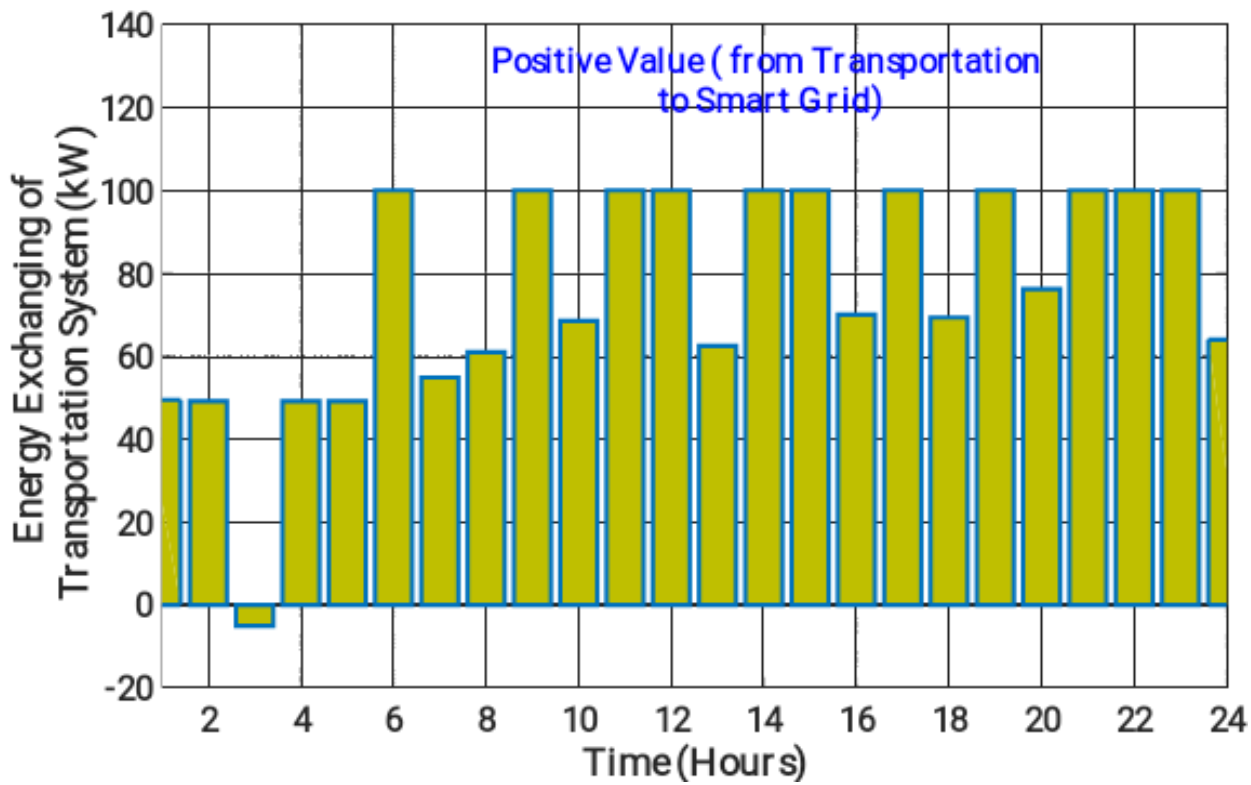


Fig. 9. Energy trading between transportation system and smart grid.

The exchanged power between the microgrid and the smart grid is shown in Figure 12. Negative values indicate that the microgrid sends power to the smart grid, and positive values indicate that the microgrid receives power from the smart grid. Additionally, energy production from renewable energy in the microgrid is shown in Figure 12. It depends on the fruit. In Figures 12 and 13, it can be noticed that when the microgrid sells energy to the smart grid, the percentage of renewable energy generation, especially wind generation, is high (between 1:00 and 9:00). However, to reduce the share of renewable energy sources, the microgrid purchases energy from the smart grid (between 9 am and 6 pm). As mentioned before, six electric vehicle parking spaces were considered for the train station. 24-hour electricity charging/discharging from the parking lot. The time is shown in Figure 14. This figure also shows the power of trading in V2S and S2V modes. In V2S mode, electric vehicles discharge and generate energy at the corresponding meter stations. In S2V mode, electric fleets draw power from the grid. The charging/discharging capacity of the EV fleet in the smart grid parking lot in a 24-hour period is shown in Chapter 15. The charging/discharging capacity of all

six car parks is maximum at certain hours, for example between 09:00. Between 12.00 and 14.00 and 19.00 in the afternoon. Apart from the aforementioned results, In order to validate and assess the procedure of the proposed PDMM method and be justifiable the PDMM method compared with ADMM [2] as one of the most effective distributed methods, here is needed to provide some of the relevant consequences. Hence, Fig. 10 is provided, which compares the mean squared error of two the distributed methods. As can be seen, the PDMM method trend has converged to zero error in 20 iterations, while the distributed method one has taken 100 iterations to get zero mean squared error. Looking over assessing the convergence speed of the PDMM method, Fig. 11 is provided to indicate how convergence speed varies by the variation of γ_{ij}^{-1} and γ_{ij} which show the primal and dual scalars, respectively. It can be seen that the difference between their values gets higher and the convergence speed of the method will be declined. While, the more they take closer, the higher convergence speed will be brought.

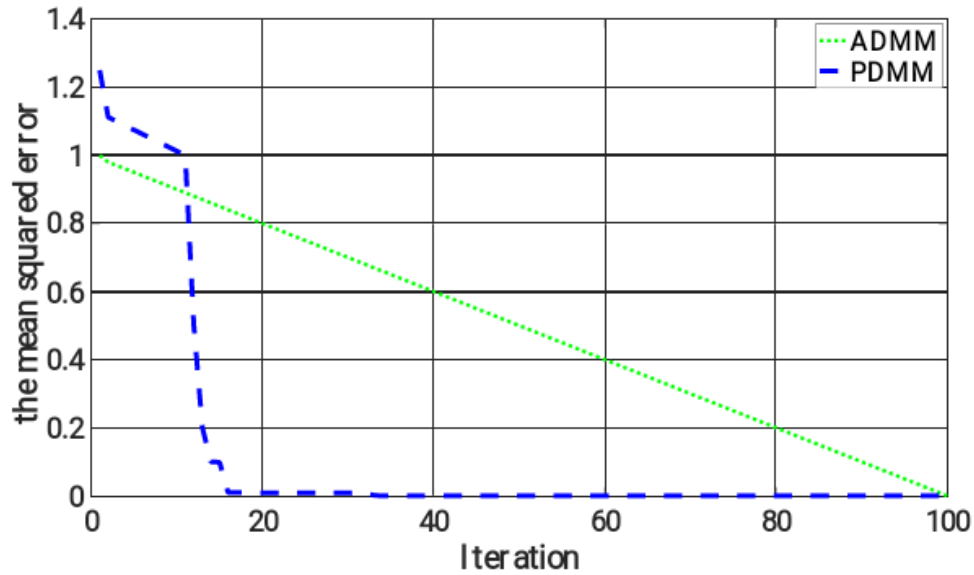


Fig. 10. Comparison between the mean squared error of PDMM and ADMM methods

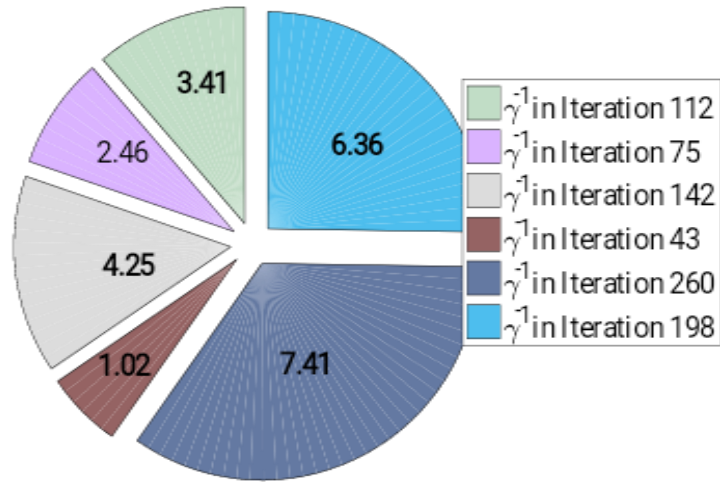


Fig. 11. Convergence speed based on values of γ_{ij}^{-1} and γ_{ij} in various iterations

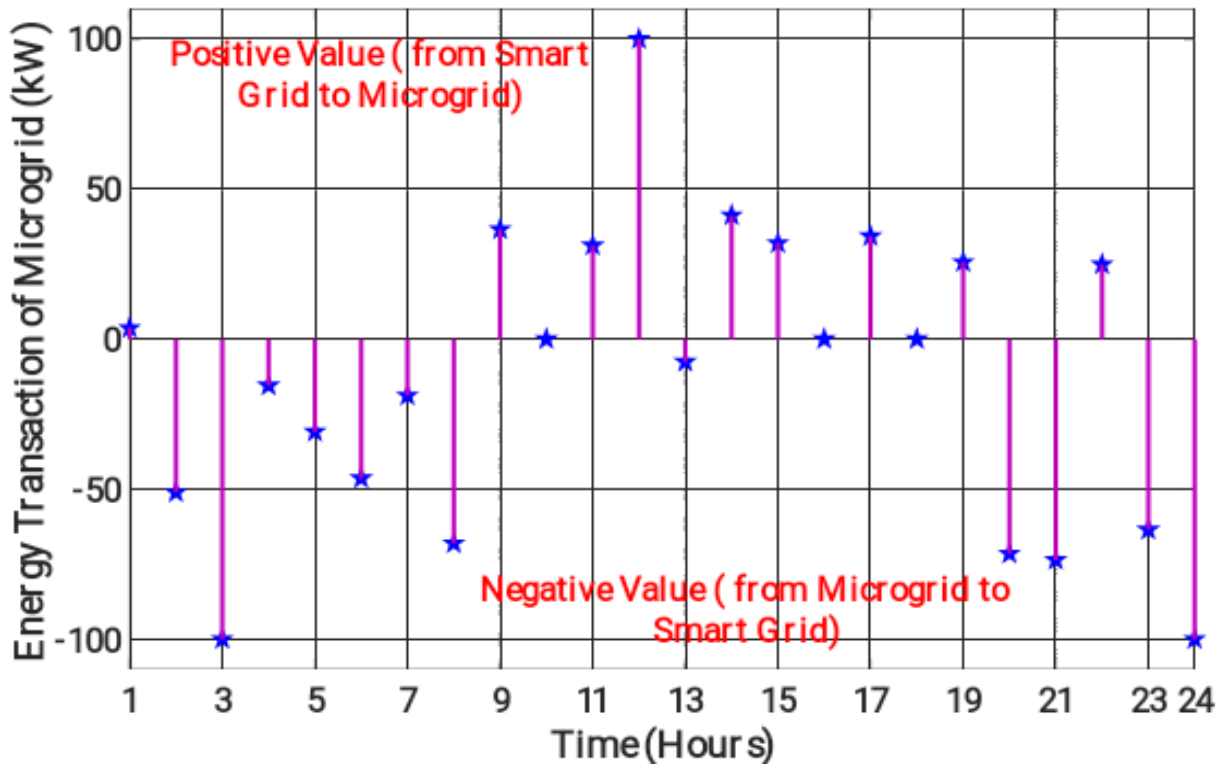


Fig. 12. Energy trading between microgrid and smart grid.

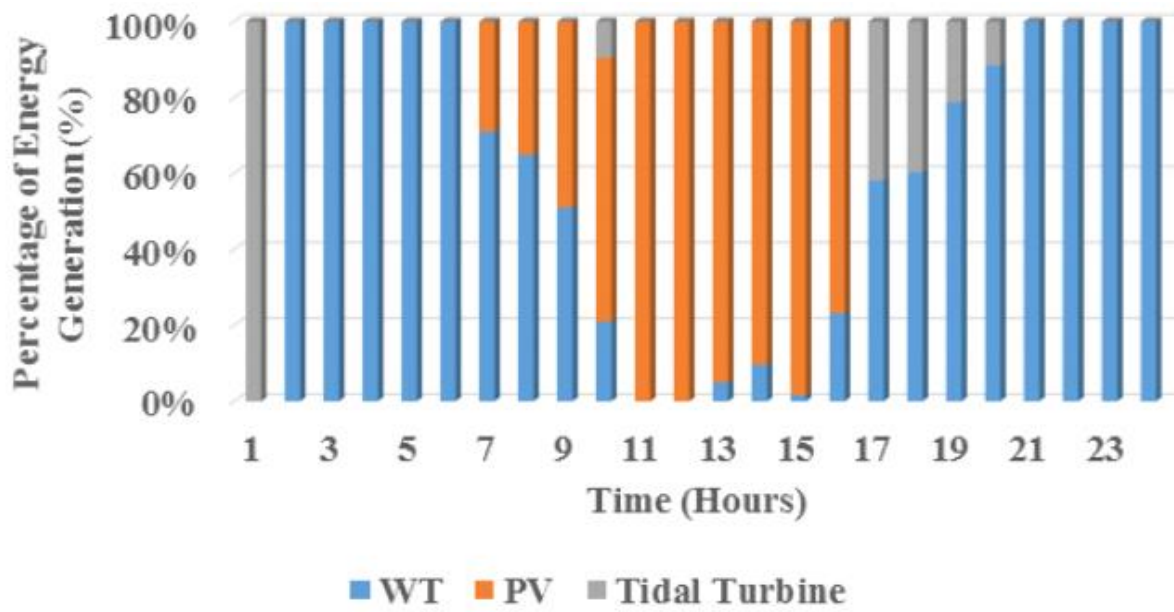


Fig. 13. Percentage of renewable power generations in the microgrid.

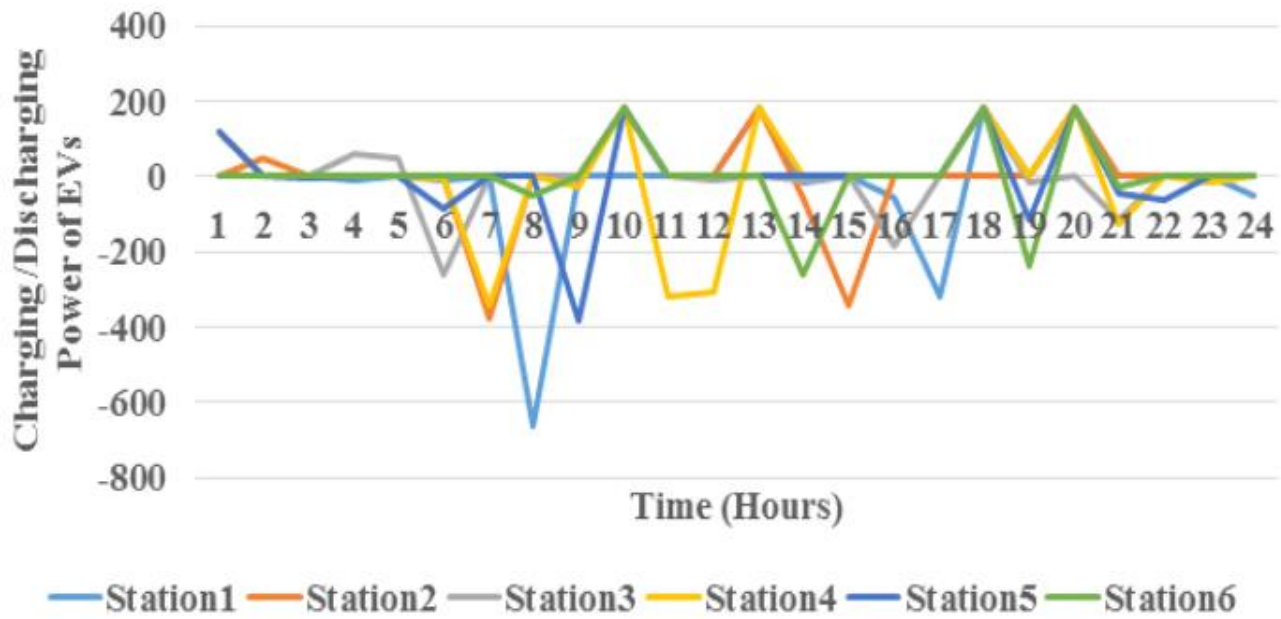


Fig. 14. Charging/ discharging power of EV parking lots in subway stations.



Fig. 15. Charging/ discharging power of EV parking lots in smart grid.

The braking energy of the subway stations is a key parameter to regulate the energy transition between the subway and the grid and EVs. To this end, Fig. 16 shows the braking energy of the six subway stations in this study. Between 2:00 to 5:00, the braking energy is zero due to the closing of the subway stations. The braking energy in the early hours of a day is higher than in other hours (at the beginning of the metro working hours).

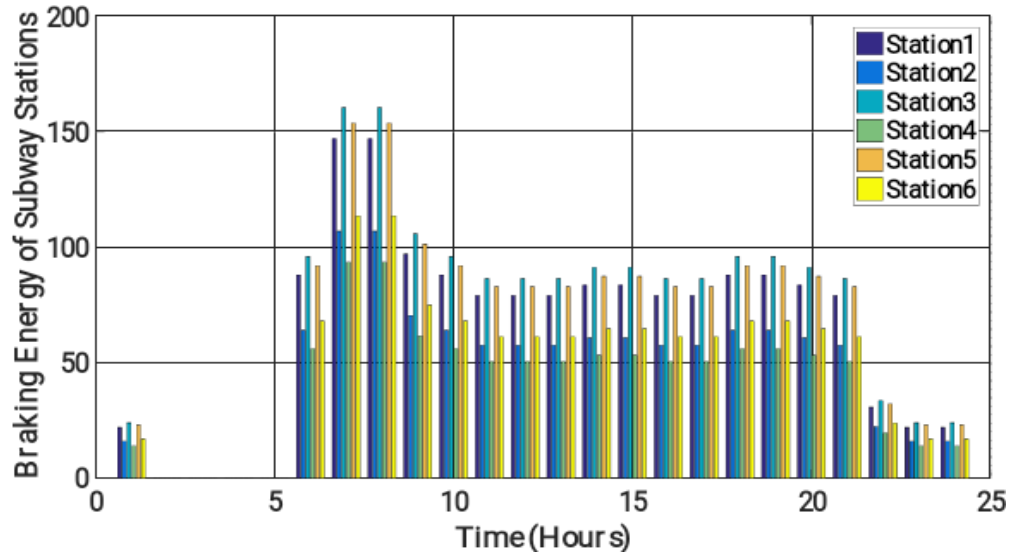


Fig. 16. Braking energy of subway stations.

B. Comparison between the Proposed Distributed Energy Transition and a Centralized Energy Transition

To demonstrate the performance of the proposed energy distribution level, this section compares the results of the proposed energy transformation strategy (step 1) with the energy transition (strategy 2). The benefits achieved by distributed and clustered algorithms are shown in Figure 17. It is clear that the benefits obtained according to the proposed distributed algorithm are much higher than the middle distance, both in terms of transportation and microbes. This is mainly because each part of the smart city tries to maximize its benefits. Costs and benefits are also compared in Table IV. As you can see, the total cost achieved by the PDMM-based algorithm is close to the total cost achieved by the algorithm. To present a reasonable method, Table III shows the computation time and number of classifications for both distributed methods. According to the results, the total time of the distributed method is 33% less than the others. All in all, this paper proposes the PDMM-based distributed energy management framework for using the various energy resources in the smart city with the aim of optimally satisfying the load. This method was able to dispatch energy among the agents with the slightest error compared to the central method, as comparative results are indicated in Table IV. Results show that the proposed method could decrease the error of solving computation to 3% in comparison with the central method. Also, the value of the mean square error related

to the proposed method was analyzed in comparison with other distributed methods, and the relative analysis is plotted in figures (10) – (11). Results show that the proposed method can improve the mean square error rather than the ADMM method for the energy management of smart cities.

TABLE III
COMPUTATION TIME FOR CENTRALIZED ANALYSIS AND DISTRIBUTED ANALYSIS

	Computation Time(sec)	Number of Iteration
centralized analysis	1983	-
Proposed distributed analysis	1321	400

C. Data Transition Evaluation

In the proposed blockchain-based data transition, three different types of blockchain have been considered, namely:

- i) private blockchain (transportation system blockchain, microgrid blockchain, and SDN blockchain), ii) general blockchain, and iii) transaction blockchain.

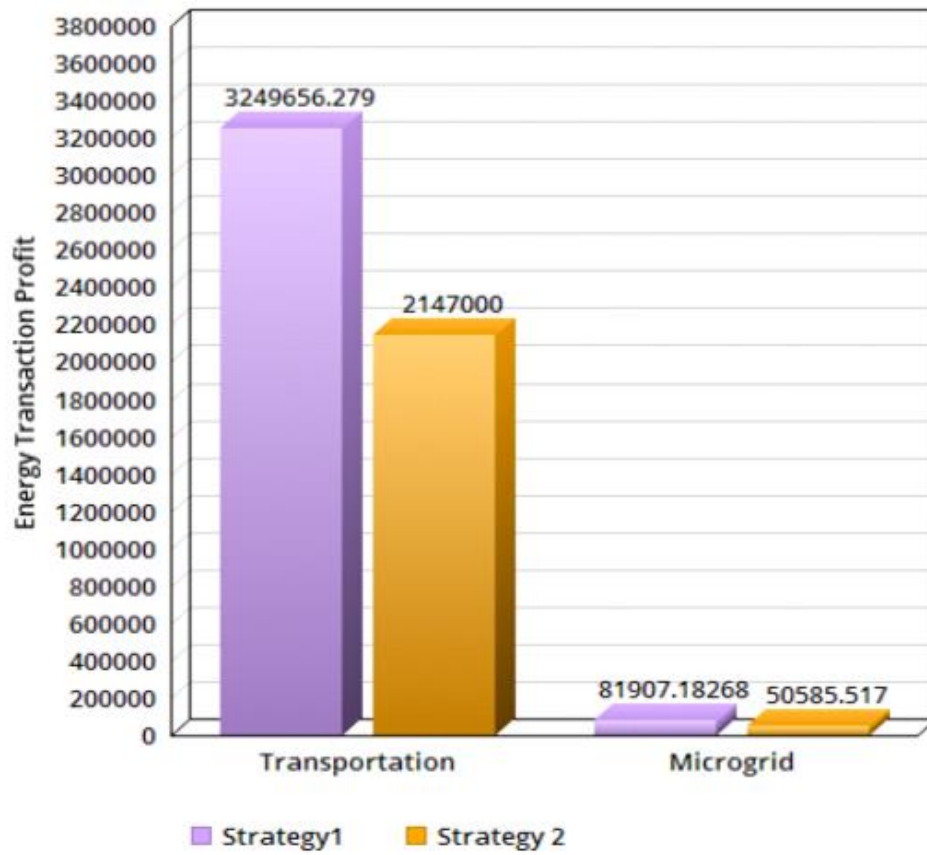


Fig. 17. Comparison between profits obtained by the proposed distributed framework (strategy 1) and the centralized framework (strategy 2).

TABLE IV
COMPARISON BETWEEN THE DISTRIBUTED AND CENTRALIZED

Parameter	Strategies	
	Proposed Form	Centralized Form
Smart Grid Cost (¢)	1668752276	-
Profit of Microgrid (¢)	2470.97054	-
Profit of Transportation (¢)	3249656.279	-
Total Cost(¢)	4424361532	4408265962

The proposed data transition mechanism is first evaluated under attack conditions. The success probability of the attack based on the percentage of iteration numbers is illustrated in Fig. 18. As can be seen, the successful probability of the attack has been significantly reduced by increasing the percentage of iteration

numbers. By increasing the iteration number in the PDMM, the hashing rate is also increased and the security of the system against the attack is also enhanced.

Tables V and VI provide information of the data block in the microgrid and transportation system, respectively. These Tables give the previous and generated hashing address in the private (microgrid blockchain), general, and transaction blockchains.

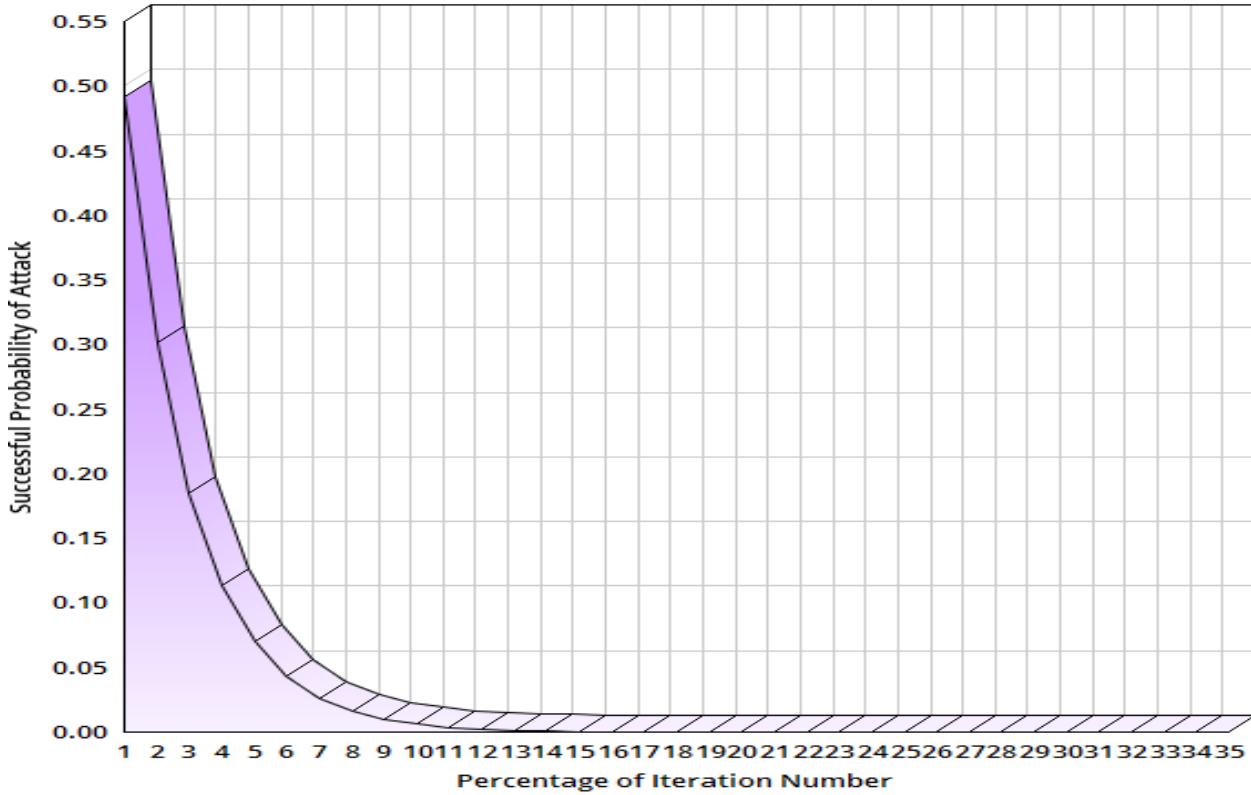


Fig. 18. Successful possibility of attack.

TABLE V
DATA BLOCK OF MICROGRID $t = 9$

Block1				
Private			General	Transaction
Previous HA			Previous HA	Previous HA
A21de8bb112351bccd63ee913256371			A2da1ee214217bba32dee1	3e6a81bb235abebacf55aa8621
a			25292664b1	14232b1
Current HA			Current HA	Current HA
3a4dd1bc461164bfda3eeb152546163b			Ea23a5aa4223aabbfe5abb5	Fea1c3aa217667afda6daa2641
			42369962b2	12531f2
PV (kW)	WPG (kW)	Tidal (kW)	Bid of Energy Transaction (ct€/kWh)	Converter

184	192	0	2.584	45
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TABLE VI
DATA BLOCK OF TRANSPORTATION $t = 22$

Block1			
Private		General	Transaction
Previous HA		Previous HA	Previous HA
3ead12bc874963bfda0aac14785616a5		Fas4785fc1582aacffec5ba df369fcfbf	Acf1c3fc236c12afda6daadef118 961aa
Current HA		Current HA	Current HA
Ab53b6ee392312bbce677a562345921 a		Deeea5aa231159bffa6dea 462132172b2	Ae4bb11abb1463bdda6deb963 245461a
Braking Energy of all Stations (kW)	Ch/Dis Power of EVs (kW)	Energy Price (ct€/kWh)	Converter
406	-62.4	15	61.1

On the one hand, in Table V, the information of microgrid data block at $t = 9$ is shown and also the generated power by wind power generation and PV systems, while the proposed bid of energy transition is also illustrated. On the other hand, Table VI provides the information obtained by the proposed data transition mechanism in the transportation system. Furthermore, Table VI shows the generated hashing address by the proposed data transition mechanism at $t = 22$ and the previous hashing address.

VI. DISCUSSION

The two primary goals of this work are to I) provide a distributed synergy mechanism in smart cities based on PDMMs, and II) improve data and energy transaction security in such an environment with a large number of data communication links. The suggested method was applied in this study to a real-world scenario taken from [12]. The simulation results demonstrate several implications, such as: 1) The suggested strategy could effectively reduce the mean square error associated with distributed computations in comparison to alternative approaches; for example, the trend of the PDMM method has converged to zero error in 20 iterations, whereas the ADMM method one required 100 iterations to achieve zero mean squared error. Also, results show that the proposed method could decrease the error of solving computation to 3% in comparison with the central method. 2) Furthermore, the security mechanism that has been proposed may lessen the

likelihood of data attacks in the smart city. As for future work, the framework that has been proposed is efficient and capable of preventing cyberattacks from frustrating the monitoring system, specifically in Peer-to-peer structure-based energy markets, where different generation units may be present and intercommoned with each other in order to trade energy. Furthermore, these energy management mechanisms can be employed to enhance the resilience of the smart city.

VII. CONCLUSION

This study proposed an innovative energy transition framework with an emphasis on the importance of security and information privacy. Thus, a comprehensive and distributed framework was developed for the energy transition between a smart grid, a microgrid, and the transportation system based on the primal-dual method of multipliers (PDMM). The attained results prove that the proposed algorithm was able to get to an optimal and true consensus among agents with an error of less than 5%. On top of that, this paper indicated that each energy segment within the smart city could be more profitable and flexible in energy management by means of participating in the proposed energy trading mechanism. In addition, having a slight deviation 1% in the total cost of a smart city proves the truthfulness of the proposed distributed method compared with the centralized one within a smart city. Finality, the proposed random hashing process-based security platform significantly reduced the success possibility of cyber-attacks on the designed energy transition framework. The numerical results validate the effectiveness of the proposed methodology by reducing the success probability of failure under 0.05. Therefore, employing all independent energy resources of a smart city in a coordination framework is one significant advance of distributed energy management proposed in this paper. However, such an energy management framework suffers the challenges at risk of changes in data from cyberattacks. This issue may be addressed through blockchain technology, but it is limited due to high energy consumption. Hence, as a future work, Due to the presence of various generation units in the future energy markets that can be intercommoned with each other with the aim of trading energy, this proposed framework is effective and is able to stop cyber-attacks from frustrating the monitoring system, specificity

in Peer-to-peer structure-based energy markets. In addition, such energy management mechanisms can be utilized to improve the resiliency of the smart city. As provided in the literature, the ADMM algorithm gained popularity recently due to its decentralization ability. Distributed processing, which is still in the early stages of development, was made possible by another recent technique called PDMM. While the PDMM algorithm is able to perform admirably when handling medium-sized problems, handling medium-scale problems remains a difficult task for the ADMM algorithm. Therefore, we considered the PDMM algorithm as a study case of a smart city with medium scale energy segments, while it may not be achievable with the ADMM algorithm. It is worth saying that improvement of the PDMM algorithm in large-scale optimization problems needs more investigation. Meanwhile, this issue can be considered a future work for researchers.

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