An Integrated and Optimal Joint Scheduling of Energy Resources to Feed Electrical, Thermal and Potable Water Demands in Remote Area

R. Ghaffarpour*, B. Mozafari* and A. M. Ranjbar** (C.A.)

Abstract: The continuous spread of distributed energy resources (DERs) such as combined heating and power (CHP), diesel generators, boilers and renewable energy sources provide an effective solution to energy related problems to serve the power and heat demands with minimum cost. Moreover, the DERs may play a significant role for supplying power and heat in rural areas, where grid electricity is not available. Also, some dry areas may face water scarcity and salinity problems. So, one important solution is the use of DERs to drive desalination units in order to solve water scarcity and salinity problems. In this study, the optimal scheduling of DERs and reverse osmosis (RO) desalination unit that feed the required electric, thermal and potable water demands are determined. The present paper describes the operation constraints and cost function of components of the system in detail. Operation constraints of generation units as well as feasible region of operation CHP in dual dependency characteristic are taken into account. To confirm the performance of the proposed model the approach is tested on a realistic remote area over a 24-h period. The results show that the economical scheduling of DERs and desalination units can be obtained using proposed methodology by implementing the proposed formulation.

Keywords: Combined Heat and Power, Desalination, Distributed Energy Resources, Optimal Joint Scheduling

1. Nomenclature

Set

t	Time index (h)

Variables

P_t^{WT}	Produced power from wind turbine (KW)
P_t^{PV}	Produced power from wind turbine (KW)
P_t^{Des}	Consumed power of RO unit (KW)
P_t^{CH}	Charged power in the storage unit at time t (KW)
P_t^{Disch}	Discharged power of storage unit at time t (KW)
P_t^{CHP}	Produced power from CHP unit at time t (KW)
P_t^{P}	Produced power from diesel generator (KW)
H_t^{CHP}	Produced heat from CHP unit at time t (KW)
H_t^{H}	Produced heat from heater at time t (KW)
E_t^{S}	Storage capacity of battery at time t (KW)
F_t	Consumed fuel at time t (m^3)
Fuel	Total consumption of fuel (m^3).
W_t^{Des}	Produced water from desalination process (m^3)
W_t^{Tank}	Provided drinking water from transferring (m^3).
NF	Number of transferred fuel.
NW	Number of transferred water.
C_t^{CHP}	Operation cost of CHP unit at time t.
C_t^{P}	Operation cost of diesel generator at time t.
C_t^{H}	Operation cost function of boiler at time t.
Of	Total operation and transferring cost.

Binary variables, $\in\{0,1\}$

δ_t^{Ch}	Binary variable to charging status of battery.
δ_t^{Disch}	Binary variable to discharging status of battery.

Parameters

P_t^{Dem}	The electric power demand at time t (KW)
H_t^{Dem}	The heat demand at time t (KWth)
W_t^{Dem}	The drinking water demand at time t (m^3)
C^{Tran}	Transferring price of fuel and water ($/Tanker)
Cap^{Tan}	Capacity of transfer fuel and water tank. (m^3)
P_{Max}^{WT}	Maximum generation of wind turbine (KW)
V_t^{Ch}	Wind speed at time t (m/s)
y_t	Solar radiation at time t (kW/m^2)
W_0^{Des}	Rated water capacity of RO (m^3)
P_0^{Des}	Electrical consumption of desalination unit (kW).
η_{Ch}	Charging efficiency of storage unit (%).
η_{Disch}	Discharging efficiency of storage unit (%).

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*The Authors are with the Department of electrical engineering, Islamic azad University science and research branch, Tehran, Iran.
E-mail: rghaffarpour@srbiau.ac.ir, mozafari_babak@srbiau.ac.ir
** The Authors is with the Department of of electrical engineering, Sharif University of technology, Tehran, Iran.
E-mail: amranjbar@sharif.edu
Corresponding Author: A. M. Ranjbar

2. Introduction

With the rapid development of the world economy, energy demand is increasing dramatically, and the energy crisis and environmental problems are constantly emerging. Power generation by distributed generators (DGs), especially renewable energy power generation and combined heat and power (CHP) technologies due to efficiency improvement, and reduction of power loss and enhancement of service reliability in distribution systems has become the focus of energy systems studies worldwide [1- 2]. On the other hand, beside the growth of energy consumptions, potable water demands increases. The problem becomes more acute in remote areas and islands where it is difficult to obtain drinking water. In remote areas, the potable water requirements can be covered by the transportation with water carrying boats or tankers. Another alternative and supplementary non- conventional solution that has already been implemented in various cases is the construction and operation of desalination unit witch desalinates sea and brackish water. On the other hand, desalination units consume energy to produce potable water from sea or well. Meanwhile, the energy carriers must be feed required electrical, thermal demands as well required energy of desalination unit in economical way.

First of all, it is important to review most technical and economical ideas presented in the literatures that focus on operation scheduling and facilities of distributed energy resources and CHP units as well as application of desalination units.

The growing pressure, driven by environmental, economic and technical challenges for generating more electricity from distributed energy resources, especially renewable energy resources. Also, improving energy efficiency has promoted the application of DER into electricity systems [3]. The survey of DER comprise several technologies, such as diesel engines, micro turbines, fuel cells, photovoltaic, small wind turbines, etc. and the coordinated operation as well control of DER together with controllable loads and storage devices are presented in [4]. The operation and control strategies of integrated distributed energy resources will be reviewed in [5]. DERs have many advantages, but the intermittence of these resources is considered their main disadvantage, so, a large storage system must be used in order to overcome the intermittence of these resources [6].

In [7- 8], a mixed integer linear programming (MILP) model for the design of a DER system that meets the electricity and heating needs of a group of commercial and residential buildings while minimizing annual investment and operating cost is proposed. In [9], the authors reported that, low voltage AC and DC micro-grid systems with multi-converter devices can achieve high reliability, high efficiency and high quality power supply for the future energy systems. In [10- 11], a local energy management strategy has been put forward for hybrid of PV units and storage units in micro-grids.

Micro-grid is an integrated form of DERs, loads and storage units, and is installed to supply small communities like universities, hospitals, schools, commercial and residential centers and industrial projects [12- 13]. The modeling and energy management of the micro-grids including renewable energy and combined heat and power generators that can meet the heating and electricity load needs is reviewed in [14]. According to literatures, such type of problems is considered as energy-related problems or energy hub concept, too. A combined heat and power (CHP) technologies with distributed generation units and renewable energy sources provides an effective solution to energy-related problems, including increasing energy demand, higher energy costs, energy supply security, and environmental concerns. Moreover, first of all, it is important to remember that in the recent years, many projects and national regulations around the world have been developed to enhance the spread of distributed generation technologies and the development of smart grid pilot facilities. One of the most significant challenges of energy distribution network companies is producing electricity, heat and cooling demands. One specific solution to overcome the problem is operating different energy networks such as gas and electricity simultaneously. A vague approach to utilization of the networks is “Energy Hubs”. Energy hub entails electricity, gas, heat, and sometimes cooling networks. Energy hub enters gas and electricity as its inputs. Renewable energy resources also can connect to the network. Energy hub function is supplying electricity and heat demands in order that operation costs minimize. CHP is employed as heart of energy hub in which simplifies integration of different energy networks [15].

In [16] an innovative method for modeling energy hubs based on energy flow between its constituent elements. Using this method, modeling of energy hubs with different elements and connections is facilitated. Also, an appropriate mixed integer nonlinear programming model is presented for short term 24-hour scheduling an energy hub, in which, the objective is to fulfill daily cooling, heating and electric demands of a hypothetical building with the maximum profit. In [17] a new formulation of hub energy systems considering certain operation constraints is presented means of limiting the number of state changes (startups or shutdowns). This is achieved by specifying a minimum time for which the plant must operate once it is running. The second innovation is the use of stepwise approximations of efficiency curves, thus allowing part-load behavior to be accurately simulated using a linear model. The third innovation adds a storage loss term that is a percentage of the current amount stored, rather than a fixed value.

Conspicuous matter in literatures related to the operation of the micro-grid and energy hub systems is ignoring water desalination units along energy systems. While, Desalination plants can provide drinking water in areas where no natural supply of potable water exists. Some islands get almost all of their drinking water through desalination plants. In other hand, in some areas drinking water can be provided through transportation fresh water by water boats in islands or tankers in another remote region.

In the last decade, desalination, especially by reverse osmosis (RO), has become one of the principal safe sources of supply of potable water, and even water for agricultural use, it is in the Mediterranean, Africa, the Middle East, and so on, where the potable water supply is a high priority problem. All this leads to the need to identify new sources of supply such as the desalination of brackish or sea water.

Coupling of power, heat energy and desalination systems holds great promise for increasing water supplies in water scarce regions. An effective integration of power technologies will allow supplier to address water shortage problems with a domestic energy source that does not produce air pollution or contribute to the global problem of climate change. In [18], the term “poly generation” is introduced to as “an energy supply system, which delivers more than one form of energy to the final user”, for example: electricity, heating/ cooling, desalination can be delivered from poly-generation process. The poly-generation demonstrates unique integration of energy efficiency and renewable energy. It is the next generation energy production technique with a potential to overcome intermittence of renewable energy, reduce cost of power generation and greenhouse gas emissions.

Meanwhile the costs of desalination and renewable energy systems are steadily decreasing [19], while fuel prices are rising and fuel supplies are decreasing. In addition, the desalination units powered by renewable energy systems are uniquely suited to provide water and electricity in remote areas where water and electricity infrastructure is currently lacking [20]. As the energy cost is one of the most important elements in determining water costs where the water is produced from desalination plants. A novel combined thermoelectric power generation and water desalination system is described with a system schematic.

The main contributions of this paper are:

The operation problem of poly-generation systems includes water and electrical as well heating is modeled. Due to achieve comprehensive scheduling model, the storage device, RESs and CHP and DERs are considered.

Time dependent parameters such as WT and PV output powers during the planning period are intended utilizing load duration curves. Model of hybrid water and energy system is accomplished using specific heat capacity of used fuels and water.

The main goal of the water-energy management system in this paper is to minimize energy and water cost under the integrated scheme by scheduling the DERs and desalination unit considering the operation cost of components and transportation cost of drinking water and fuel to remote considered area. Therefore, optimal scheduling of all energy resources and desalination unit is the most important step in achieving economic operation scheme. So, the accurate model of operation cost, technical constraint of components is including diesel generator (power only unit), boiler or heater (heat only unit), renewable energy resources such as wind turbines and photovoltaic panels as well as CHP unit presented.

The rest of the paper is organized as follows: The proposed hybrid water- energy system architecture and components are described in Section 3. Section 4 presents the mathematical models of scheduling problem developed which is a mixed integer non-linear program. Extensive realistic study is discussed in Section 5 and concluding remarks are drawn in Section 5.

3. Problem Mathematical Model

The main goal of the energy and water management system in this paper is to obtain optimal scheduling of DERs and RO desalination unit through minimizing operation and transportation cost of components and carriers, respectively. The overall architecture of the proposed system is demonstrated in Fig. 1.

In this paper, the energy management problem in a remote area is modeled as a MILNP over a specific prediction horizon of period (T) along with discrete time steps ($t \in T$). In this study, the time resolution is considered 1-hour, therefore one day has 24 slots.

3. 1. Distributed energy resources

The main energy resources are heater or boiler (heat only unit) and diesel generator (power only unit) that are described in this section.

A diesel generator is the combination of a diesel engine with an electric generator to generate electrical energy. Diesel generating sets are used in places without connection to a power grid, or as emergency power supply if the grid fails, as well as for more complex applications such as peak-lopping, grid support and export to the power grid [21]. Also, the boiler is considered in this paper which can be produce heat. The operation cost of power and heat units can be written as follows [22]:

$$C_t^P = \psi^P \times P_t^P \tag{1}$$

$$C_t^H = \psi^H \times H_t^H \tag{2}$$

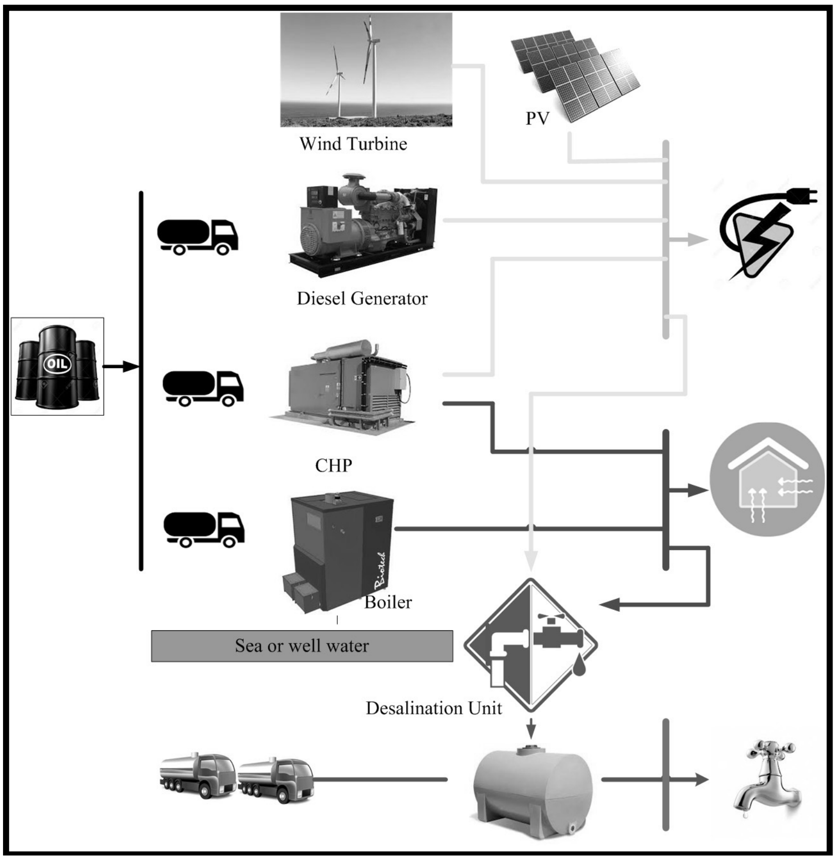

Fig. 1. The architecture of management of multi- generation system

As depicted in Equations. (1)- (2). The operation cost of a conventional only power and only heat (boiler) units are supposed to be linear and.

3. 2. Combined heat and power unit

The primary motivation for incorporating CHP units is providing electrical and thermal energy, simultaneously. During electricity generation process of CHP systems, waste heat is employed to provide thermal energy. This process will result in the improvement of energy systems efficiency as well as a significant reduction in the cost of thermal energy generation. It should be mentioned that, in a CHP unit, the power generation boundaries depend upon the heat generation of unit and the heat generation boundaries depend on the power generation of the unit. The feasible operation region of CHP is illustrated as Fig. 2. As shown in Fig. 2, boundaries of FOR is limited by minimum and maximum fuel consumption as well maximum heat extraction of CHP units which can be formulated as Equations. (3)- (7).

The CHP operation cost modeled as [23]:

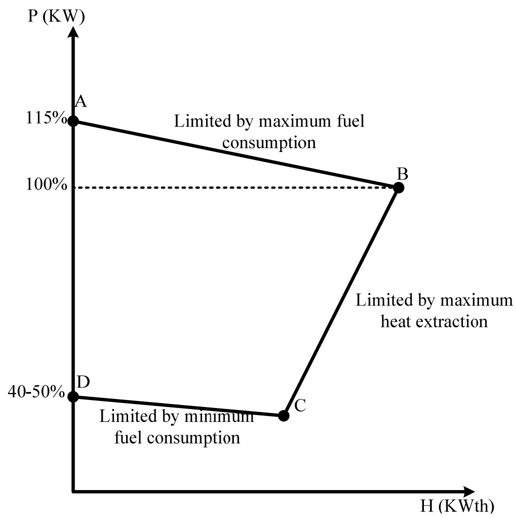

Fig. 2. Power-heat feasible region for a CHP unit

$$P_t^{CHP} - P_A^{CHP} - \frac{P_A^{CHP} - P_B^{CHP}}{H_A^{CHP} - H_B^{CHP}}(H_t^{CHP} - H_A^{CHP}) \le 0 \tag{3}$$

$$P_t^{CHP} - P_B^{CHP} - \frac{P_B^{CHP} - P_C^{CHP}}{H_B^{CHP} - H_C^{CHP}}(H_t^{CHP} - H_B^{CHP}) \ge 0 \tag{4}$$

$$P_t^{CHP} - P_C^{CHP} - \frac{P_C^{CHP} - P_D^{CHP}}{H_C^{CHP} - H_D^{CHP}}(H_t^{CHP} - H_C^{CHP}) \ge 0 \tag{5}$$

$$H_t^{CHP} \le H_A^{CHP} \tag{6}$$

$$P_t^{CHP} \le P_A^{CHP} \tag{7}$$

The operation cost of CHP is defined as [23]:

$$C_t^{CHP} = a \times \left(P_t^{CHP}\right)^2 + b \times P_t^{CHP} + c + d \times \left(H_t^{CHP}\right)^2 + e \times H_t^{CHP} + f \times H_t^{CHP} \times P_t^{CHP} \tag{8}$$

where a, b, c, d, e and f indicate the cost function coefficients of CHP unit. Also, and state the produced power and heat from CHP units at time interval t, respectively.

3. 3. Wind turbine

Nowadays, the use of wind energy for power generation is continually increasing. The wind turbine is one of the commonly used renewable energy sources for the micro-grid systems. It converts the wind energy coming from air current flowing across the earth's surface into electrical energy. Depending on controllability, the operating systems of the wind turbine are classified into either variable speed wind turbines or constant speed wind turbines [24]. The total available wind power of a WT is a function of the wind speed and turbine characteristics and can be modeled by Eq. (37) as follows [25]:

$$P_t^{WT} = \begin{cases} 0 & V < V^{CI},\ V > V^{CI} \\ P_{max}^{WT} \times \dfrac{V_t - V^{CI}}{V^R - V^{CI}} & V^{CI} \le V_t \le V^R \\ P_{max}^{WT} & V^R \le V_t \le V^{CO} \end{cases} \tag{9}$$

3. 4. PV arrays

PV is a prominent renewable energy resource. It is the second most expanded power supply in which, the global operational installed capacity reached to 100 GW, in 2012 [26]. It is considered as one of the commonly used renewable energy sources for the micro-grid systems [27]. The power generated by a PV system, is a function of the solar radiation and is expressed as follow [28].

$$P_t^{PV} = A^{PV} y_t^2 + B^{PV} y_t + C^{PV} \tag{10}$$

in which and are generation power function coefficients of PV, and is forecasted solar radiation at time t.

3. 5. Storage devices

The energy storage devices such as batteries, flywheels, and ultra-capacitors must be included in micro-grid operation, especially in islanded mode to ensure uninterrupted power supply during disturbances and/or drastic load changes [29]. These devices have a limited energy storage capacity due to their physical limitations. Rechargeable battery is commonly used in micro-grid operation [30]. The operation characteristic of storage units can be defined in the operation problem as follows [31]:

Energy balance constraint of the storage can be explained as:

$$E_t^s = E_{t-1}^s + \Delta t \times \left[\eta_{ch} P_t^{Ch} - \frac{1}{\eta_{Disch}} P_t^{Disch} \right] \tag{11}$$

$$\underline{E} \le E_t^s \le \overline{E} \tag{12}$$

$$\underline{P}^{ch} \times \delta_t^{ch} \le P_t^{ch} \le \overline{P}^{ch} \times \delta_t^{ch} \tag{13}$$

$$\underline{P}^{Disch} \times \delta_t^{Disch} \le P_t^{Disch} \le \overline{P}^{Disch} \times \delta_t^{Disch} \tag{14}$$

$$\delta_t^{ch} + \delta_t^{Disch} = 1 \tag{15}$$

It should be noted that the battery does not charge and discharge simultaneously. Therefore, binary variables and are implemented to model the status of energy storage. In the Equations. (13)- (15), ( ) means that the energy storage is charging (discharging) at time interval t related to the scenario. These limitations will force the storage device to buy and charge energy at low market price hours and sell it at high market price hours.

3. 6. Desalination unit

Desalination is one of the most important processes to provide water to population in water scarcity areas. But desalination processes consume a lot of energy; unfortunately, the majority of the energy currently used for desalination is obtained from oil or natural gas. Co-generation plants providing freshwater but also electricity are installed in the arid areas; the combination of steam turbine plants and multi-stage flash (MSF) units is one of the most common schemes for the water and energy requirements [32]. If desalination is powered almost entirely by the combustion of fossil fuels, these fuels are rapidly being depleted because of their finite supply, but also they pollute the air and contribute to global climate change [33]. Development of renewable-driven desalination is still severely impeded, if not buried, by the pressure of contemporary economic factors and political inertia.

Reverse Osmosis process is used chiefly for separating the solvent (water) from aqueous salt solutions. The brackish water, pumped from a well to a storage tank, passes through the desalination unit and exits in two branches, one as potable water that is stored in special tank and another as brine water. The feed water enters the unit at a salinity value of around 3400 ppm and exits as fresh water permeate at a salinity of around 30 ppm. An external mixing process is arranged at the exit to produce water for consumption at a salinity level of around 300 ppm.

The electric power consumption of desalination unit is considered as:

$$P_t^{Des} = W_t^{Des} \times \frac{P_0^{Des}}{W_0^{Des}} \tag{16}$$

4. Solution procedure

In other hand, some other constraint and parameter must be considered in the optimization problem such as power, heating and water balances as follows:

Water balance

$$W_t^{Des} + W_t^{Tank} = W_t^{Dem} \tag{17}$$

Heat balance

The balance of thermal energy resources must satisfy heat demands over operation periods which can be explained as:

$$H_t^{H} + H_t^{CHP} = H_t^{Dem} \tag{18}$$

The cost of transferring required fuel and drinking water is considered in the objective function. The cost of transferring fuel and water are fit with number of fuel and water tanks. So, the amount of fuel and water tanks which is transferred by boats or tanker is determined as follows:

The fuel consumption can be calculated using thermal value of energy carrier and produced power of energy resources as the following equations.

$$F_t = \frac{\left[P_t^{P} \times 855 + P_t^{CHP} \times 855 + H_t^{H} \times 344\right]}{9220} \tag{19}$$

$$\text{Fuel} = \sum_{t=1:T} F_t \tag{20}$$

$$NF = \text{Fuel} / \text{Cap}^{Tank} \tag{21}$$

$$NW = \sum_{t=1:T} W_t^{tank} / \text{Cap}^{Tank} \tag{22}$$

It is must be noted that the conversion of energy from watt to Cal is implemented in the above equations. As we know 1 Kw is equal to 9920 Cal.

The amount of consumption fuel in the energy resources can be determine using thermal value of energy carrier and such as gasoil or other fossil carriers.

In the proposed paper, the operation costs of energy recourses and transferring costs of fresh water and fuel by boats or tankers are considered as objective function over scheduling period. The mathematical form of objective function and constraints are written in the next sections.

$$of = \sum_{t=1:T} \left[C_t^{P} + C_t^{CHP} + C_t^{H}\right] + C^{Transferrig} \times \left(NF + NW\right) \tag{23}$$

The objective of the proposed method is minimizing (23) subjected to the constraints and Equations (1)- (22). The employed optimization method in this research is based on mixed integer programming (MILP). The GAMS software package is used for simulating the proposed method.

5. System study

In this section, the proposed method is implemented in optimal operational scheduling problem of multi carrier systems over a 24-hour time interval. The consumer considered in case studies comprises desalination unit, transferring fresh water to supply drinking water requirements. Also, renewable energy resources, CHP, boiler as well as diesel generator are energy sources to meet power and heating demands. Desalination process is considered based on reverse osmosis technology, which consumes electricity. The heating and electricity end-uses during typical July in week day are presented in Table 1. Also, the need of drinking water is assumed to be 3.5 m3 in all hours.

The feasible operation region of CHP and parameters of boiler and diesel generator is scaled and adopted form of a simple test case proposed by Ref. [24]. Parameter of wind turbine and photovoltaic arrays, desalination units and cost coefficients of problem are listed in Table 2. Table 3 summarizes the simulation results of study with-

Table 1. Electric and heat demands and speed of wind as well radiation of solar

Time	$P_t^{Dem}(kW)$	$H_t^{Dem}(kWth)$	$v_t(m/s)$	$y_t(kW/m^2)$	Time	$P_t^{Dem}(kW)$	$H_t^{Dem}(kWth)$	$v_t(m/s)$	$y_t(kW/m^2)$
1	15.78	11.59	1.2	0	13	17.27	10.51	2.142	4.68
2	14.01	8.52	0.828	0	14	17.71	14.48	2.171	4.58
3	13.85	8.97	0.285	0	15	17.75	15.43	2.028	4.68
4	13.25	6.93	0.371	0	16	17.96	11.12	2.4	3.67
5	12.87	3.61	0.885	0	17	18.23	15.43	2.4	3.16
6	12.68	5.14	0.685	0.06	18	18.20	14.38	2.4	0.63
7	12.89	10.62	0.171	0.43	19	17.77	12.75	2.4	0.43
8	13.06	11.35	0	0.63	20	17.39	15.01	2.4	0
9	13.86	12.30	0	2.24	21	16.76	16.34	2.4	0
10	14.91	10.70	0	3.41	22	16.85	16.28	2.4	0
11	16.09	11.06	0	3.67	23	16.24	13.43	2.4	0
12	16.69	13.70	2.142	4.48	24	15.32	10.47	2.4	0

Table 2. Parameters of implemented in the scheduling problem of multi-generation system

Parameter	Amount	Parameter	Amount
Cap^{Tan}	30	A	0.0000000435
C^{Tran}	10	B	0.036
η_{Ch}	0.9	C	0.0125
η_{Disch}	0.9	D	0.0006
P_0^{Des}	1.8	E	0.000027
W_0^{Des}	3	F	0.0234
ψ^P	0.0256	$A(P_A^{CHP}, H_A^{CHP})$	(1.25,0)
ψ^H	0.0234	$B(P_B^{CHP}, H_B^{CHP})$	(0, 0.46076)
P_{max}^P	2	$C(P_C^{CHP}, H_C^{CHP})$	(13.069, 8.64)
H_{max}^H	5	$D(P_D^{CHP}, H_D^{CHP})$	(0.46881, 0)

out considering desalination procedure.

According to Table 3, total power and heat generation cost concerning this case is $4.329. This cost consists of CHP and boiler. Transferring cost of fuel and water to considered remote area is equal to 40 $. The daily transferred fuel and drinking water is 3 and 1 tankers with capacity 30 m3, respectively. The daily power and heat obtained from energy recourses over operation hours are illustrated in Fig. 3- 4.

If the desalination unit as the contribution of this paper is used, the operation and transferring costs as well other economic characteristics can be modified as Table 4.

As reported in the Table 4, the operation cost of energy resources is 4.029 $ which is increased 25% respect to previous state. Also, the implementation of desalination process to provide drinking water can reduce %75 cost of transferring. In this state, number of required tankers to transfer carriers (water and fuel) is 1 and 1, respectively. Figures 5-7 depict the generated power and heat and water by generation units in the scheduling horizon, respectively. In the best of authors knowledge there is not a paper which scheduling energy resources to feed water and electricity and heat demands. To validate the proposed method, the method in [34] are implemented for the prob-

Table 3. results of multi carrier system without desalination unit

Variable	Value
NF	1
NW	3
Operation cost	4.329
Transferring cost	40
Objective function	44.329

Table 4. results of multi carrier system with desalination unit

Variable	Value
NF	1
NW	1
Operation cost	4.829
Transferring cost	10
Objective function	14.029

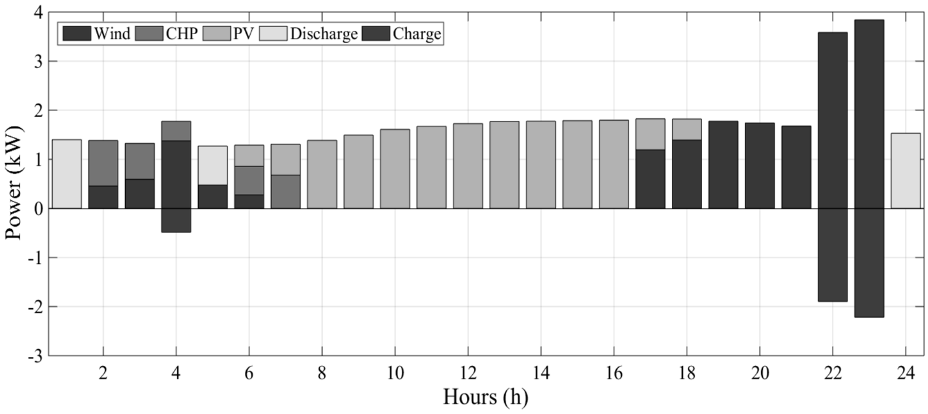

Fig. 3. Scheduling of electric power in the without desalination unit

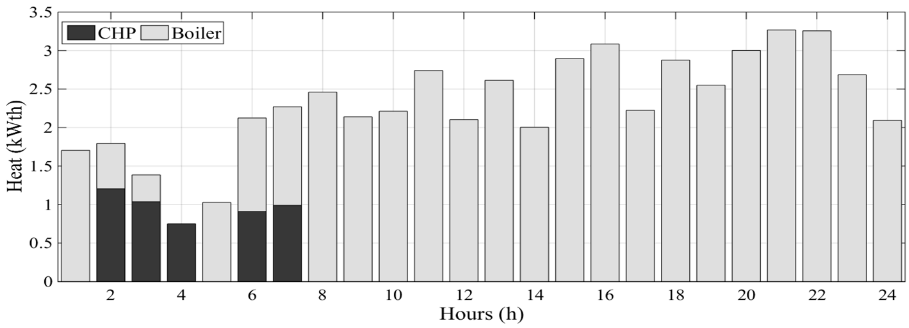

Fig. 4. Scheduling of heat in the case of without desalination procedure

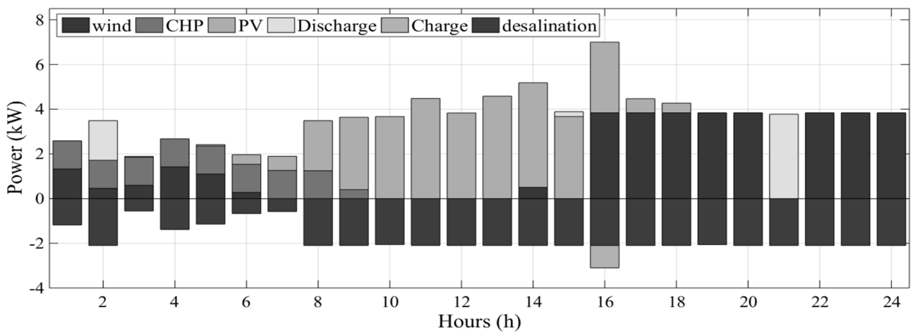

Fig. 5. Generated and consumed power of energy resources in the scheduling period

lem and it is assumed that the water is supplied with the transferred tankers from remote areas. In [34] the feasible operation region of CHP is considered simple and convex. Therefore, the real characteristic for CHP is not presented in [34]. Regard this that in the presented paper, the characteristic of CHP is more exact, the result shows the effectiveness and validity of proposed method. Considering the above comparison shows the exact results can be achieved by real and exact models. The results of this case are denoted in the Table 5. As shown in Table 5, the use for fuel regarding sample and inexact model of CHP is increased. This is due to the inefficiency of CHP consider-

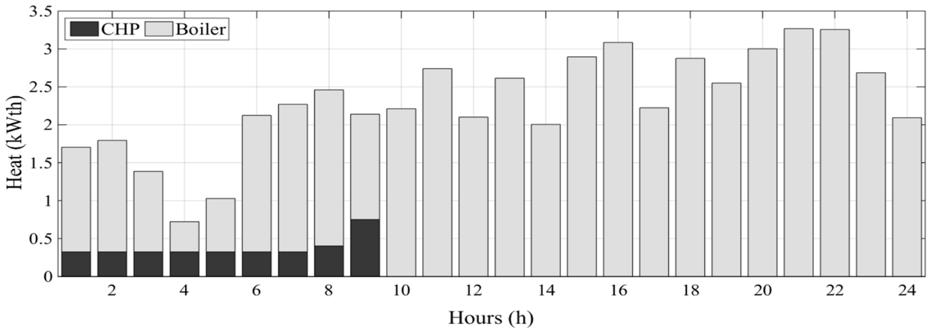

Fig. 6. Generated and heat of energy resources in the scheduling period

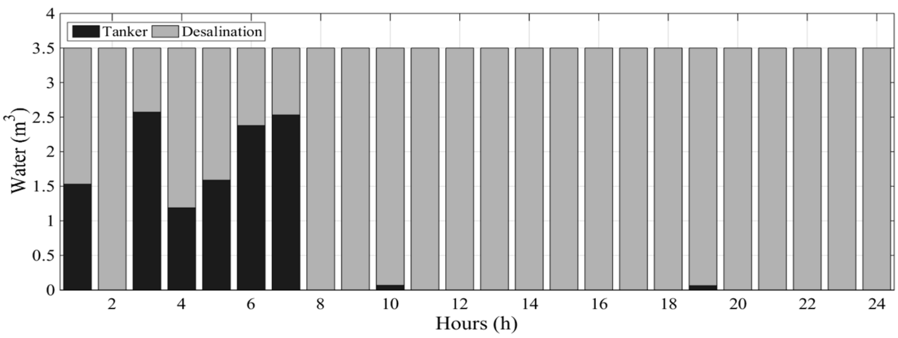

Fig. 7. Provided water of system in the scheduling period

ing sample model.

These figures illustrate the thorough participation of generation units as PV, WT, storage and CHP units. As shown the conventional generation such as diesel generator and non-participation of the conventional generation units. This fact is due to less operation cost of cogeneration units as well as their high efficiency. The priority in the scheduling problem is to satisfy the consumer's demand with minimum cost. Therefore, CHP unit produces heat more than heater unit in order to supply the heat demand with less cost. In addition, as it can be inferred and was expected, renewable energy resources participate in supply electrical demand of customer and desalination units due to their less or zero operation cost.

Table 5. results of multi carrier system using simple characteristic of CHP and without desalination unit

Variable	Value
NF	2
NW	3
Operation cost	4.637
Transferring cost	50
Objective function	54.637

6. Conclusion

This paper presented the optimal operation scheduling of a remote customer with different types of energy requirements consists of electrical, thermal and drinking water which there is no access to main electrical and water distribution grid. The required demands can be supplied by renewable energy resources, CHP, boiler and diesel generator and desalination units. Besides, renewable energy resources and desalination unit transferring fuel and water are options which can be meet other energy sources and drinking water. The decision-making problem to determine optimal scheduling and scheme of resources are modeled based on MILP and implemented on GAMS optimization software package and using CPLEX solved. A new framework has been proposed to implement the hybrid water and electrical as well heating systems. In the proposed framework, all operation constraints of resources such as FOR of CHP unit in its dual P-H characteristic are considered. Also, the optimal scheme determines amount of generated power and heat of all considered energy resources, WT, PV, diesel generator and boiler as well CHP unit. The amount of transferred fuel and drinking water considering the transferring cost in objective function is determined. The performance of the proposed framework is confirmed through studying case. The results show that the total costs decrease from \$40.329 to \$14.029 by implementing RO desalination units to supply drinking water, when the capacity of desalination unit is limited.

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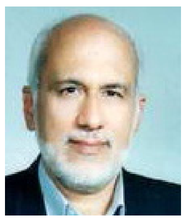
Reza Ghaffarpour Received his B.S. degree in Electrical Engineering from Shahid Bahonar University in 2008, Kerman, Iran, and M.S. degree in Electrical Engineering from Amirkabir University of technology in 2010, Tehran, Iran. He is currently a Ph.D. student in the Department of Electrical Engineering at Islamic Azad University, Science and Research Branch, Tehran, Iran. His research interests include hybrid renewable energy systems planning.

Babak Mozafari Received his B.S., M.S., and Ph.D. degrees in Electrical Engineering from Sharif University of Technology, Tehran, Iran in 1998, 2001, and 2007, respectively. He is currently faculty member of Department of Electrical Engineering of Islamic Azad University, Science and research branch as associated professor. He is the author of about 50 scientific publications on journals and international conferences. His research interests include power system operation and planning.



Ali-Mohammad Ranjbar Received his B.S., M.S., degrees in Electrical Engineering from Tehran University, Tehran, Iran in, 1963, 1967 respectively and Ph.D. degree in Electrical Engineering from Imperial College, London in 1976. He is currently faculty member of Department of Electrical Engineering of Sharif University of Technology as professor. He is the author of about 200 scientific publications on journals and international conferences. His research interests include power system protection, hybrid renewable energy system, and power system operation