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Analysis of Stand-Alone Micro-grid with Photovoltaic, Diesel Generators and SOFC

Abeer Galal and M.Said

KEYWORDS:
Microgrid, Solid Oxide Fuel Cell, Photovoltaic, Diesel generator and Ammonia

***Abstract*— Analysis of a hybrid system, comprising of photovoltaic (PV), diesel engine generators (DEGs) and solid oxide fuel cells (SOFCs) is proposed in this study for a stand-alone micro grid. This proposal system is a source for energy in a typical city in Egypt. The component specifications of the hybrid system were discussed. Ammonia (NH_3) is a hydrogen supply for the fuel cell is clarified in this work. The hydrogen generating from synthesizing ammonia from nitrogen and hydrogen separated with renewable energy is applied to generate electrical power from the SOFC. In the present paper, the operation plan of the proposed system is optimized as a non-linear system without using battery. In addition, the analysis of the overall efficiency is shown. The operational advantages of the system were clarified. Using PV power contribution reduces the fuel consumption of the system by 33% compared by the hybrid system without using renewable energy. Moreover, this paper reported that there are reductions in fuel consumption of the proposed system with using ammonia synthesizing by 25% compared with the same hybrid system without using NH3. The methods proposed in this work can be applied to develop comprehensive analyses in energy storage solutions using a hydrogen carrier in hybrid systems and micro grids. Moreover, increasing the efficiency and decreasing the operating cost are the advantages of powering a stand-alone micro-grid using this hybrid system; so this is proposed hybrid system becomes more economic than other hybrid systems.**

I. INTRODUCTION

Renewable energy resources are several such as photovoltaic, wind energy and fuel cell. These sources are used for several applications from satellite application to indoor utilization [1-4]. This paper is interested with photovoltaic and fuel cell. Ammonia is a promising hydrogen carrier because of its high hydrogen density, low production cost and ease in liquefaction and transport. The hydrogen in ammonia is 107 kg-H_2/m^3 at1.0 MPa and 25^{O}C [5]. Furthermore, fuel cells have recently been the focus of great interest as a distributed generation technology [6, 7]. A hybrid system of solid oxide fuel cell (SOFC) and polymer electrolyte fuel cell (PEM) is illustrated [8, 9]. SOFC is a high-temperature technology, thus its exhaust streams will tend to have high temperature [10]. In addition, photovoltaic power presents the most economically viable renewable solution. A fuel cell micro-grid with a small-scale was studied for a cold region [11]. Moreover, high grade exhaust heat can enable with high-efficiency by triple combined cycle combinations such as SOFC/gas turbine/steam turbine [12-14]. For example, development of the independent micro-grid by the interconnection of two or more diesel engine generators installed in buildings is expected at an early stage. Moreover, the engineering development in regard of improvement of the power-generation efficiency of an independent micro-grid by the interconnection of SOFC described in the top is expected. Studies about ammonia as a carrier for hydrogen are illustrated [15], storage and transportation are introduced [16], and kinetic enhancement of ammonia decomposition is shown [17], and the efficiency of

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production is improved [18]. In this research, the energy flow analysis with ammonia (NH_3) used as hydrogenated fuels is discussed. The transmission system fluctuations are controlled by fuel cells.

In this paper, a proposal system of a stand-alone micro-grid with the number control of diesel engine generators (DEGs), SOFCs and photovoltaic system (PV) is investigated with ammonia to a city, Egypt. The hydrogen supply using Ammonia (NH_3) energy flows is discussed in this work. This study clarifies a need with numerical analysis of the energy exchanges involved by using ammonia as hydrogen supply chain. The objective of this study is to clarify the power generation output characteristics and the operation of two methods of the proposal system. The operation conditions of an independent micro-grid with SOFCs, DEGs and PV power generation were investigated to an extensive treatment for hydrogen supply chain efficiency. Furthermore, the optimal operation of SOFCs with DEGs and PV is developed to minimize the system fuel consumption. This research study has finished up to the strategy of energy management is essential for the optimal utilization of the power-hydrogen-power systems as well as the optimization of the hybrid system. The proposed hybrid stand-alone system has several advantages such as economic development, energy security and feeding remote communities with energy of low costs that is helped in future energy sustainability and cleanness of it.

II. -LAYOUT OF THE PROPOSAL SYSTEM

This article proposes a hybrid system with using hydrogen carriers for long-term energy storage. The power to hydrogen to power system comprises three components; the electrizer, hydrogen storage and fuel cell is shown in Fig. (1). the proposed approach is applied to a case study of a hypothetical power-system of a stand-alone micro-grid. A combined system of diesel engine generators (DEGs), fuel cells (SOFCs) and large-scale PV system are used to supply energy to a demand side is shown in Fig.2. The proposed system is used to supply energy to a stand-alone micro-grid in a city, Egypt. A large-scale PV system with 18%power generation efficiency and 1000m^2 is proposed in our hybrid system. Furthermore, a block diagram of the proposed system with hydrogen and dehydrogenated process is shown in Fig. (2). The power balance equation in sampling time t of the proposed system is shown in Eq. (1). Left side is the output power and the right side is the consumption power. The output e_{pv} of the photovoltaic system, output e_{sofc} of SOFC power generation, and output e_{eg} of the engine generators are supplied to the demand side. The electric power is consumed by the electricity demand Δe_{load} of the right-hand side of Eq.(1), power consumptionΔe_{hp} , and loss Δe_{loss} are the loss of a power conditioner for PV and the loss of all generators**.** The exhaust heat from engine generators and SOFC are used to supply heat to the water electrizer.

$$e_{pv}+e_{sofc}+e_{eg}=\Delta e_{hp}+\Delta e_{load}+\Delta e_{loss} \qquad (1)$$

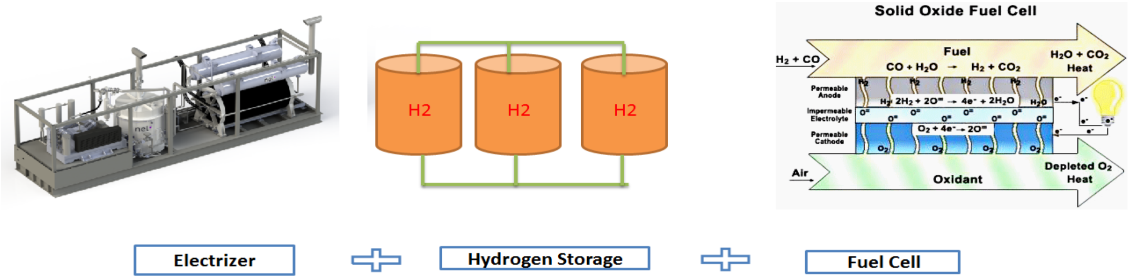


fig1. Power to hydrogen to power system components

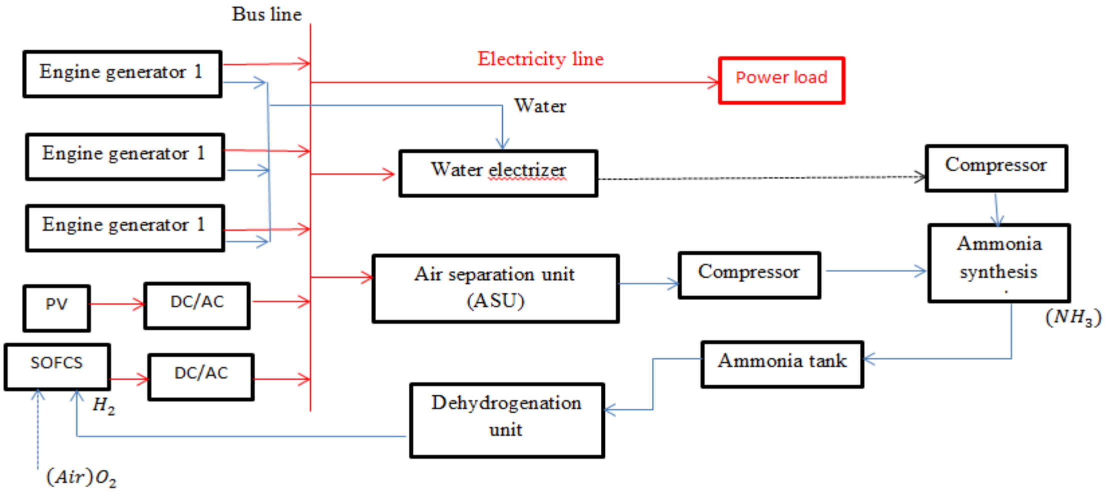


fig2. Block diagram of the proposed system

III. SPECIFICATION OF THE PROPOSAL SYSTEM COMPONENT

3.1 Water Electrizer

The components of the water electrolysis system are shown in Fig.3 (a). η in this figure is efficiency, η' is time-dependent efficiency, $\dot{e}$ is energy, $\dot{e}_{hg,3}$ is obtained from using the amount of electricity $\dot{J}_{we}$ supplied to the water electrizer, The electrizer efficiency η_{we} is calculated, in which η_j and η_e are the efficiency of electricity and efficiency of voltage, respectively. In addition, water electrizer runs at efficiency varying from 70% to 90%. The water electrizer is analyzed as a proton exchange membrane device. The efficiency of the water electrizer is 80%. The enthalpy $\dot{e}_{hg,3}$ of hydrogen extract from the water electrizer in Fig. 3(a) is computed as the product of the electricity input to the water electrizer and the efficiency $\dot{J}_{we}$ of water electrolysis. Additionally, $\dot{e}_{hg,3}$ is calculated from using the input water electrizer electricity $\dot{J}_{we}$.

3.2 Ammonia synthesize

The ammonia mass production from chemical reaction between nitrogen and hydrogen should be at about 500 ºC with pressure of 25 to 35 MPa is shown in Eq. (2). The ammonia hydrogenation process uses hydrogen generated from the water electrizer and nitrogen spread out from air with a conversion rate of 90% [19]. Then, the ammonia gas is cooled to about −30 ºC in Eq. (3). Ammonia synthesis unit generates liquid ammonia that is stored in storage tank of ammonia. Ammonia synthesis systems explained in Fig3 (b).

$$N_2(gas) + 3H_2(gas) \rightarrow 2NH_3(gas) - 924\ KJ/mol \tag{2}$$

$$NH_3(gas) \rightarrow NH_3(liquid) - 21.49\,\frac{KJ}{mol} \tag{3}$$

The energy flows of this process are in Eqs. (4) to (7). The energy;$\dot{e}_{hg,4}$ input to the ammonia synthesis unit without the power consumption ($\Delta\dot{e}_{hg,cp}$) of the hydrogen compressor from the water electrizer output energy ($\dot{e}_{hg,3}$). When the reaction efficiency; $\dot{\eta}_{hu}$, generation of heat by ammonia synthesis; $\Delta\dot{e}_{huh}$, and the loss $\Delta e_{\dot{a}su}$ are considered, $\dot{e}_{hg,5}$ in equation(5) is the output energy from the ammonia synthesis unit. Equations (6) and (7) are the pump output and the energy in the ammonia storage tank. A pump is used to supply the generated energy from the hydrogenation unit to the ammonia tank. The pump power consumption is $\Delta\dot{e}_{pump}$. Eqs (6) and (7) express the energy relationship between the pump and the ammonia tank outlet.

$$\dot{e}_{hg,4} = \dot{e}_{hg,3} - \Delta\dot{e}_{hg,cp} \tag{4}$$

$$\dot{e}_{hg,5} = \dot{\eta}_{hu}.\dot{e}_{hg,4} - \Delta\dot{e}_{huh} - \Delta e_{\dot{a}su} \tag{5}$$

$$\dot{e}_{hg,6} = \dot{e}_{hg,5} - \Delta\dot{e}_{pump} \tag{6}$$

$$\dot{e}_{hg,7} = \dot{e}_{hg,6} \tag{7}$$

3.3 Dehydrogenation unit

Dehydrogenation system is explained in Fig,3(b). Hydrogen is separated from ammonia by the dissociation reaction describes in equation (8). The dissociative reaction of hydrogen from the ammonia which requires temperatures of 400 to 800 °C at air pressure 400 to 800 A C (Endothermic heat) is shown in figure 8. The energy used in the dehydrogenation process of ammonia $\dot{e}_{hg,7}$ is shown in Eq. (9) from Eq. (7). The energy $\dot{e}_{dh,1}$ absorbed by the dehydrogenation unit, the heat in the range 400–800 during the reaction is required for hydrogen dissociation at air pressure, and $\Delta\dot{e}_{hnit}$ is the enthalpy of nitrogen. Then, the hydrogen is converted to electric power by solid-oxide fuel cells (SOFCs). The hydrogen output from the dehydrogenation unit is supplied to the SOFC and also the SOFC takes O_2 from air.

$$NH_3(gas) \rightarrow 1.5H_2(gas) + 0.5N_2(gas) + 92.4\ KJ/mol \tag{8}$$

Table 1 lists the conditions for the proposal system. The reaction temperature and conversion ratio of dehydrogenation unit are 800 and 90%. The energy $\dot{e}_{dh,2}$ consumed by the dehydrogenation unit is obtained from the reaction efficiency $\dot{\eta}_{dh}$, the heat required for hydrogen dissociation $\Delta\dot{e}_{hsd}$, and the enthalpy $\dot{e}_{hnit}$ of nitrogen.

$$\dot{e}_{dh,1} = \dot{e}_{hg,7} \tag{9}$$

$$\dot{e}_{dh,2} = \dot{\eta}_{dh}.\dot{e}_{dh,1} + \Delta\dot{e}_{hsd}.\dot{e}_{hnit} \tag{10}$$

Table 1
The ammonia synthesis Specifications

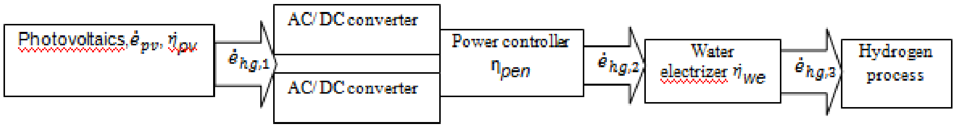
Parameters	Value
hydrogen compressor efficiency	55%
pressure of reaction	35MPa
Ratio of Conversion	90%
Pump efficiency	80%
heat storage efficiency	95%

Table 2
Specifications for SOFC

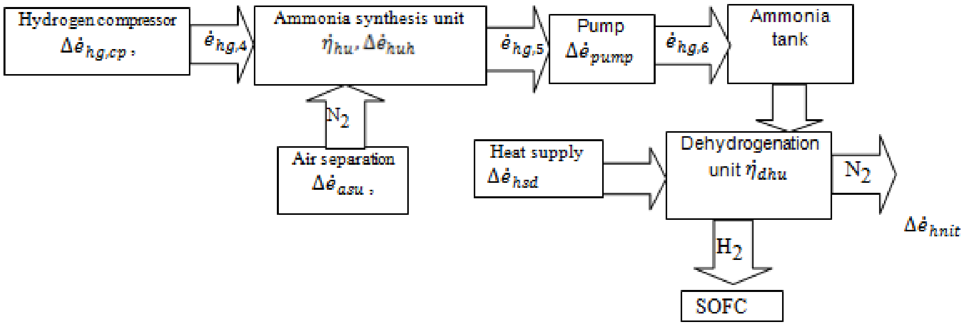
Parameters	Value
Power generation efficiency	50%
SOFC inverter efficiency	95%
Reaction pressure	0.1 MPa
Efficiency of heat output	40%
hydrogen utilization factor	90%
air compressor efficiency	55%
Power conditioner efficiency	90%

3.4 SOFC

The fuel cells systems are identified in this research are solid oxide fuel cell (SOFCs). SOFCs efficiency and power generation is higher and it operates with gases variation so that SOFCs are becomes used widely. This work discusses the variation of load factors on the SOFC power generation efficiency and the SOFC accompanied by internal reforming. The specifications of SOFC used in this scheme are illustrated in table 2. The exhaust heat out from SOFCs is stored in the storage tank and it is used for the water electrizer. The working temperature of the SOFC is illustrated by the heat balance at which the enthalpy change of the anode and cathode, enthalpy change of the heat medium for temperature control, and the energetic change by chemical reaction of SOFCs are equal to the direct current electricity output, radiation of heat, and the quantity of heat transferred to the heat medium and the cell stack for cooling. A control of the working temperature of SOFCs is required to meet load fluctuation. The rated temperature is 850 °C, and the amount of air and heat-medium circulation are based on maintenance of the rated temperature.



(a) Water electrizer system



(b)Ammonia synthesis system and dehydrogenation

Fig.3 Energy flow (a) Water electrizer system, (b) Ammonia synthesis system and dehydrogenation

3.5 Engine generators (DEGs)

Three diesel engine generators (DEGs) of one MW each are suggested to supply energy to the demand side in Fig4 (a), this load is in Sharm El Sheikh City, Egypt. Fig4 (b) explain the outside air temperature of the city. Operations of DEGs are into two methods. One method with its maximum output rating with its maximum efficiencies is used. Method 2 with partial load operation is identified. The power generation efficiency η_{egei} of each DEG is calculated from Eq. (12). The engine's maximum efficiency is 43.6%. The load factor λ_{egi} of each DEG and the heat power are from Eq. (12) [16].

$$\eta_{egei} = \left(-0.00000356\lambda_{egt}^{2} + 0.0014943\lambda_{egt} + 0.3128\right)\eta_{gti} \tag{11}$$

$$\eta_{eghi} = 0.001.\,\lambda^{2}_{egi} - \lambda_{egi} + 41.6 \tag{12}$$

3.6 Photovoltaic (PV) and load profile

Recently there are many types of PV systems; the most commercially are polycrystalline silicon PV with power efficiency of 18% was considered in this research. Power output from a PV system can be calculated as equation (13):

$$I_{pv} = \eta_{pv} * I_G * A_{pv} \tag{13}$$

Where I_G is global radiation [kW/m2] and A_{pv} is area of the PV [m^2]. Global radiation data in Egypt was used as the input of the PV. Optimum area of the PV was determined according to the power the load. In this paper the used area of PV system is 1000m^2. Demand electrical loads for a stand-alone micro-grid in Sharm El Sheikh City, Egypt as shown in Fig.4 (a) in a representative day each month. In this figure, peak values of demand are occurred in July and August while minimum values in March and November. Additionally, outside temperature and solar radiation in representative day each month are shown in Fig.4 (b), (c). In the present work, the hybrid system of PV, DEGs, and SOFCs is used to apply the requirements of the load with using of a genetic algorithm of parameters of individuals number is 2500, generation number is 1000, sampling time is 1 Hour, crossing probability with 95%, mutation probability of 1% and selection 5% replacement of all individuals.

IV. ANALYSIS PROCEDURE

The development of hybrid storage energy system with PV energy with large scale is proposed in this work for a remote community in a city, Egypt. The analysis of the characteristics of supplying energy to the demand side, as well as the techno-economic potentialities of a hybrid system of PV, DEGs, and SOFCs with ammonia (NH_3) as a hydrogen supply for SOFCs is proposed. In this study, no batteries are used and the back-up will be from DEGs or SOFCs. Two operating methods are suggested, the operation of DEGs or SOFCs with maximum rating in method 1 and remain of demand from the PV system (base load operation). The other is to apply the demand by using all out from PV system then the fluctuating operation of DEGs or SOFCs to supply remain of demand (power match operation). Battery is not introduced in this scheme. The two methods have been modeled; simulated and evaluated using the genetic algorithm and their performances are compared.

The surplus PV power is supplied to the electric heat storage and the water electrizer. The amount of surplus PV power which is supplied to the water electrizer affected on the amount of stored hydrogen energy carrier and fuel consumption. Thus, the power used for hydrogen storage is optimized with the amount of DEGs deployed on an hourly basis.

The following analysis procedures are done:

1) The Genetic algorithm chromosome model for optimizing a stand-alone micro-grid as in figure 5. The chromosome model group in the objective functions to be minimal is the best. In addition, the genetic algorithm is used because only optimal solution that a designer does not consider might be obtained. Furthermore, the operation methods shown in this research is based on sufficient number of trial, and computer applies the optimal solution objectively.
2) The objective function of this work is minimizing the fuel consumption in the micro-grid. The micro-grid fuel consumption is extracted from the DEGs fuel consumption F_{eg} from the following equation:

$$F_{eg} = {}^{e_{eg}}/_{\eta_{eg} * \eta_{gt}} \qquad (14)$$

Where; e_{eg} is the electrical power of the engine and η_{eg}, η_{gt} are the efficiencies of the diesel and electricity generators respectively.

3) The efficiency of power generation and load factor for DEGs are calculated by Eqs. (11), (12). The DEG fuel consumption and heat exhaust from it is determined. Furthermore, heat required to supply water electrizer is showed. An electric storage heater and a hydrogen-carrier storage system are used to store energy are identified in this paper. Energy production is suggested in our proposal system by adding supply control with three sets of DEGs, SOFCs and large scale of PV output.
4) Three SOFCs are controlled to supply energy to the stand-alone micro- grid proposed in this work. The load factor and power generation efficiency of SOFC are calculated. In this study SOFC has the specifications of power generation efficiency is 50%, efficiency of heat output is 40%, Air fuel ratio is 3.0, reaction temperature is 850 °C, reaction pressure (gage) is 0.15 MPa, SOFC inverter is 95%, utilization factor of hydrogen is 90%, efficiency of air compressor is 55%and power conditioner is 90.
5) The meteorological data in figure 4 referred to the output power of PV system. The random process is the property of the chromosome model. Based on the proposed algorithm the rate of DEGs and its fuel consumption and feeding the water electrizer with electricity are calculated. The balance of electricity is calculated from Eq. (1) to obtain the surplus PV power. After that, the amount of electric energy and thermal storage in the storage tank is shown. Step 3 is repeated for each DEGs and SOFCs.
6) The chromosome model extracts the SOFC exhaust heat and electricity output. The optimal variable that achieves the most economics objective function of less fuel consumption is obtained from the chromosome last generations.

V. RESULTS AND DISCUSSION

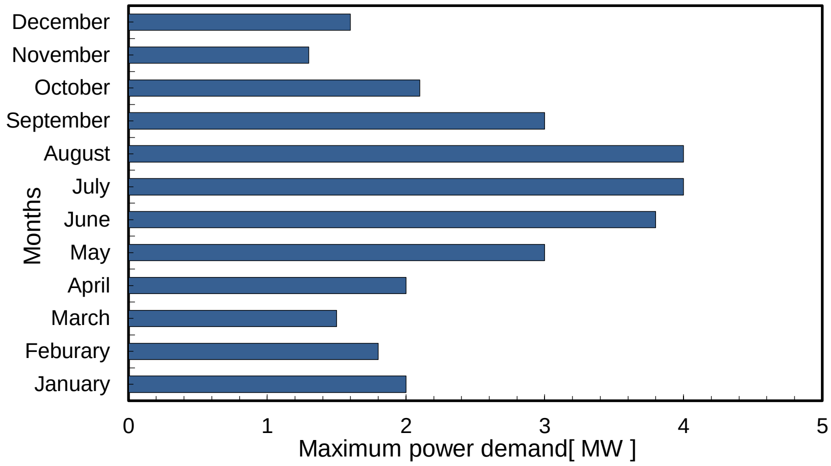
The output power from PV system in a representative day each month is shown in Fig.6. The total area of PV system is 1000 m^2 with absorption rate of 70%, heat transfer rate 10%, and temperature coefficient of 0.4%/K, large solar PV generation capacity of 1.118 MW. In this figure, maximum out from PV system in June while minimum value in December. Results of operation with base load operation in method 1 are shown in Fig.7. In this is figure, operation of the proposal system with two cases, case one at which the three DEGs or SOFCs with its maximum output power of 3MW are supplied the demand side and PV power are used after that to supply the reset of demand as shown in fig7 (a). In this is case the operation of DEGs or SOFCs with its maximum efficiencies. On the other hand, in the second case, only two of DEGS or SOFCs are operated with its maximum setting and the third DEG or SOFC is fluctuated operation after used PV power as shown in fig7 (b). In method 1, there are a surplus power from PV system because we do not use all the output from PV as shown in Fig.7(c). The surplus power has its maximum value in May and September and its minimum values in July and August. This surplus power is used to supply the electric heat storage and water electrolyzed.

The PV systems monthly contribute mean power to the hybrid proposal micro- grid power system in case of method 2, with maximum and minimum of 1.1 MW and 0.6 MW in June and December, respectively, as shown in Fig. 8. The total power generated by all the generators (DEGs) was identify to be maximum in August and minimum in March. The annual diesel and fuel cell efficiencies variation with solar energy fraction is shown in Fig.8 (b) and (c). It is evident from these figures that PV power penetration has direct impact on them.

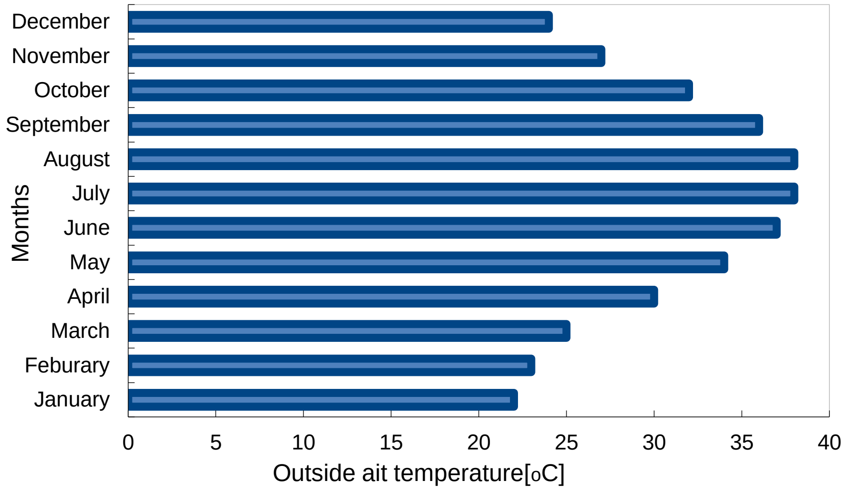
The exhaust heat from DEGs or SOFCs are supplied to heat storage tank to use it for ammonia synthesis operation as shown in Fig.9. In this figure, the performance of DEG operation in method 2 is shown. The load factor of DEG is illustrated in Fig9 (a) with high values in months May, June and July and less values in February and October. In additionally, the fuel consumption of the operating DEG in this method is shown in Fig9 (b).

Figure10 shows the effect of PV power contribution on the performance of the system. In this figure, there is a comparison between the two methods and without using of PV system. The benefits of PV system are reducing 200 m3 of fuel consumption, that cause reduces annual consumption by 10%. The proposed system with ammonia synthesis reduces monthly fuel consumption by an average of 25% compared with the same hybrid system without using NH3 as shown in Fig10(b). Due to dependence on increasing capacity of generation power from PV and improvement the efficiency of engine generator, the fuel consumption is decreased.

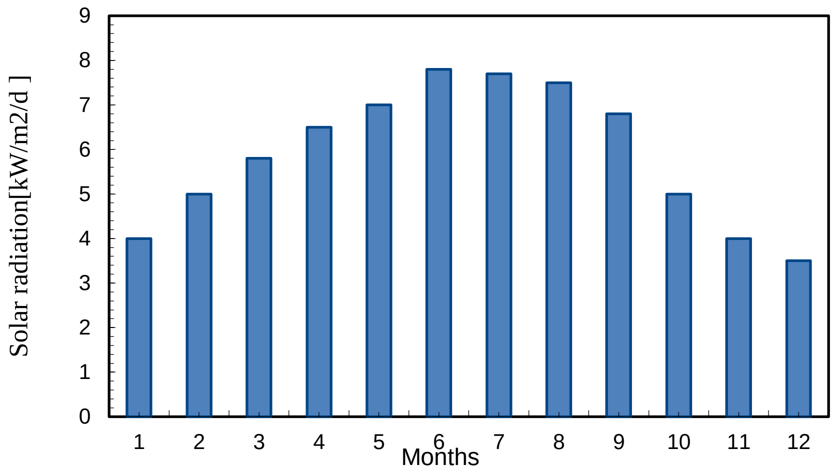
Figure 11 shows the energy analysis results for water electrolysis system, hydrogenation and dehydrogenation process. In this figure, 10% is the loss from AC–DC and DC–DC conversion, 9% is loss from power controller and 16% is the loss from the water electrizer in the first stage of water electrolysis system. Then, in the second step in the hydrogen process, 19% is the electricity consumption, 9.5% is the loss of hydrogen process and 2 % is the loss of ammonia synthesis unit. In the third step, 4.2% is the loss in the dehydrogenation process, and 7.5% is the heat supply to dehydrogenation process. The final step is the energy supply system. In this step, 3% are losses from gas off boiler, heat storage and back-up boiler. Also, 3% is loss of SOFC. Thus, the largest losses come from water electrolysis process and hydrogenation process.



a:Load profile in a representative day each month



b: outside air temperature



(C) Solar radiation

Fig.4 In a representative day each month (a) Electric power demand, (b) Outside air temperature, (c) Solar radiation

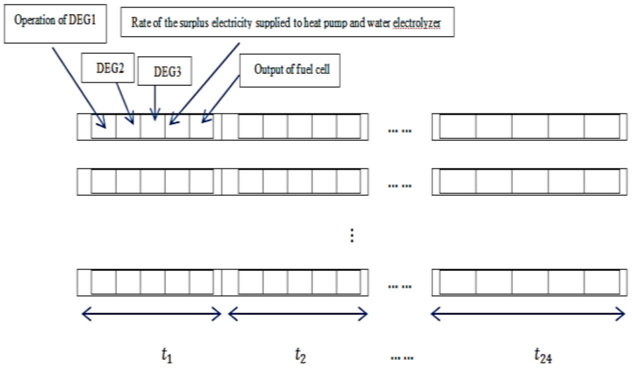


Fig.5 Genetic algorithm chromosome model for optimizing a stand-alone micro-grid.

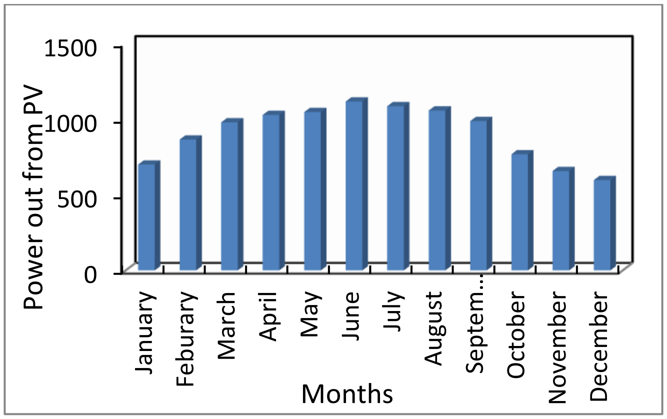
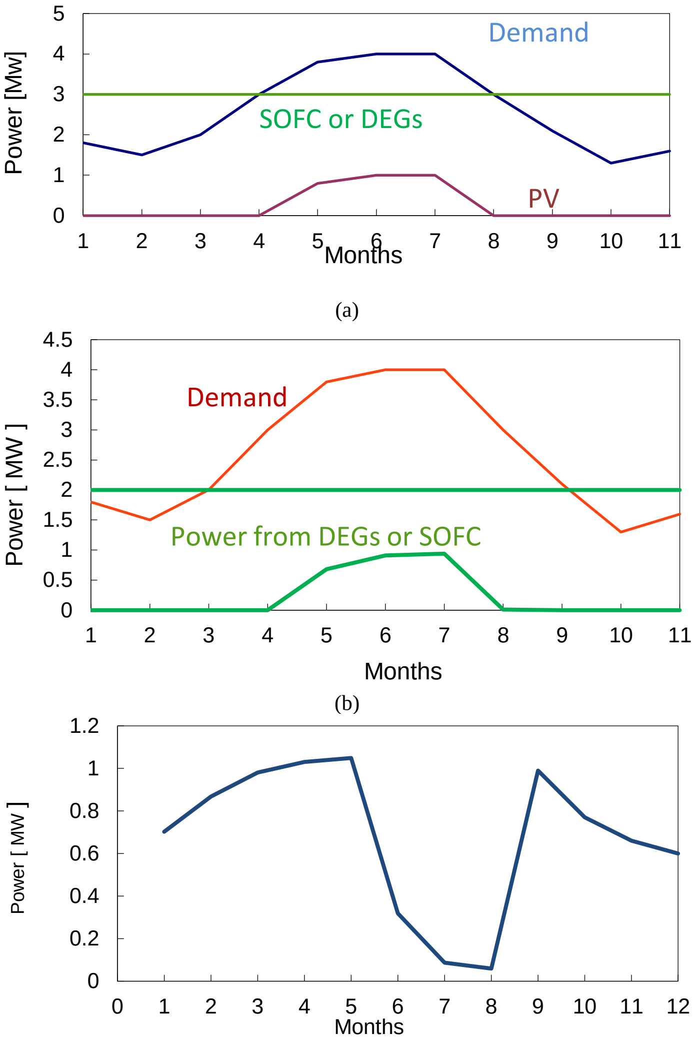


Fig.6 Output power from PV system in a representative day each month

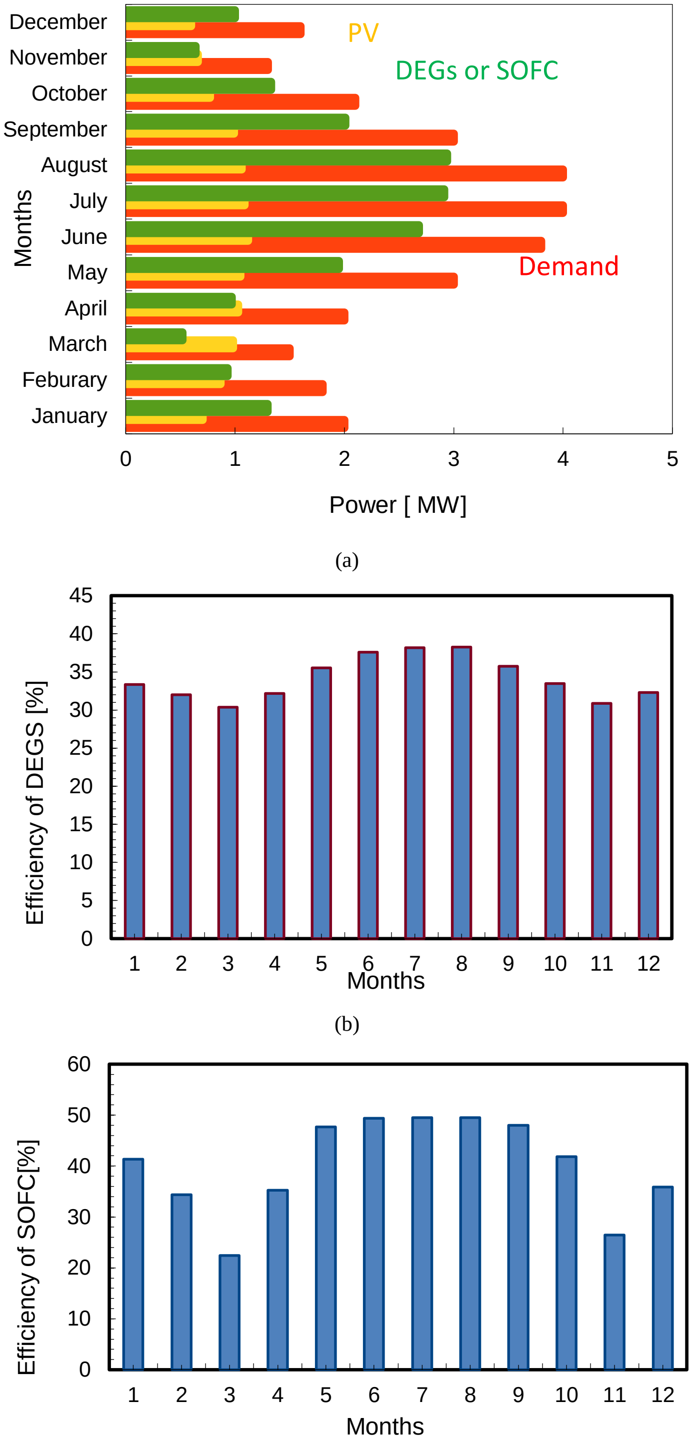


(a)

(b)

(c)

Fig.7 Method 1 at base load operation every month (a) maximum out from DEGs or SOFCs, (b)maximum out from only 2 sets of DEGs or SOFCs (c) surplus power from PV

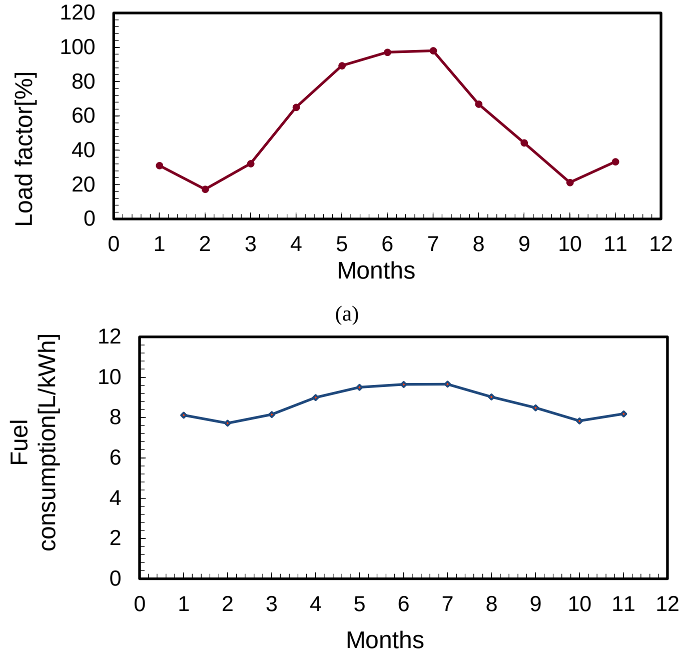


(a)

(b)

(c)

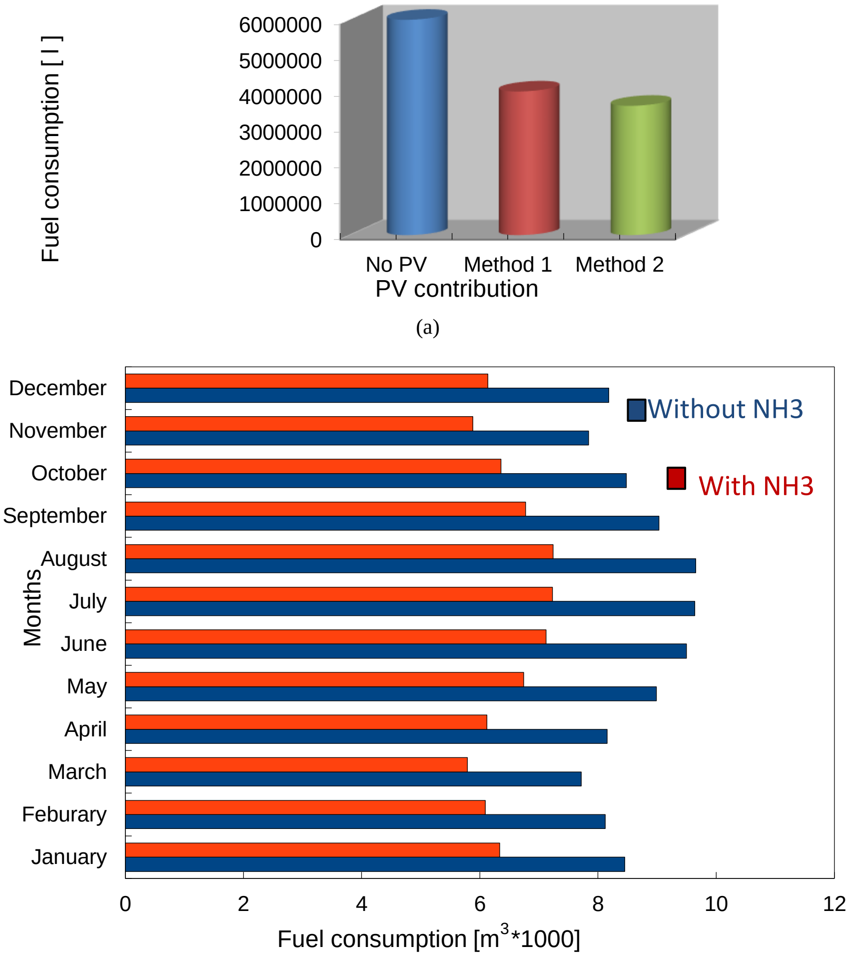
Fig 8 Method 2 at power-match operation every month (a) Output power from each supply, (b) Efficiency of DEG, (c) efficiency of SOFC



(a)

(b)

Fig.9 Performance of DEGs operation in method 2 (a) Load factor of DEG (b) Fuel consumption of DEGs



(a)

(b)

Fig.10 Parameters effect on fuel consumption of the system on a representative day of each month.
(a) Effect of PV penetration on consumption, (b) Effect of using ammonia synthesis.

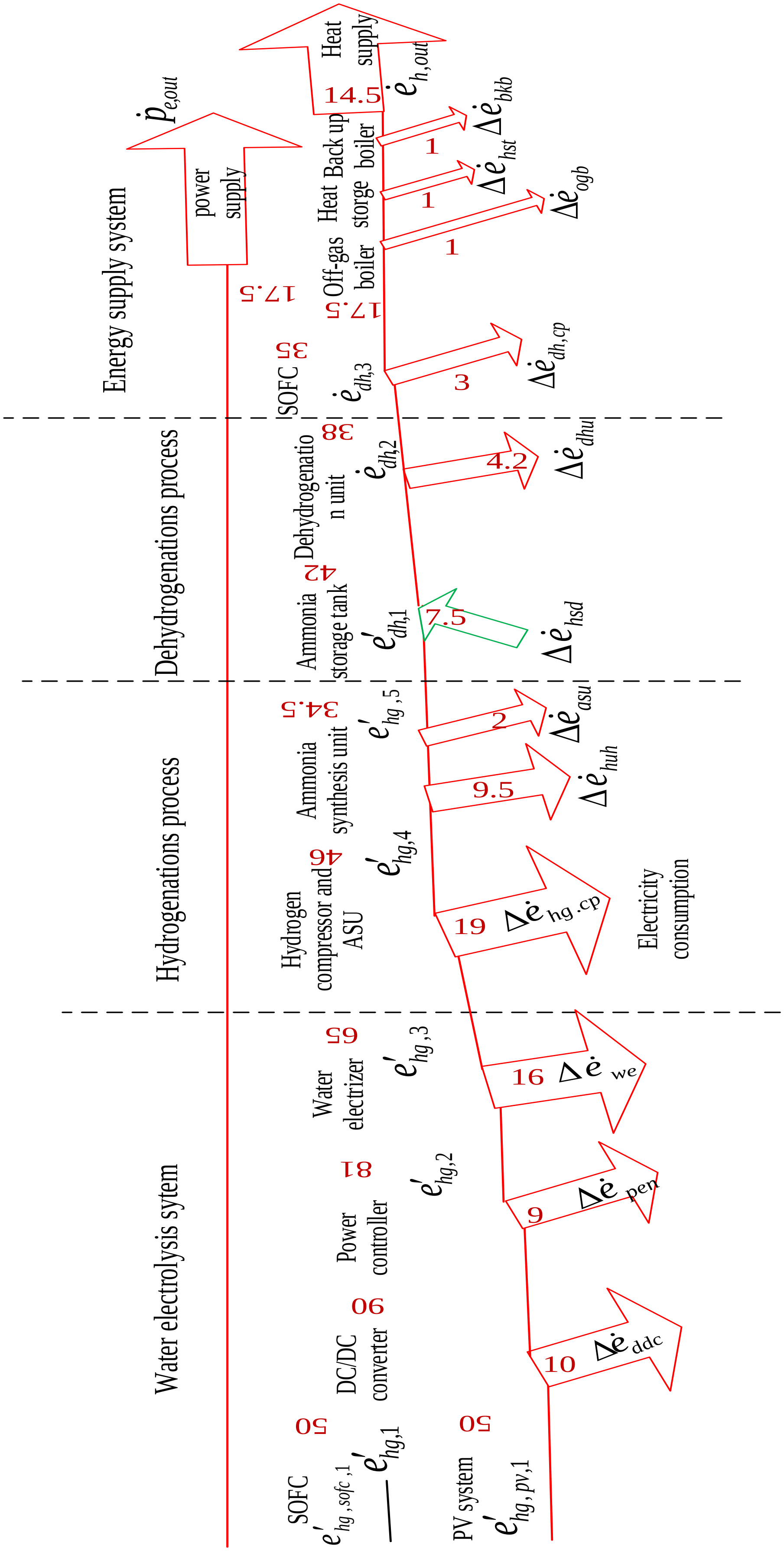


Fig.11 Results of energy flow for Ammonia process

VI. CONCLUSION

The techno-economic feasibility of a stand-alone micro-grid with renewable PV energy and SOFC hybrid systems is evaluated in this paper. It is indicated the construction of a micro-grid of green energy utilization accompanied by power storage by ammonia. Moreover, it proposes method for optimizing an independent micro-grid that uses hydrogen carrier. It is investigated by a proposal system consists of engine generators (DEGs), PV system and fuel cells (SOFCs) to supply energy to a demand side in a city, Egypt. Two methods were analyzed in the proposal system. Once is the operation of DEGs or SOFCs with maximum rating and remain of demand from the PV system in method 1(base load operation). The other is to apply the demand by using all out from PV system then the fluctuating operation of DEGs or SOFCs to supply remain of demand (power match operation). Battery is not introduced in this paper so the surplus power from PV system in method 1 is used to supply the electrical heater and to the water electrizer. The two methods can apply the demand with highest profile compared to others hybrid system because we do not use high price of battery and using ammonia synthesis technology. In addition, the area of PV is large and many DEGs are introduced in this paper, the fuel consumption of the energy system of the proposal power supply system will decrease. A hydrogen supply using Ammonia (NH_3) is clarified. Furthermore, the loss of energy with percentage 45% comes from water electrizer, hydrogen compressor, hydrogeneration and dehydrogeneration. The electrolysis loss 16% of these energy losses, 15% of these is losses in hydrogenation and dehydrogenation losses are 12%. In addition, the losses of electric energy conversion are 10% and 19% of the system energy is consumed compression of hydrogen.

This paper states that the reduction of fossil fuel can be obtained by using hydrogen energy supplly by 25%. In addition, the analysis quantifies the improvements that can be gained with using fuel cell. Using a fuel cell (SOFC) tends to reduce the number of DEGs and this is process leading to reduce the fuel consumption of DEGs and improving the efficiency of the whole proposal system. Finally, these results showed that the modeling and optimization in this study for hydrogen carrier energy storage is effective for large scale of PV, DEGs, and SOFCs hybrid system. Therefore, when the green energy levels are increased in this research, the proposed power supply system will likely reduce the fuel consumption. Furthermore, this proposed hybrid system and the evaluated model can be replicated within a similar load with small scale of each component according to the demand side.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author upon reasonable request.

AUTHORS CONTRIBUTION

Abeer Galal: Software, Formal analysis, writing – original draft, Supervision. Mokhtar Said: Conceptualization, Resources, Writing - review \& editing and final approval of the version to be published. All authors read and approved the final paper.

All authors are responsible for ensuring that the descriptions are accurate and agreed by all authors.

Title in Arabic:

تحليل شبكة صغيرة قائمة بذاتها من الخلايا الكهروضوئية , مولدات الديزل وخلايا الوقود

Abstract in Arabic:

هذه الاطروحة تقوم بتحليل نظام هجين مكون من الخلايا الكهروضوئية , مولدات الديزل وخلايا الوقود. هذا النظام يستخدم كمصدر للطاقة فى مصر. تم تحديد مواصفات المكونات المختلفة للنظام الهجين. الامونيا هى مصدر الهيدروجين لخلايا الوقود. عند تصنيع الامونيا من النيتروجين والهيدروجين المنفصلين بالطاقة المتجددة, يتم توفير الهيدروجين الي خلايا الوقود ومن ثم تحويلة الى طاقة كهربية. تم تحسين خطة تشغيل النظام المقترح كنظام غير خطى بدون استخدام البطارية. بالاضافة الى ذلك يتم عرض تحليل الكفاءة الشاملة وتوضيح المزايا التشغيلية للنظام المقترح. استخام الخلايا الكهروضوئية فى النظام الهجين يقلل استهلاك الوقود للنظام بنسبة 33% عن نفس النظام بدون الخلايا الكهروضوئية. وايضا استخدام الامونيا فى النظام الهجين يقلل استهلاك الوقود للنظام بنسبة 25% عن نفس النظام بدونها. لذلك يعتبر هذا النظام الهجين اقتصاديا اكثر من انظمة اخرى وذلك لانة يقلل من تكلفة التشغيل واكثر كفاءة ويقلل من استخدام الوقود الحفرى.

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