Optimum Hybrid Renewable Energy Systems Suitable For Remote Area

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ABSTRACT
An optimum hybrid renewable energy system (HRES) includes diesel as main sources combine with wind and solar energy as intermittent renewable energy sources with a battery bank storage is proposed to achieve the load demand of a remote village, Kiyalo, in west of Iran. The optimized system is based on the feasibility, load profile, and environmental consideration of this village. The aim is to have an environment-friendly energy system, reasonably priced over the long-term, with high sustainability and reliability. To explore suitability of the proposal system, a diesel-based power system as an eco-unfriendly system is balanced with the proposal eco-friendly system. National Renewable Energy Laboratory’s (NREL) HOMER software is applied to assess and contrast the best possible configuration of green energy system with the diesel-based power system in terms of sensitivity analysis, greenhouse gas emission, and net present cost. The optimization of the eco-friendly energy system is fulfilled through unit sizing to discover the optimum power management with minimum cost of the system. The HRES can handle the entire load consumption at a much lower cost and greenhouse gas emission and with much more reliability and sustainability as compare to that of standalone diesel energy system.

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1. Introduction

Energy is one of the main factors for enhancing social development, economic and high-quality living standard. Increased access to electrical power will enhance education, health, and improve opportunities for industrialization [1–5]. Problems such as greenhouse gas emissions, energy resources depletion, and increase of fossil fuel price motivate humans to introduce other types of energy resources [6,7]. However, there are still some concerns about price, sizing, locating, and reliability of renewable energy resources [8–12]. A possible solution for these difficulties, especially in an unconnected power generation at distant locations can be defined as a hybrid energy system, where the price of grid expansion is too expensive, and the cost of fossil fuels severely increases daily [13–18]. Hybrid power systems, micro-generation, for example, from diesel and wind provide an alternative to deliver small electrical loads at off-grid connection [19,20].

Diesel energy is available all times, but the accessibility of wind energy is strongly based on the wind speed. Nevertheless, the cost of maintenance for diesel is more than wind. A stand-alone wind system is unable to satisfy all the load requirements for the entire day [21,22]. The cost of maintenance and operation are usually high for a stand-alone diesel generator at small load levels. The energies from wind and diesel complement each other; capital cost of wind generation is higher in contrast to diesel generation. The usage of battery in remote stand-alone applications could contribute price and size reduction of the system. The technology for battery has improved from many aspects. In this research, several hybrid renewable energy systems (HRESs) are investigated and the prices of the produced electricity of different scenarios are compared [23,24].

While energy consumption in Iran is far higher than international standards, this country has plane to save energy in the subsidy reform program. According to Table 1, at present (June 2018), electricity generation in Iran is about 80 GWh. Accordingly, in 2012, the $500 million from the National Development Fund for renewable energy projects and a budget of about $60 million by the Ministry of Energy to the Renewable Energy Organization of Iran (SUNA) were allocated to support the program [25]. Iran is a country that has 300 sunny days per year and more than two-thirds of it has highly solar potential of an average of 5.5–4.5 kilowatt-hours per square meter per day. It is possible to install more than 60,000 MW of solar thermal power in an area of more than 2000 km². Approximately 83% of electricity generation capacity (Table 1) is allocated by thermal fossil fuel power plants and less than 1% of this amount is dedicated to renewable energy. This paper will be focused on the use of renewable energy in a remote area in Iran.

Many endeavors are lately being dedicated to improving models that seek to make senses into the techno-economic advantages of HRES. An optimization model was extended and simulated to optimize feed-in tariff income streams for the present photovoltaic (PV) system for a complete year with real half-hourly PV production profiles. Distributed Energy Resources Customer Adoption Model (DER-CAM) software optimization tool for a novel PV system was examined in the consequence of the unit cost of storage (price/kWh) on the reception of the battery as storage system. The result of the unit cost of storage (price/kWh) on the acceptance of the battery as a storage system for a novel PV system was also examined in the Distributed Energy Resources Customer Adoption Model (DER-CAM) software optimization tool [24,26]. Usually, use of combined heat and power plants (CHP) improves the efficiency of the HRESs. Due to the large number of installed solar water systems in our case study, CHP does not add much of economic value [27].

A complete research was done by the aim of recognize newest encouraging techniques for the optimization of solar PV–wind based on HRESs was performed on trends in optimization techniques. Dissimilar techniques consist of conventional and new generation methods were studied and 16 optimization methods were reviewed including hybrid PV–wind power systems. It was established that unlike optimization methods have various performance organization and computation speed, so assortment of appropriate touch might alter with user demands, type of usages, etc. [28–32]. In this research the optimal size of HRES was evaluated by the total net present cost (NPC) and the levelized cost of energy (COE); the result of optimization will compare and the best one was chosen.

| Type                               | Nominal capacity (MWh) | Percentage of electrical generation type in Iran |
|------------------------------------|------------------------|-------------------------------------------------|
| Steam                              | 15,830                 | Rechargeable                                   |
| Diesel and Gas                     | 29,318                 | Hydro                                           |
| Combined cycle                     | 21,780                 | Nuclear                                         |
| Total Thermal                      | 66,928                 | Renewable                                       |
| Hydropower                         | 11,838                 |                                                 |
| Renewable (Wind, Solar, Geothermal.)| 575                    |                                                 |
| Nuclear                            | 915                    |                                                 |
| Total power generation             | 80,256                 |                                                 |
The key contributions of this work compared to previous literature are consideration of real data for a remote Iranian community and investigation of various possible configurations of hybrid power generation considering available energy resources. The study is based on the special weather conditions of the region and its limited accessibility via roads in winter season. This article addresses the possible environment-friendly and eco-unfriendly systems with the aim of reduced system NPC and greenhouse gas emission while meeting the operational constraints. In all the proposed hybrid power systems in this study, similar level of sustainability and reliability is considered. The actual hourly data of system including the load, ambient temperature, wind speed, and solar radiation as well as the capital, maintenance, and fuel costs of various components are fed to HOMER as optimization software. Capacity of the hybrid power system components are obtained based on the economic calculations for a 20-year system life. A comparison is made of the results for the five optimized systems against feasibility and economy of the systems as well as the consistency of the results. In this study, sensitivity analysis has been properly addressed.

2. Background Information

The data to assess and analyze the HRE-based systems and diesel-based energy system are as follows:

2.1. Site Location

There are about 1,500 villages located beyond the reach of normal electricity supply in Iran. They are far away from power networks serving the major urban areas and the main supplement of them are mini diesel. One of these villages is Kiyalo. It is situated 135 km Southwest of Khorramabad of Lorestan province (Figure 1(a)). Kiyalo have 120 inhabitants (May 2018). The road has no asphalt access and it takes about 4 h to reach this area from the nearest town. The main reasons for choosing Kiyalo as a case study are acceptable wind speed, pleasantly high altitude and extremely exposure to sunlight for using PV, remote and disconnected area from unity grid; its data are readily available from [25]. This site has not been previously studied and there is a big problem for the electricity generation. Diesel generators have been the main and first source of power generation in remote villages since long time. Similarly, in this especial location, the power generation type is diesels generator. It seems that usage of the HRES is the best choice due to many reasons such as hardly available remote area, high fluctuation in diesel price, environmental problem, and travel difficulty for these kinds of location. The total COE would be greater than normal for these kinds of remote areas if the supply of electricity is based on such diesel energy. Kiyalo has many problems with the supply of diesel fuel, and the cost is sometimes much higher than normal, and it results into no electricity for many hours during year. This study intends to analyze a possible application of hybrid diesel/wind/PV energy system as electrical power generation and battery as storage system in this rural region. The number of hours of diesel generation function and the rate of available energy would be balanced for different configurations. The percentage of fuel saving and reduction of greenhouse gases or carbon emission for different hybrid systems is discussed.

The high cost of fuel delivery in this area and the bulk fuel storage tanks for this location are a main concern for the local and authorities of this area. Addition problems for the communities are environmental dangers associated with diesel generators which include fuel storage tanks for this location are a main concern for the local and authorities of this area. Addition problems for the communities are environmental dangers associated with diesel generators which include fuel spills from cars, emission of particulates, and greenhouse gases. Figure 1(b) illustrates the daily load profile. The average load is about 50.1 kW and the average required energy per day is 1,203 kWh/d with a Load Factor of 0.261 [25].

The demand load varies each month during each year and the random variability of day-to-day is 15% and time-step is 20%. The maximum peak of load is 192 kW. Figure 2 shows the annual change of electrical load per month, at different times of the day in a three-dimensional diagram.

2.2. Input Data

2.2.1. Wind Profile

Figure 3(a) shows the wind speed data taken at the height of 10 m above ground level in Kiyalo. At this height the annual average wind speed is 4.35 m/s. The maximum and minimum of wind speed have been recorded in June with 4.9 m/s and January–December with 3.7 m/s, respectively [33].

2.2.2. Solar Profile

Figure 3(b) shows monthly average solar global horizontal irradiance data for Kiyalo village. The scaled annual average solar radiation was measured to be 5.024 kWh/m²/day. A significant amount of PV power output can be achieved when the solar radiation available during the year [33].

3. Power System Under the Study

One of the main aims of power system is generating a sustainable power generation. Generally, two types of loads can be considered for this system. First, the size
Figure 1. The village under the study and its daily load profile. (a) Location of Kiyalo (b) Daily load profile.

Figure 2. The average of seasonal load profile.

Figure 3. The monthly average profile of the input data. (a) Wind profile (b) Solar profile.
and quantity and also time of the loads that use are clear. This class of loads is called static loads. Second, another category is unpredicted loads with unknown value and added to the system at an unspecified time. This class of loads is called dynamic loads. In addition, wind, solar, and other renewable energy resources, due to their intrinsic instability on the electricity generation is compared to diesel generators, hardly and in certain circumstances are able to provide all the load demands. Thus, one of the best solutions is to integrate intermittent sources of energy such as solar and wind with diesel generator and the energy storage system such as battery. Such a system, if optimally designed for the existing conditions, could enhance the production security and reliability of the electricity generation. This design could be able to solve unwanted dynamic load-related problems.

3.1. Configuration of System

This study proposed a diesel generator sets hybrid with wind turbine, PV array, and battery units. The maximum peak-load demand of moment is 192 kW. Two diesel generators (G1 and G2) and load are connected to AC bus and wind turbine (BWC XL.1 24VDC), PV (Flat plate), and battery (Surrette 4KS25P) as storage system are connect to DC bus and a converter AC/DC (Leonics GTP503S) is connected between two buses. The proposed configuration of HRES for the case study is exposed in Figure 4. Table 2 lists the sizes and prices of the energy components of the proposed system under the study [25].

3.1.1. Diesel

The number-one chosen generators for emergency and standby systems around of the world is diesel-powered generator sets. These sets usually are very fast to connect to the load and also very fast to disconnect from the load. But beyond these advantages, there exists some disadvantage such as the cost of operation and maintenance (O&M) are very high, especially at low demand loads. There are other problems which are the storage and transportation of fuel to remote areas. These systems are usually very noisy and are not completely suitable for inhabited areas. In Kiyalo, two diesel generators are used for feeding the whole load demand. For calculating the operating costs of diesel fuel, it is required for mode of fuel consumption. Another difficulty is exhausting emissions which comprises oxides of nitrogen (NOx), hydrocarbons (HC), particulate matter (PM), and carbon monoxide (CO) in the form of visible smoke and soot [34]. For the environmental protection group and various state groups, the standards were enacted to authorize significant decreases in all these substances (particularly NOx) to decrease influence on the environment and public health. Diesel generator 1 and 2 may be in a range from 0 to 200 kW and 0 to 100 kW, respectively.

3.1.2. Wind Turbine

The energy from the wind turbine is powered based on the wind velocity speed. The velocity of wind is usually much higher contrasted with the standard of power demand load. The wind generator produces electricity by extracting energy from the kinetic energy come from moving air. The Bergy BWC XL.1, 1 kW, 24 VDC wind turbine has been chosen for simulation that can carry out the goals. Wind turbine may be in a range from 0 to 200 kW.

3.1.3. PV Array

PV arrays are electronic devices that convert the solar radiation of sun light into electrical power output. This study considers the flat plate 1 kW PV module. PV arrays may be in a range from 0 to 500 kW.

3.1.4. Battery and Converter

Not only does the optimal size of an energy storage device help to reduce the capacity of generators, but also provide cheaper power, boosts efficiency, and
reliability of system. The battery is chosen as the most suitable energy storage device in the existing system. It is necessary to mention that the battery itself is a precious element. However, new technologies have significantly reduced the initial price of this element. Batteries, also, regularly are used to remove fluctuations in systems for short time. Today’s batteries are better than ever. Flooded lead acid batteries have more reasonably priced and tend to last longer than sealed batteries, however they need ordinary maintenance. This study has chosen the Surrette 4KS25P with two batteries per string (4 V, 1,886,525 Ah, and 8 kW) due to its commercial availability and high capacity. HOMER Software as per the proposed optimization in Figure 5 calculates the charging state of battery dynamically based on the demand and power production. In addition to charging/discharging of the battery, HOMER software includes the capital, operation, and maintenance costs for the optimization purpose. Optimum capacity combination of battery is finally extracted from both technical and economic considerations [35].

### 4. System Optimization and Operation Strategy

In this study, the HOMER software, developed by National Renewable Energy Laboratory (NREL) [36], was employed to a techno-economic analysis for proposed HRES. The required inputs for this software include the amount of power supplies consist of diesel generators, wind turbines, PV arrays, and battery cells as the storage system. Table 2 lists size of these elements in this study.

Figure 5 illustrates the operating strategy flowchart of the proposed hybrid power systems for supplying the load demand as a sample for 24 h. HRES operation strategy considers two main parts: load flowing and cycle charging. It is expected that the systems supply entire load demand if enough solar radiation and wind speed are available. If renewable energy resources could not feed the whole demand, battery bank supply the load accordingly. In the worst condition, without renewable energy recourses and energy saving, diesel generators start feeding the load. The decision on which system operate is based on the energy balance computation and also the status of charging/discharging of the battery is depended on by this system. The operating reserve is the amount of electrical power which is online to support immediate unexpected load variation without delay.

In this study, the following six standalone systems are considered:

1. standalone diesel (current condition),
2. standalone PV (with or without battery),
3. standalone wind (with or without battery),
4. hybrid diesel/PV (with or without battery),
5. hybrid diesel/wind (with or without battery), and
6. hybrid diesel/PV/wind (with or without battery).

Please note that not all the above scenarios are practiced.

The total power ($P_{\text{gen}}$) achieved from wind turbines ($P_W$), PV arrays ($P_{\text{PV}}$), diesel generator ($P_G$) and batteries ($P_B$) and the numbers achieved from wind turbines ($N_W$), PV arrays ($N_{\text{PV}}$), diesel generator ($N_G$) and batteries ($N_B$) generation injected to the AC and DC buses are assumed as follows:

$$P_{\text{gen}} = N_W \times P_W + N_{\text{PV}} \times P_{\text{PV}} + N_G \times P_G + N_B \times P_B$$

(1)

The system is able to operate in three following scenarios:

- If $P_{\text{load}}(t) = P_{\text{gen}}(t) \times \eta_{\text{conv}}$, then all load demand is provided by renewable resources.
- If $P_{\text{load}}(t) > P_{\text{gen}}(t) \times \eta_{\text{conv}}$, then battery bank compensates the deficit of producing energy.
- If $P_{\text{load}}(t) < P_{\text{gen}}(t) \times \eta_{\text{conv}}$, then not only all load requirement is fed by renewable resources, but also some of energy excess.

where $P_{\text{load}}(t)$, $\eta_{\text{conv}}$ have chosen as momentary load demand and the efficiency of converter, respectively. Moreover, in second scenario, if energy deficit is greater than the energy stored in the battery, in which case the rest of the deficit could not be provided by

| Description          | Specification       | Unity cost | Capital cost ($) | Replacement cost ($) | Operation and maintenance ($) | Lifetime (year) | Size          |
|----------------------|---------------------|------------|------------------|----------------------|-------------------------------|-----------------|--------------|
| PV                   | Flat plate          | 1 kW       | $1,500           | $1,200               | $50                           | 20              | 0~500 kW     |
| Wind Turbine         | BWC XL1 24VDC       | 1 kW       | $2,500           | $2,000               | $75                           | 20              | 0~200 kW     |
| Converter            | Leonics GTP035      | 1 kW       | $890             | $800                 | $10                           | 10              | 0~250 kW     |
| Battery              | Surrette 4KS25P     | 2 units    | $1,200           | $1,170               | $10                           | 12              | 0~1,200 strings |
| Generator G1         | 1 kW                | $220       | $200             | $20                  | $0.15                          | 20              | 0~100 kW     |
| Generator G2         | 1 kW                | $220       | $200             | $20                  | $0.15                          | 20              | 0~100 kW     |

Table 2. Sizes and prices of the energy components in this study.
renewable resources. In this case, the stability of the system collapses and hence the available relays trip. It may result in a black out. In third scenario, the excess of energy could save in the battery bank. In the case of power production more than the storing capacity of the battery bank, the excess power is used for water heating. Because of the uncertainty of generating renewable energy from their dependence on wind speed or solar radiation, in almost all situations that are being investigated, there is a need for diesel generator or battery storage [37].

The optimization management is carried out for the proposed standalone hybrid systems to achieve unit sizing with respect to cost and power management analysis. The capital cost ($), replacement cost ($), O&M ($) for each element, lifetime by year, and number of proposed variables for each element for performing this optimization is required. In this purposed system, the quantity and quality of wind turbines, PV arrays, and battery capacity are extremely important. The simulation is run based on the quantities and prices of energy components shown in Table 2. The COE per kW and the cost of systems per year, NPC, are considered. The NPC value is a more reliable value than the COE value because the concept of COE is very simple, and this is only an average cost per kilowatt-hour of electricity.

5. Result and Discussion

Simulation is accomplished by harmonizing the usage of: previous systems (standalone diesel) and different hybrid systems as per the Table 3. The optimization has assisted to spot the best probable design for the HRES composing of all generating elements. The most favorable types of systems are the one with satisfying demand and with lowest price from the economic point of view. In this design, it is presumed that
Table 3. Proposed optimized systems with various generation options.

| System no. | Optimized configuration  | PV kW | Wind kW | G1 kW | G2 kW | Battery strings | Converter kW | NPC $ | COE $/kWh |
|------------|--------------------------|-------|---------|-------|-------|-----------------|-------------|-------|-----------|
| 1          | Hybrid PV/Diesel         | 300   | N/A     | 100   | N/A   | 400             | 125         | 2,087,010 | 0.370     |
| 2          | Hybrid PV/Wind/Diesel    | 200   | 100     | N/A   | N/A   | 400             | 125         | 2,160,041 | 0.385     |
| 3          | Standalone Diesel        | N/A   | N/A     | 100   | N/A   | 400             | 125         | 3,018,454 | 0.538     |
| 4          | Hybrid PV/Wind           | 400   | 100     | N/A   | N/A   | 800             | 250         | 3,216,316 | 0.573     |
| 5          | Standalone PV            | 500   | N/A     | N/A   | N/A   | 1200            | 250         | 3,812,230 | 0.679     |

Variables of this optimization such as wind speed, solar radiation, and load profile and so on are exclusive for this special location. Table 3 confirms that the best optimized system is hybrid PV/diesel. This system consists of 100-kW diesel generator (G1), 300-kW PV array, 400 battery strings, and 12-kW converter, respectively. This system configuration offers lowest NPC compared to other systems.

Second optimized configuration is hybrid PV/wind/diesel. This hybrid system consists of two diesel generators (G1 and G2), PV array, wind turbine, and battery with a converter. The system is very similar to previous system except that in the addition to the increased capacity of wind turbines and reduced capacity of PV, a small 50-kW diesel generator is necessary. It means that with the reduction of 100 kW of PV, this capacity has been transferred to the wind turbine while a backup diesel generator is required for having a stable grid. It tries to reduce the adverse effects of wind speed.

Third optimized system in Table 3 is the generation system which currently exists. This system only works with two 100-kW diesel generators. Apart from the simplicity of this system, it suffers from environmental disadvantages. Figure 6 illustrates the cost breakdown and the environmental factors of the proposed optimized system. Figure 6(a) confirms that system 3 consist of standalone diesel that has very low price for initial capital, while other systems have high capital cost. This means that each configuration consists of renewable energy for initial cost should pay much as compare to diesel generators. Figure 6(b) shows that the ratios of the total NPC and COE increase smoothly. Figure 6(c) shows that the O&M costs of the system consist of diesel generators only are higher than the other proposal optimized systems.

Figure 6(d) confirms that in hybrid power systems with higher portion of electricity production from renewable energy sources, greenhouse gas emission is lower. The optimization in this study is based on the optimum capacity of the hybrid energy system components. Optimized system with the minimum NPC means that the optimized configuration guaranties the lowest components costs. The percentage of electricity generation for each component is illustrated in Figure 7. Since the production of PV is lower in some months of the year and is more in other months, presence of diesel generator makes the electricity production stable and reliable (see Figure 7(a)). With the addition of wind turbines, a large share of production is allocated to this source (see Figure 7(b)). Generator 2 has a very small share in production and mainly acts as the backup for the system. As such, if the wind speed and/or sunlight were inadequate for some reason during some hours of inappropriate weather, this generator would compensate the production shortfalls. System 4 in Table 3 only includes the PV, wind turbines, and battery bank with converter. Such a system is not very economical but environmentally friendly. If the fossil fuel is not available for any reason, the combination of these elements is useful. Lack of fossil-based electricity production results in significant increased capacities of the PV, battery bank, and converter. It means that the COE or NPC increases. Figure 7 shows the percentage of renewable sources production for a standalone system. In fact, a standalone PV system is also possible, but very expensive (NPC is double in contrast to the first system).

While the capital cost of wind turbine is more expensive than diesel generator, the total cost for wind generation is low in comparison with diesel generator. It means the renewable types have more capital cost, but total cost is less. Wind is forever blowing free and all the money is paid only for wind turbine, its equipment and nothing more except a little price for O&M. Therefore, as time goes on, using HRE...
completely become more economic. The wind power generation depends on the wind speed which is not predictable. Batteries are able to compensate deficiency of electrical generation caused by wind speed reduction in limited time. Batteries are joined online to this load demand. It could be charged when the energy usage far exceeds the capacity. The duty of loading battery is dependent on technical explanation of system. The cost of a batteries stack is typically precious. It is also normally planed for ejecting fluctuations in system. The only endeavor of HRE is not intended to answer to the load request. Consequently, the proportion of generation for batteries is presupposed very low.

6. Green House Gases Reduction

These days human are concern about the air and earth than energy shortage. The most of green gases are due to burn of fossil fuel. Those pollutions influences in the life of human and environment. The HRE is one of the best ways to assist the environment and human. By increasing the usage of HRE the greenhouse emissions can be decreased. Figure 8 demonstrates the highest different of pollutant productions succeed by selecting to provide the load via HRES instead of the diesel generation. The total quantity of greenhouse emission by reason of the employment of HRES is 69,447 kg/year which is approximately 88.27% lower than the make use of standalone diesel system by 592,274 kg/year. It is to be noted that technical feasibility of system is not possible to neglect all diesel generators but try to use more HRES can be more useful to decrease greenhouse gases emission.

7. Sensitivity Analysis for Diesel Price

Research results for many optimization solutions show that economic sensitivity often has higher importance with respect to other aspects. It means that if a system has the best operating condition from energy point of view but no economic justification, it will not be a favorable system [38]. The variation of fuel price creates many problems for any economic system. So, it seems to be realistic to search a system with less sensitivity with respect to fuel price for power generation. The total NPC for HRES 1 (with diesel generator and PV arrays) for $0.6/L was $2,087,010. Assessment of available retail prices for Kiyalo showed that prices were on average $0.6/L to $1/L during 2016 and 2018, respectively. During the winter of 2017, due to fuel transfer difficulty, prices in rural area exceeded $1.5/L. The price of fuel was
varied from $0.6/L to $1/L for sensitivity analysis and simulation is done as per the NPC at Figure 9. In this figure, the rising fuel costs increase the COE and NPC with more use of renewable resources. With the increase in fuel price, the total NPC climbs and despite the fact that initial capital cost of PV is more than diesel generator but installing more PV arrays result in cheaper price of energy.

8. Conclusion

In this study, the performance of the current and proposed scenarios of power station located in Kiyalo, Lorestan province, Iran, has been investigated. The impact of injecting of PV/wind and battery power into off-grids based on significant operational process over various HRE penetration levels (0%, 83%, 88%, and 100%) was considered. The available system was compared to the optimum sizing of the PV/wind system to check whether the prior system for the same load profile, solar radiation, and wind speed data sets is optimum. The results of standalone diesel, standalone PV, hybrid PV/wind/diesel, hybrid PV/diesel, hybrid PV/wind systems on NPC, COE, Initial capital, operation cost, penetration of renewable energy, and levels on the harmful emission generation were discussed. The optimal size of independent hybrid production units, including diesel, wind, and PV design objective function with respect to the cost of diesel fuel was studied. Five of the best configurations were selected and respective price analyses between different configurations were performed. Comparison of the existing system with the optimal system showed that the existing installed systems are not properly selected. The best performance of the various configurations, in terms of technical aspects and 24-h electricity supplying of load demand, is the hybrid PV/diesel/battery system. Battery, as one of the main components of the proposed systems, is used to save energy in excess production as well as to increase the efficiency and reliability of the system. The consequences of
sensitivity analysis performed based on variation on fuel prices, demonstrates trends toward using more RE resources in energy generation and less hope to standalone diesel generators. The importance of including storage system like batteries includes storing the surplus energy and reduction of losses. By using HRE in Kiyalo, the gas emission of the system could drop to 88.27%. The results show that due to the high percentage of fuel costs and CO2 emissions from diesel, the use of HRE will lead to a significant reduction in the cost of the 20-year-old system.

The next phase of this study will consider the load management and demand response. It means that with introduction of tariff incentive and load shifting, the peak load and hence the capacity of the proposed systems could be reduced. The aim is to have a proportional load distribution and reduction energy damping. It is very important to make the smart grid more reliable and stable considering the intelligence production and consumption.

Disclosure statement
No potential conflict of interest was reported by the authors.

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