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OPTIMUM MANAGEMENT AND CONTROL OF SMART MICROGRID WITH RENEWABLE DG

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Abstract- Nowadays, new technologies such as renewable distributed generation (DG), distributed storage and demand-side load management play an important role to change the energy generating and consuming methods. Indeed, by intelligent saving, production and energy consumption methods in the future the more efficiently energy supply will be obtained. In this paper, different models of domestic smart microgrid with thermal and electrical load for local and global connected network are discussed and simulated. The mentioned modelling of systems is carried out using hybrid DC/AC micro-grid considering renewable DG units such as solar, wind energy and battery storage units so that in each condition operating cost (OC), capital cost (CC) and net price cost (NPC) are compared. It can be concluded that although the initial installation cost of renewable DG units are high but more reliable and cost-effective operation will be deduced by renewable connected power supply.

Keywords: Distributed Generation, Domestic Home, Hybrid Micro-grid, Renewable Energy, Smart Microgrid, Load Management.

I. INTRODUCTION

Today, with rising energy prices and the impact of greenhouse gas, clean electricity supply with higher efficiency such as renewable DG sources play an important role in the grid production [1, 2]. In recent years, more technologies have been developed to improve the efficiency of electricity supply [3, 4]. In contrast, power demand is increased so that electricity peak demand should be generated and transferred with minimal equipment. Due to fluctuating demand, required equipment of the grid has increased and this reduces the efficiency [3, 5].

Transforming and changing domestic customers from conventional consumers into active participants in the production procedure may be count as a solution to this problem [6]. Customer participation could be achieved by developing new domestic appliance load control, micro generation with DG sources and internal energy storage of both thermal and electrical demand [3, 6, 7]. These devices have the capability of shifting electricity consumption in time without disturbing the inhabitants. In general, operation, management and optimization of DG units and their efficiency are desirable and necessary.

Recently, different works has been studied the micro grid capability with renewable DG units and domestic managing program [7-12]. In reference [7] the effect of DG units in optimal operation of microgird was discussed. In reference [8] it was shown that switching on/off appliances will cause stability problems. Also, restarting large-scale renewable sources need a new network design and management. Although, the DG has more initial total cost of production than commercial power plants, it has the potential cases that may be supplied all demand load with the same reliability, along with less capacity ranges.

In reference [9] the optimal method of using domestic potential was expressed. In this paper a more detailed description of the control method is given to use domestic optimization capability. In reference [10] the impact of DG on the stability of the network oscillation was studied and this work results in improved stability when the generators are properly management. In refrences [11 and 12] grid dependent devices were described. It is mentioned that these devices remove their load when the frequency of the grid changes substantially.

This paper aims to control and management of the energy flow in one or a group of the smart microgrid house with considering demand management. This optimal management of resources and DG units can be achieved by applying a proper sensitivity analysis through the optimal cost functions. Firstly, the DG sources such as photovoltaic, wind turbine and etc. are modelled. Then, economic modelling and the different system costs by taking the operation cost, the cost of replacement and maintenance into account are calculated and compared.

The proposed domestic microgrid system varies with thermal and electrical load in the presence of local and global grid will be simulated using HOMER software [13] to show the proposed optimization method superiority. Simulation results depict that with punctual investigation and consuming and generating collation also in time control we could reach to cost reduction through optimized energy control.

II. SMART HOME GRID

The aim of power management technique introduced a generic solution to the different household technologies are configured in different houses. Moreover, multiple objectives are possible in this method and the goal of it can differ [3, 7]. Consequently, the method is very general and flexible. While, there is a common purpose and real control equipment in the home for both the controller and the overall area is required. Additionally, an optimization technique should be able to control a large number of homes. The method may be considered potential constraints and cooling equipment with technical constraints. The results can be optimized differently depend upon the optimization and management subject [11]. Figure 1 shows the schematic model of a domestic smart grid and energy flows which an be operated locally or connected to the grid.

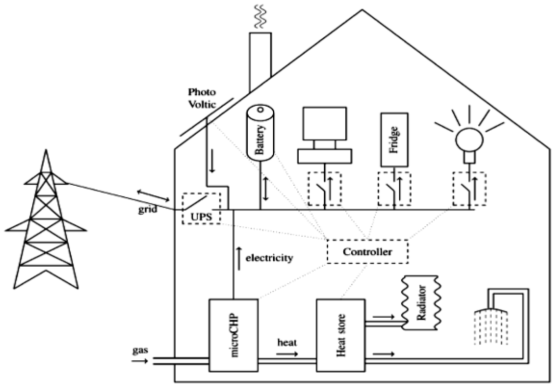

Figure 1. Schematic of domestic system load [3]

A. Regional or local network

The exchange of the electricity energy from and into the grid can be optimized without requiring to be cooperated with other houses on a local scheduling [11]. Optimization may be subject to a shift in demand for electricity to useful periods (e.g. overnight), and the peak is corrected.

The ultimate goal is to create an independent house. A house that is physically separate network, called an islanding house. Relatively, easy fault detection and loss reduction of transmission line are the advantages of local network [8, 10].

B. Global Network

The electrical energy of a group of houses is optimized together in the microgrid. This reduces network congestion at peak times and peak shaving occurred so that better adapted between demand and production is obtained. Compared to previous network, a better load profile with less changing is produced. Moreover, this system required more sophisticated algorithms for controlling large scale demands [3, 8].

III. DG MODELING

In this paper, a hybrid electrical-thermal demand has been studied by using wind power, solar arrays, batteries, transformers, generators, boilers and electricity grid. To determine economical modeling of domestic system, modelling of DG units and their main components are necessary, which are explained mor in detail in this section.

A. PV System

In this paper, a PV array dc power source to produce the scattered radiation, direct solar radiation is considered. The system output is equal to [14]:

$$P_{pv} = f_p P_p \frac{I_T}{I_s} \qquad (1)$$

where P_{pv} is the PV de-rating factor, f_p the rated capacity of the PV array (kW), I_T the global solar radiation incident on the surface of the PV array (kW/m^2) and I_s is the standard amount of the radiation used to rate the capacity of the PV array (1 kW/m^2). Figure 2 shows solar radiation profile for the proposed case study of this paper [15].

B. Wind Turbines

The power of the wind turbine type, turbine height and area of operations is dependent. Overall, the results of the third wind power wind speed are related as follows [16]:

$$P_w = \frac{1}{2} C_p \left(\rho A_r\right) v_w^3 \qquad (2)$$

where ρ, A_r, C_p and v_w are air density, useful cross area of the turbine blade, turbine power coefficient and wind velocity, respectively. The wind turbine extracts a specific percent of the whole wind energy depends on the turbine tip-speed-ratio and blade pitch angle [17].

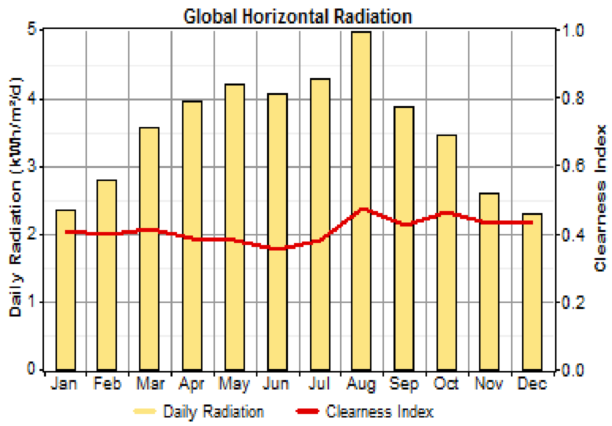

Figure 2. Intensity of solar radiation [15]

C. Synchronous Generator

The basic characteristic of the generator are the minimum and maximum power output, its expected lifetime of operation, type of fuel and the associated curves. In this paper, the fuel curve calculated by assuming the straight line for fuel curve which only depends on the output power and fuel factor according to [11]:

$$F = F_0 P_{Ngen} + F_1 P_{gen} \qquad (3)$$

where F_0, F_1, P_{Ngen} and P_{gen} are the fuel curve intercept coefficient, the fuel curve slope, the rated capacity of the generator (kW) and the electrical output of the generator (kW), respectively.

D. Batteries

A series of multiple battery banks Battery can store a certain amount of energy per unit of electricity in the energy storage capability to provide proper and desirable energy efficiency. This bank has ability to charge and discharge batteries in domestic systems in various operating conditions. The lifetime and its state of charge (SOC) are the important parameter of the battery in the control method [11].

To calculate the maximum rate of charge or discharge of the battery, using the kinetic model that the two tank batteries as energy modelling and demonstrate the battery capacity curve, Battery lifetime is expressed as [11]:

$$R_{bat} = \min\left(\frac{N_{bat} Q_{lifetime}}{Q_{thrpt}}, R_{bat,f}\right) \quad (4)$$

where N_{bat} is the number of batteries in the battery bank, $Q_{lifetime}$ the lifetime throughput of a single battery, Q_{thrpt} the total amount of energy that cycles through the battery bank in one year and Q_{thrpt} the maximum life regardless of throughput.

IV. ECONOMIC CALCULATIONS

In this section, estimates of costs and revenues and ultimately economic analysis of local and global networks of smart home are described. Capital cost includes cost of construction, electromechanical equipment, power transmission, engineering and project design costs, capital depreciation, Maintenance and replacement cost.

The initial cost of the entire plant, the cost of replacement and repair, annual operation and maintenance and operation should be considered for DG. Economic modelling plays an important role in the optimization and simulation process in order to operate the system to minimize total cost (NPC). The idea of finding a minimum total NPC among all the possible combinations for a house grid is the purpose of optimization.

The total NPC represent the whole life-cycle cost of a DG system. An initial construction costs for each system equipment (year zero), replacement cost (at the end of life), interest expense, operation and maintenance during the lifetime of the system is considered. It should be noted that the cost of fuel for the generators has been considered individually. The total NPC is expressed as [11, 15]:

$$C_{NPC} = \frac{C_{ann,tot}}{CRF\left(i, R_{proj}\right)} \quad (5)$$

where $C_{ann,tot}$ is the total annualized cost, i the annual real rate, R_{proj} the project lifetime and $CRF(.)$ is the capital recovery factor. The salvage value of the equipment at the end of each life period is calculated from the following equation [18]:

$$S = C_{rep}\frac{R_{rem}}{R_{comp}} \quad (6)$$

where C_{rep}, R_{rem} and R_{comp} are the replacement of the component, the remaining life of the component and the lifetime of the component, respectively.

Also, the costs of the energy consumed in the average cost per kWh of electric energy produced by the system are calculated as [11]:

$$COE = \frac{C_{ann,tot}}{L_{prim} + L_{def} + L_{grid,sales}} \quad (7)$$

where L_{prim} and L_{def} are the total amounts of primary and deferrable load, respectively, that the system supplies per year. Also, $L_{grid,sales}$ is the amount of energy sold to the grid per year.

Besides, the costs for equipment construction, replacement, repair and fuel costs combined with annual cost of equipments are obtained. This amount along with any additional cost such as the cost of pollution fines will result the total annual cost of a home system. Although, the cost associated with the cost of energy impact on the smart home operation but the total NPC cost is even more important [3, 7].

V. CASE STUDIES

In this section, different domestic system models with electrical and thermal loads are simulated by using DGs modelling explaned in the perviuose section. The simulation is carried out by HOMER/ENERGY software [13]. To aim the goal of the paper in each state the calculated operational cost (OC), capital cost (CC) and the NPC will be compared.

A. Domestic Microgrid Isolated from Gird

Figure 3 show the schematic model of a isolated microgrid with renewable DG units. The renewable units consist of solar and wind power supplies.

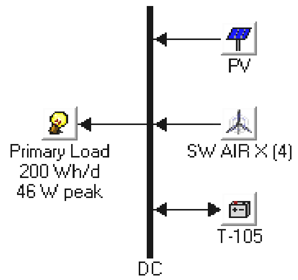

Figure 3. Schematic model of isolated domestic microgrid [13]

The proper economic configurations for the proposed model are listed in Table 1. It is obvious that between different structures for the isolated domestic microgrid, the economic model related to the case consist off battery and solar units. Also, it can be concluded that the case with wind power supply will not be cost effective. It should be mentioned that for case-1 both the operating cost and NPC have also the lowest values.

Also, as expected and reported in [19], except the cost related to instalation of PV cells, for a specific operating cycle there is no need to additional cost that show the superiority of using solar units.

Table 1. Economic conditions domestic load model issolated form the global or local grid

Case	Instalation cost [$]	OC [$]	NPC [$]	COE [$/kWh]
with solar power only	1060	16	1239	1.479
with wind power only	1460	59	2142	2.558
With both wind & solar units	1860	58	2520	3.010

B. Domestic Load with Independent Generator

In the current system in addition to renewable energy sources and storage devices, a conventional AC generator system is also used for feeding load. The schematic is shown in Figure 4. To charge and discharge the battery and interact with AC systems the power electronic converters must be used. Electrical and thermal load data used on the network is shown in Figure 5 [15].

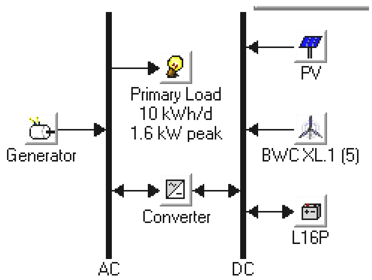

Figure 4. Schematic model of hybrid AC/DC microgrid with standalone generator [13]

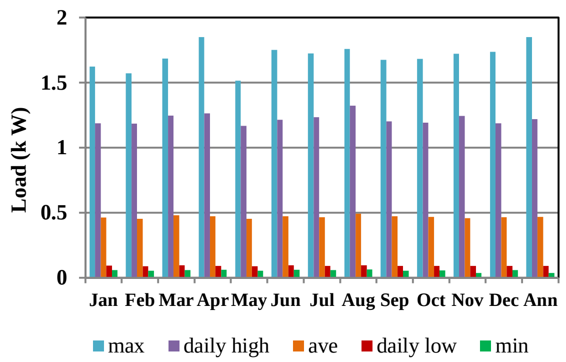

Figure 5. Monthly Load Profile [15]

Table 2 shows the best configuration that is economically possible. The lowest OC is obtained for the states that the generator don't exist (case-1). This is despite the fact that the total cost of NPC has the highest value in this case.

Table 2. Economic configuration for the system with standalone generator

Case	Instalation cost [$]	OC [$]	NPC [$]	COE [$/kWh]
With both wind & solar units and without generator	34260	639	41082	1.073
with solar power and generator unit	9970	1181	22577	0.579
With wind & solar & generator units	13870	1165	26304	0.675

The second and third cases presented in Table 2 that the PV system with batteries and generators for wind power in the system are used have been analyzed in detail. It is obvious that the system using renewable DG, the solar system - Batteries - Generators (case-2 in Table 2) has the lowest cost to the NPC system and is desirable respect to the other. Thus, the wind turbine is not favourable for single house from an economic standpoint.

Figure 6 shows the costs of operation, installation, replacement and salvage of all available resources for the case-3 in Table 2. As illustrated in this figure, the operating and fuel costs of the system for the different operating years almost constant and have considerably low values. Also, the contribution of each component in these costs is shown in Figure 7. It is obviuos that during the opearting cycle the major cost is related to wind power units and no additional cost required for solar cells.

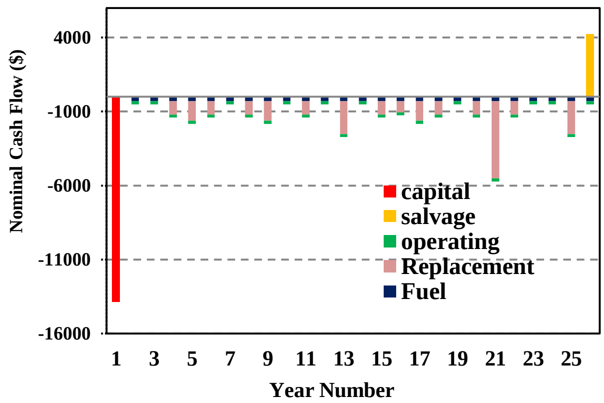

Figure 6. Costs of operation, replacement, installation, and storage for case-3

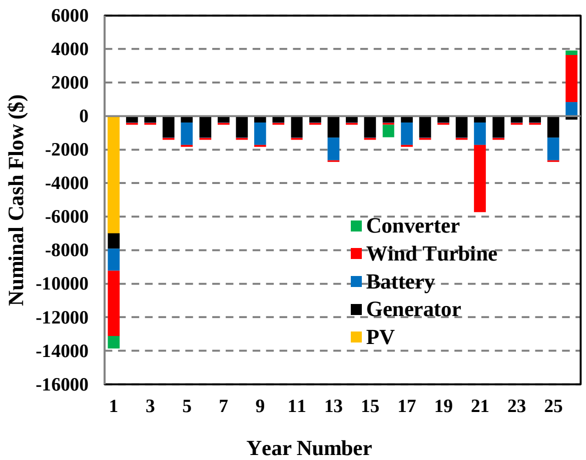

Figure 7. Costs associated with each component for case-3

Figures 8 and 9 show the cost of operation, installation, replacement and maintenance of the proposed model and each component from all sources for the case-2 in Table 2. It is observed that due to lack of wind systems in this state, the cost of a generator a little increases with compared to Figure 6. However, this system has the lowest cost of NPC. It can be deduced that because of no using wind power unit both the installation and NPC costs of the system will be decrease. Also, the overall cost of energy is considerably reduced in this case respect to other structures.

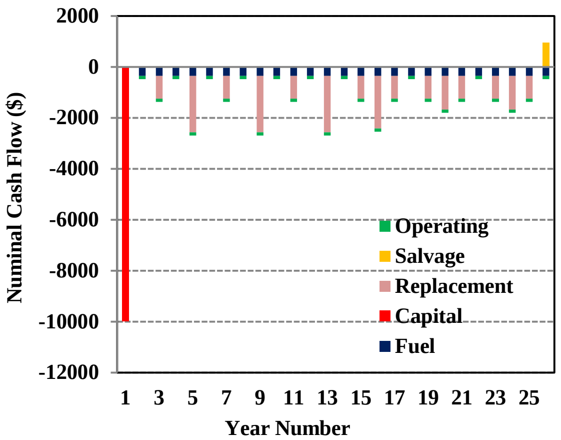

Figure 8. Costs of operation, replacement, installation, and storage for case-2

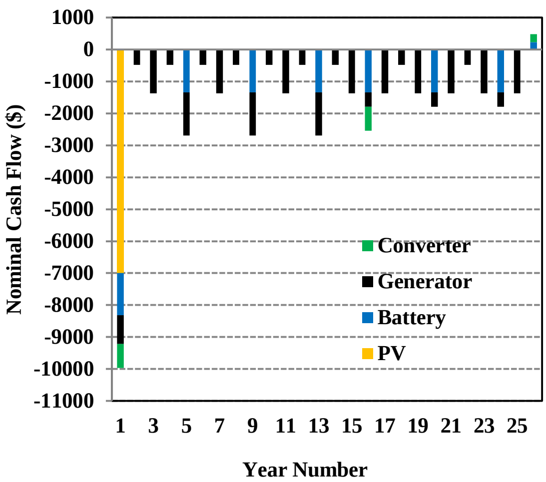

Figure 9. Costs associated with each component for case-2

C. Micro-Grid Including Thermal Load Management

In the third model, a group of house connected to the electrical grid is studied. Also, In this case thermal load is applied and thermal-electrical management system will be simulated. The system schematic is shown in Figure 10.

Table 3 summarizes the best economic cases can be defined for the system. As can be seen in the third case that the renewable sources in used, the lowest OC can be obtained and the NPC is not too much difference. For better comparison, this case and the configuration that neither of the renewable sources is used (case-2) will be described in detail.

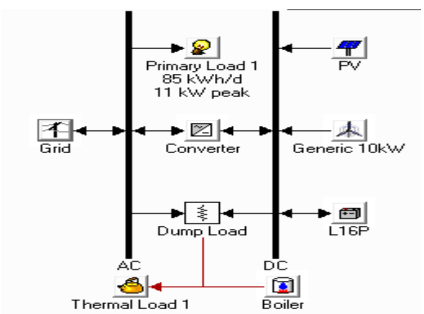

Figure 10. Schematic model of hybrid AC/DC microgrid with thermal-electrical load [13]

Table 3. Economic conditions improved for thermal–electrical domestic load model connected to the grid

Case	Instalation cost [$]	OC [$]	NPC [$]	COE [$/kWh]
with wind power only	18400	35125	421282	0.553
without renewable DG	8400	36061	422017	0.555
With both wind & solar units	25400	35022	427098	0.569
with solar power only	15400	35948	427718	0.571

Figure 11 shows the OC and the CC of case-2 and case-3 associated with Table 3. As expected the costs substantially decreases in case-3 especially in the last year. Figures 12 and 13 show the costs of operation, installation, replacement and maintenance of the entire grid and each units of the system in case-3 where all the renewable DG units are used to supply load in different years. It is observed that due to the use of wind and solar systems in this case, the overall cost of system will be reduced over time.

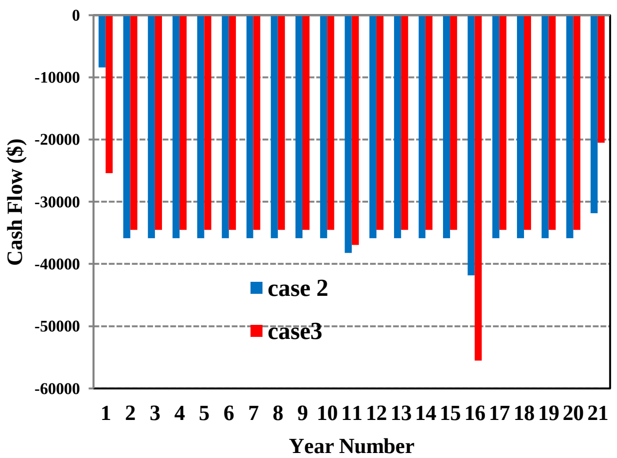

Figure 11. Comparison of cash flow costs as function of operation years for case-2 and case-3 in Table 3

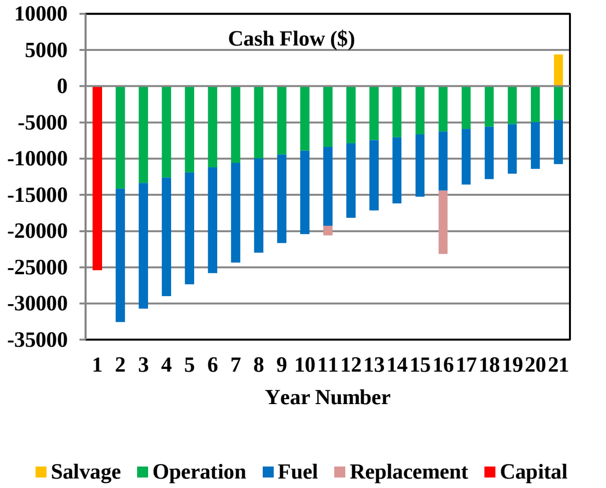

Figure 12. Modification costs of installation, operation and replacement for a operating cycle for case-3

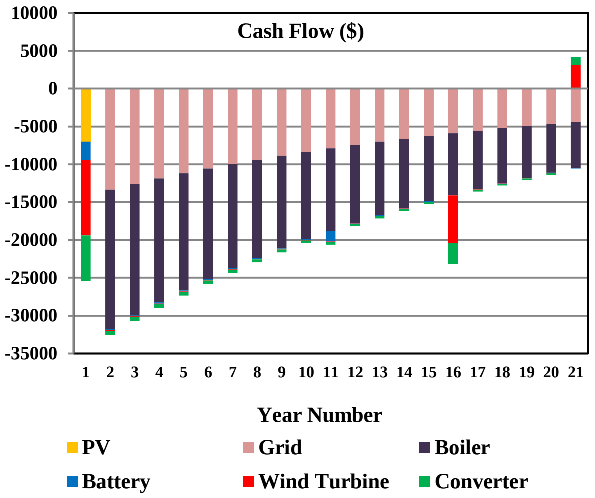

Figure 13. Cost variations for each thermal and electrical units as function of operation year for case-3

It can be obtained that the loads can be controlled suitable in the smart microgrid by applying proper management and control. Also, Although renewable DG unit especially wind power supply have large instalation cost but more cost effective operating and also salvage cost will be achieved during whole life cycle of operation. Indeed, a few years after instalation the spending cost is compensate compred to microgrid system without uisng renewable power units.

VI. CONCLUSIONS

In this paper management and control of smart microgrid with regard to load control including DG units is studied. This optimal management of resources and renewable distributed generation is achieved through sensitivity analysis and cost effective model is concluded. Different domestic micro grid systems by taking the costs of replacement and repair, operation and also capital cost into account are simulated and the comparisons are classified and discussed. The proposed models include hybrid AC/DC microgird connected into or isolated from global grid. The results show the effect of each DG resource on the overall cost of the system and also represent how much of each DG unit supports the demand.

It can be deduced that the domestic loads can be controlled suitable in the smart microgrid technologies. Also, competitive market in the early years may not be aligned with other sources, but only a few years after their initial, the compensation in the cost is deduced. It can be concluded that although the initial installation cost of renewable DG units especially wind power units are high but more reliable and cost-effective operation will be deduced with renewable connected power supply.

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BIOGRAPHIES

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