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RESEARCH ARTICLE

Modeling and Cost Optimization of an Islanded Virtual Power Plant: Case Study of Tunisia

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ABSTRACT

The renewable energy resources placed a crucial aspect in all residential, and industrial communities. In this article presents the optimal sizing for the design of virtual power plant (VPP) to plan, and operate the system proposed is a solution for Djerba Island in Tunisia also to determine the management over six different models as taking the factor cost, economics, and environment criteria, etc. An analysis is carried out by studying the potentials of wind energy, solar energy, water flow, and biomass, as well as collecting data from different sources. For the optimization of the virtual power plant, the HOMER Pro is the software utilize for help analyze an available data, also an economical utility form virtual power system project with a battery. The results showed that the best structure of virtual power plant among all feasible configurations, with a net present cost of the design proposed is 314.846 $, and a cost of energy (COE) produced are 0.4031$. We have obtained a good result to use the sources of the proposed system by providing a cleaner, and environmentally friendly environment for the communities by using renewable energies resources meeting the charge requirements as per Kyoto protocol.

Index Terms—Virtual power plant concept, cost of energy, optimal system design, economic and environmental optimization, HOMER Pro.

I. INTRODUCTION

Nowadays, as renewable energy sources are developed, and the demand for them increases. At the end of their useful life, conventional power plants are expected to be replaced by renewable energy sources and cleaner technologies. While renewable energy is expected to grow incredibly in coming years, its absorption rate is very low compared to other non-renewable energy sources [1]. In addition, there is a need to integrate renewable energy technologies into hybrid power systems to improve power reliability and capacity and to effectively reduce fluctuation [2]. A many research paper on off-grid and on-grid hybrid energy system utilizing a variety of optimization and tool. In [3] has proposed an autonomous renewable hybrid system energy hydro/wind/solar/diesel/battery to supply the Persian Gulf islands utilizing Hybrid Energy Resource Optimization (HOMER) models. In [4], a hybrid solar/wind/diesel/battery energy system that is isolated from the grid was studied on HOMER for a local village called Perumal Kovilpathy, an off-grid solar/wind/hydro/battery hybrid energy system designed on HOMER to electrify the remote and hard-to-reach villages in India's Himalayan region has been suggested by [5]. In [6], a comparative study of off-grid and grid-connected solar/battery systems for a rural community in Rwanda was examined by using HOMER.

Electrical energy has become a basic requirement for people to live in both rural and urban places, and the request is urban and island areas, and the request is rising day by day [7]. The huge increase in the fossil fuel prices [8] and decreasing fossil fuel reserves have led to an energy emergency. Alternative renewable sources of energy are suggested to face this energy crisis and reduce harmful gas emissions. Yet, a single renewable energy source could not satisfy the energy demand of the meet the energy demands due to the uncertainty of production renewable energy sources. As a result, hybrid renewable energy systems, including a variety of sources such as solar, wind, biomass, hydro, and energy storage systems are being recommended [9]. Hybrid energy system can be developed to operate off-grid or grid-connected systems and can use Energy Storage System (ESS) [10].

To use the renewable energy sources efficiently, and economically, each component must be aggregated, and selected. To ensure

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minimum investment and full utilization of the virtual power plant, we have chosen sizing and optimization techniques. As a result, the system can operate in optimal conditions with the appropriate configuration. In these locations, renewable resource has been the best alternative source of electricity generation. The most recognize alternatives of electricity generation are hydroelectricity, wind plant, tidal plant, photovoltaic also the biomass [11].

This system configuration offers greater reliability, and down cost than single-feed system. However, sizing of the system components is an important factor in the technical and economic viability of the system [13].

Generally, virtual power plant uses a both operating modes: on-grid, and islanded (off-grid). In two operating modes, virtual power plants system has there are some implications for consumer, and power systems. In [14], a hybrid system supplies the energy from Wind Turbines (WT), PhotoVoltaic (PV), Tidal Turbines (TT), Hydraulic source (Hy), Biomass source (Bio), and battery. Fuel cells, and storage batteries store the excess energy generated by the generators and release it in the event of a power outage.

The HOMER program provides a robust frame for user to compare many different economic, and technological options. In addition, it is possible to account for numerous variations, and uncertainties in the input data. A HOMER simulates the energy systems performances at every time of the year and display the energy available supply patterns and life cycle costs.

During the optimization process, the program searched for different possible configuration, renewable resource sizes, and demand satisfactions, taking into account the constraints to reach the most economical state [15] [16].

In this paper proposes the optimal solution of virtual power system composed by PV,WT,TT,Hy,Bio, and battery using HOMER software.

This article is organized as follows: section II presents the HOMER software, section III presents a description of study area location, section IV presents the energy demand, resources, and metrological data of proposed community, section V includes the best model of VPP and its components, and section VI includes main component models of the VPP. The evaluation of the system includes the economic and environmental criteria presented in section VI and section VII demonstrates the results and discussion of the work. In the end, the conclusion is presented in section VIII.

Main Points

- The core capabilities of the HOMER software make it easier to evaluate any possible system configurations and more precise in simulation, optimization, and sensitivity analysis.
- This study presents a virtual power plant's (VPP) optimal design and comparative studies based on real data on the Djerba Island, Tunisia, of six models and how it can be beneficial to the island to adapt to the frequent disturbances.
- With proper planning and sizing, it is possible to provide electricity to the island community in Tunisia.
- The results showed that the best structure of VAA among all feasible configurations, with a net present cost of the system, is 314,846$ and the cost of energy produced is 0,4031$.

II. HOMER SOFTWARE

A Hybrid Optimization of Multiple Electric Renewable (HOMER) software system simplified the assignment of designed on-grid and off-grid distributed generation (DG) systems for a variety of application.

In this study, the HOMER software was used for designing VPP. The HOMER is an optimization tool for VPP developed by National Renewable Energy Laboratory [5][6]. The basic functions of HOMER are imitative, optimization, and sensitivity analysis.

The HOMER Software helps in configuration of the suggested renewable electrical hybrid system, and leads to the answer to the following two questions:

- Which component makes sense including in the system design.
- You must use the quantity and size of every component.

A core capability from HOMER software helping with the evaluation them any possible system configuration, too more precisely in:

- *Simulation*: It attempts to create a feasible configuration for every possible combination you would like to take into consideration.
- *Optimization*: HOMER is an economical optimization model, allows to reduce fuel consumption. It's possible to define the criteria, so that you can see the best possible fits. Analog systems are classified also according to these criteria.
- *Sensibility testing*: It's a stage that models the effect of a variable on the control, e.g., the meteorological data, fuel cost, besides view the responses in the optimization virtual power plant.

The objective of using the HOMER function is to obtain a minimum net present value (NPC) is the present value of the system costs, e.g., of installing also operating all component over their lifetime less the current value of the components income he has been making money all his life. The cost includes capital cost, replacement cost, operation and maintenance cost, fuel cost, also network purchasing power costs. Revenue includes residual value and turnover of the network, in this case zero, because there is no connection to the network.

III. LOCATION OF THE STUDY AREA

Figure 1 present the geographic position of the study area on a plan. The study zone is situated in the Djerba quarter of Medenine, Tunisia. Djerba is an island of the Mediterranean Sea region of 514 square kilometers (25 kilometers by 20 kilometers, with a coastline of 150 kilometers), located to the east of the east coast of Tunisia. It is the biggest island on the North African coast and is located southeast of the Gulf of Gabes, bordering the eastern coast; Djerba is the closest to the southern bay of Boughrara.

Fig. 1. Geographical location of the study area.

The island of Djerba, Tunisia, is chosen as the case study to assess and analyze the potential resource and the feasibility of a proposed VPP for the community while considering the cost factor, economics, environmental criteria, etc.

IV. ENERGY DEMAND AND RESOURCES

A. Load Profile Assessment

The monthly charge profiles for the suggested communities are calculated with the residential charge demands in mind. Fans and lights are basic devices for charge calculation. The loading is divided into two seasons: winter and summer. In the summer, the charge is high due to the weather. In contrast, winter loads are lower. The HOMER profiles for daily and seasonal profiles are shown in Figure 2, and the mean power is 6.9 kW.

B. Resources and Meteorological Data

The power output of renewable energy sources depends primarily on meteorological data and the available resources in the project location area. The HOMER program processes those variables as inputs. The relationship of the output energy to the parameters is described in Section VI. Djerba Island parameters were taken from the NASA databases.

Figure 3(a) shows live global solar radiation; on the other hand, Djerba island as caught in Solar and obtained through HOMER

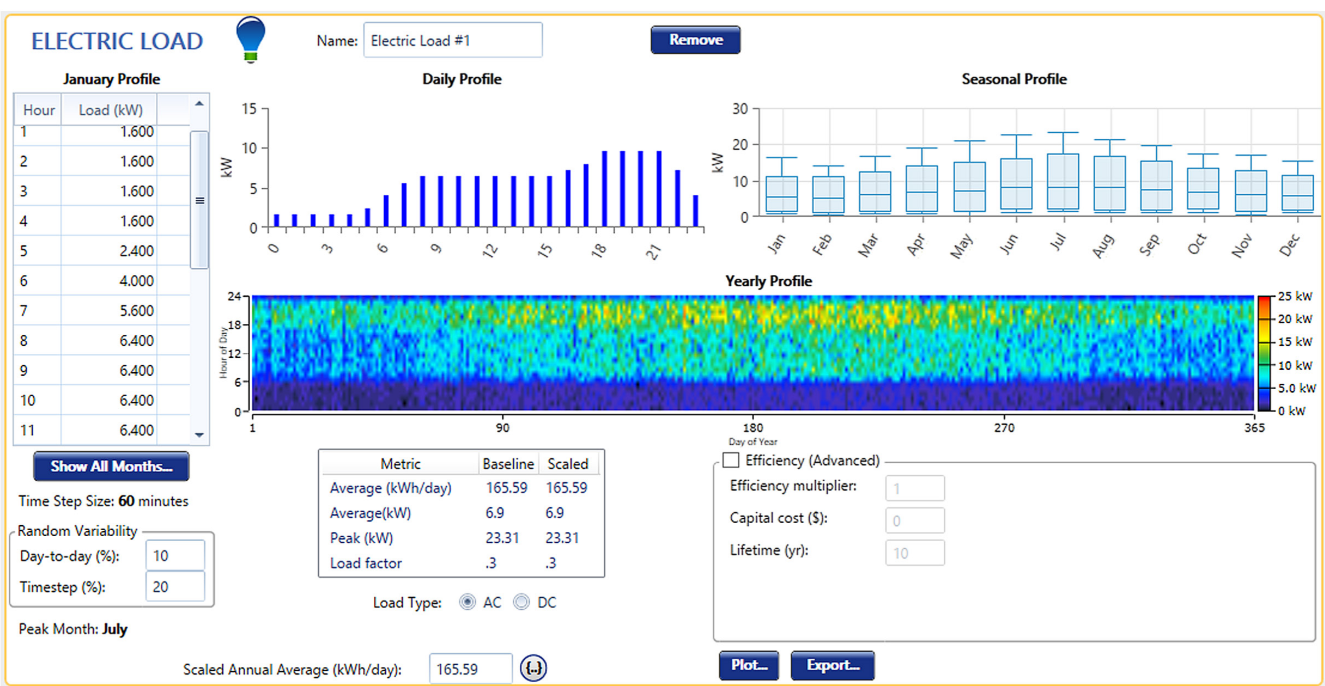

Fig. 2. Load profile.

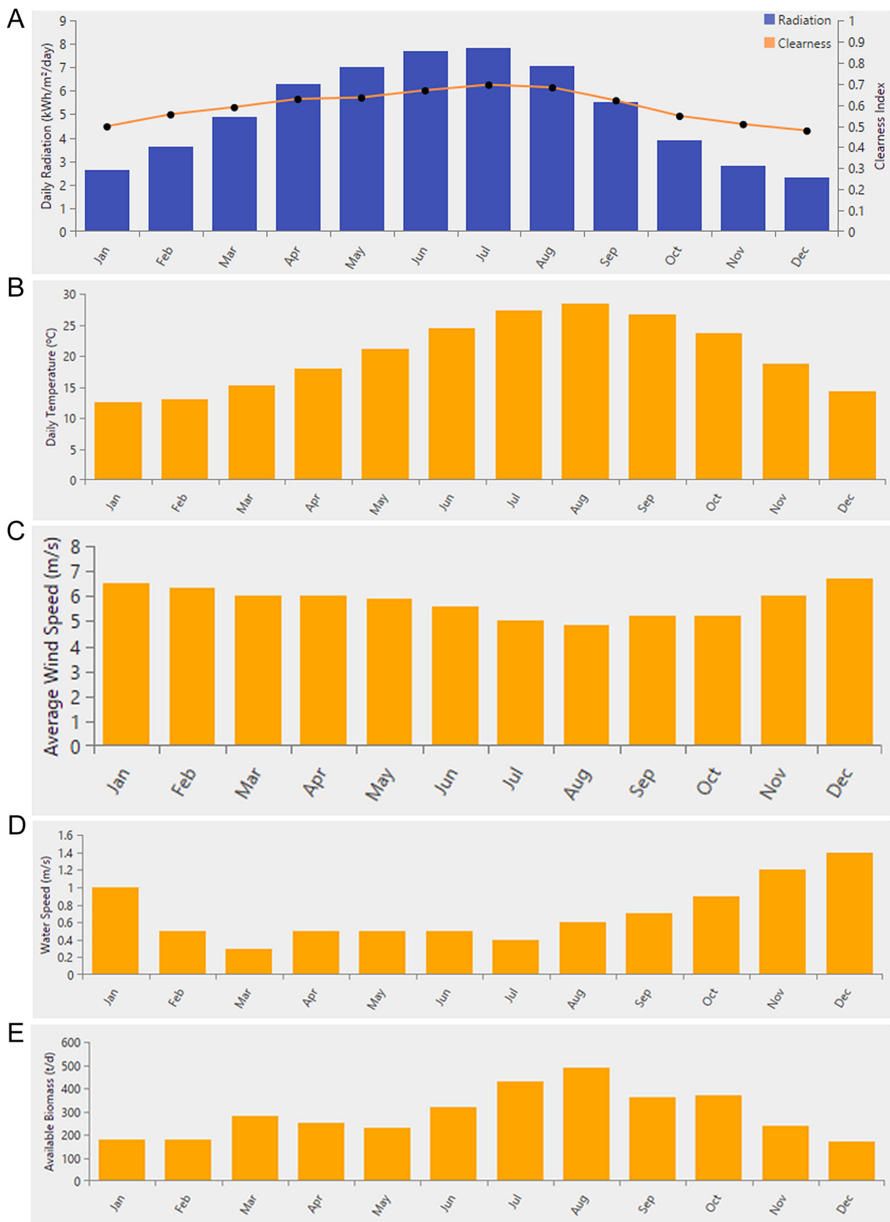

Fig. 3. Annual meteorological data of the Djerba Island: (a) daily irradiance; (b) daily temperature; (c) average wind speed; (d) water speed; (e) biomass resource.

software. The average solar access index was recorded at 0.6 and the average daily radiation was registered at 5.13 kWh/m^2/day with the mean temperature of about 21°C.

Figure 3 (b) shows the ambient daily temperature average. The mean yearly temperature was 23°C, with the top temperature in the summer from May through October and lowest temperatures in the winter. The hottest ambient temperature was recorded in August with a temperature of 28°C, while January was the coldest month with an ambient temperature of 12°C.

Figure 3(c) shows wind speed probability distribution and the average wind speed for this island was found to be 5.77 m/s. Also, the average tidal speed is 0.71 m/s as shown in Fig. 3(d). The available biomass resource for 1 year is 291.67 t/day in average value as shown in Fig. 3(e).

V. ISLAND VIRTUAL POWER PLANT STRUCTURE

Figure 4 shows the available energy delivery options and diagrams the virtual power plant system on the island of Djerba in Tunisia. This system is composed of photovoltaic power plants, wind power plants, tidal power plants and hydro power plants are considered as a renewable energy source. The biogas producer is used for a backup power supply to be activated in case of inadequate generation, and a battery bank as a source of compensation generation, converters and controllers.

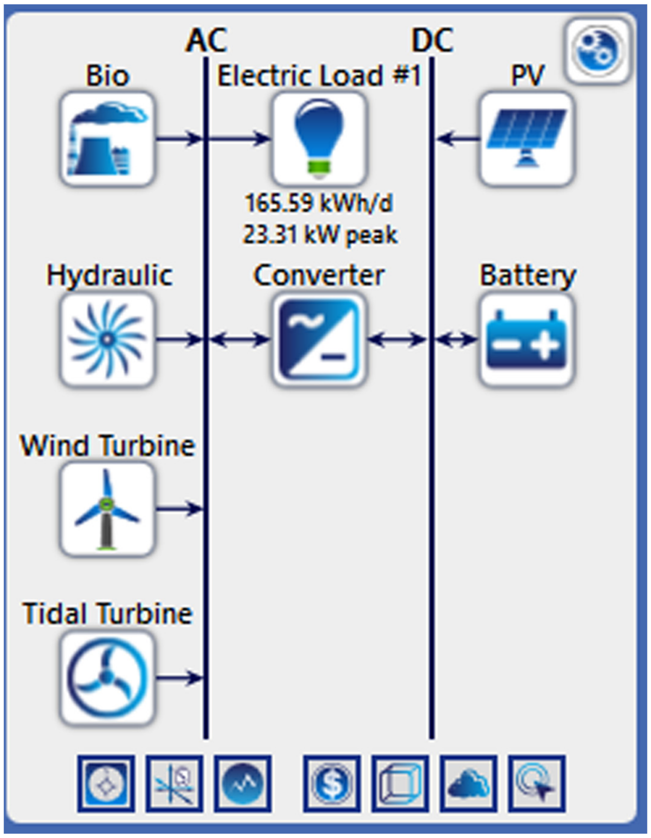

Fig. 4. Proposed scheme of an islanded virtual power plant in HOMER software model.

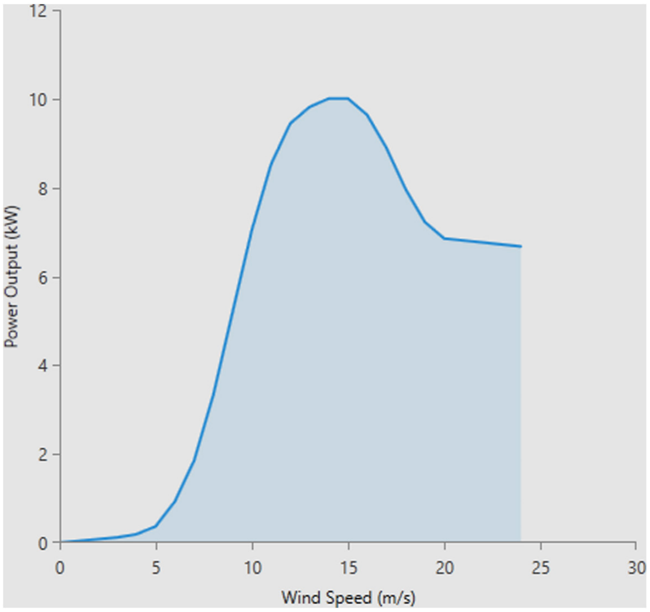

Fig. 5. The power curve of the generic 10 kW wind turbine.

TABLE I.
GENERIC 10 KW WIND TURBINE SPECIFICATIONS

Wind Turbine	Value
Type	Generic 10 kW
Rated power	100 kW
Startup. wind speed	3 m/s
Rated wind speed	12 m/s
Cut-out wind speed	21 m/s
Tower height	50 m
Rotor diameter	22 m
Swept area	2300 m²

VI. MAIN COMPONENTS OF THE ISLAND'S VIRTUAL POWER PLANT

The components of the energy optimization system involve hybrid modeling, in order to achieve its performance under various circumstances. The following mathematical model is used to demonstrate the proposed VPP system components:

A. Windpower Plant Model

Figure 5 indicates the power graph of a generic 10 kW WT. The capital, exchange, maintenance with the life from the turbine is represented by 18 000 $, 18 000 $, 200 $/year, and 20 years, respective. The output power for the wind turbine is shown by equation (1) [3] [17]:

$$P_{wt} = \frac{1}{2}\rho_{wt} C_p R_{wt}^2 v_{wt}^3 \tag{1}$$

where R is the blade radius, ρ_{wt} is the density of the air, C_p is the coefficient of power, and v_{wt} stands for the speed of wind.

The pertinent details for the generic 10 kW wind turbine are presented in Table I.

B. Photovoltaic Power Plant Model

The power produced by a photovoltaic module is proportional to the area of the semiconductor that is exposed to sunlight, the area of the photovoltaic module, the average temperature, and the properties of the photovoltaic cell under industry standard solar radiation test condition [18]. So, the generated power can be determined by (2):

$$P_{pv} = \eta_{pv} A_{pv} G_t \tag{2}$$

where η_{pv} represents the rapid efficiency for the PV module table, A_{pv} represents the position of the module used in this system, G_t represents the total radiation. The photovoltaic panels are Trina Solar 300TSM-300PA14, with a lifespan of approximately 25 years, and the capital cost is 120 $/kW, the replacement cost is 120 $/kW, and the maintenance price is 10 $/kW/year.

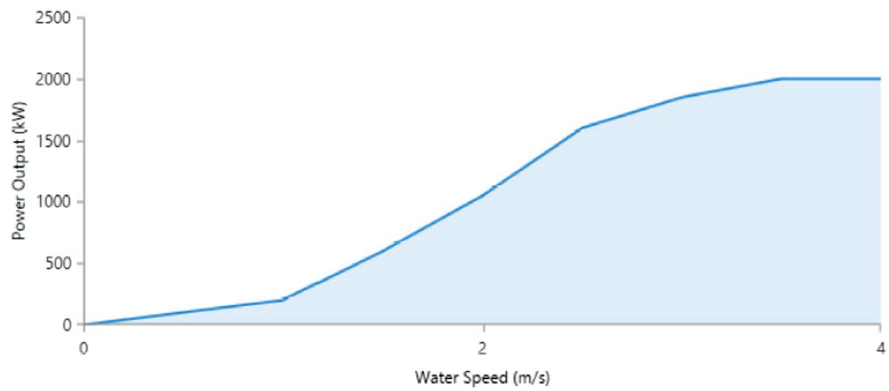

Fig. 6. The power curve of the AR2000 tidal turbine.

C. Tidal power Plant Model

The HOMER program offers various type of tidal turbine for use in Hydrokinetic, part of its component library. When selecting a Generic hydrokinetic 40kW tidal turbine, 4 cost parameters must be entered into the program, (a) capital (or installed cost and wire); (b) replacement cost; (c) maintenance cost; and (d) life span of the tidal turbine. For the purposes of this study, the following parameters were used: 14 000 $, 14 000 $ and 2700 $/year and 20 years, respectively. The power curve for the tidal turbine is shown in Figure 6. The output of the tidal turbine is represented by (3):

$$P_t = \frac{1}{2}\rho_t C_p \pi R_t^2 v_t^3 \tag{3}$$

Among them, ρ_t represents the density of seawater, R_t is the radius of the tidal current generator blades, v_t is the tidal flow speed, and C_p represents the coefficient of the power of the turbine, ranging approximately 0.35–0.5 [19].

The pertinent details for the Generic hydrokinetic 40kW tidal turbines are presented in Table II.

TABLE II.
TIDAL TURBINE SPECIFICATIONS

Tidal Turbine	Value
Type	Generic hydrokinetic 40kW
Rated capacity	40 kW
Manufacturer	SAE/GE
Cut-in tidal speed	1 m/s
Cut-out tidal speed	3.05 m/s
Operational tidal speed range	1–4.5 m/s
Swept area	314 m²
Rotor diameter	20 m

D. Hydroelectric Power Plant Model

The Generic 5 kW hydraulic pump component newly added in the HOMER components libraries was used to model the hybrid system for this purpose [20].

$$P_h = \rho_h gHQ \tag{4}$$

Where, is power capacity (5.494 kW),is water density (1000 kg/m^3), g is due acceleration at gravity (9.8 m/s^2), Q is the tip rate (0.0231 m^3/s), and H is effective gauge height through the turbine (m) is assumed by 80%. With a lifetime of approximately 25 years, it being noted that the capital cost is equal to 40 000 $/kW, and the replacement cost is 20 000 $/kW, and the maintenance and operation cost is 1200 $/kW/year.

E. Biomass Resources

Biomass is every organic material which can be convert to energies sources. It consists of materials of plant origins (agricultural residue, leave, and wood) and materials of animal origins (animals or humans wastes, soil organisms, animal carcass). In our case, the hotel wastes have been considered as the single biomass resources used for power generation. The input to the HOMER is the daily mean of the waste generation that could be utilized for biogas production. Based on survey conducted in the project area.

Biomass expressed as a net change in biomass, as biomass can change significantly over a specified period. The calculation is defined as [21]:

$$P_B = \frac{C_B \mathrm{h}_B m_B}{3.6} \tag{5}$$

Where, is the output power of biomass and is measured in kW. (in percentage) is the power conversion efficiency of biomass. The unit is the, and the unit is the kg/h. is the heating value of a biomass measured by MJ/Kg. In This study, a general-purpose biogas plant attached to an AC outlet.

HOMER considers the amount of the biogas generated when dimensioning the power plant. The capital costs, replacement costs, and maintenance cost for 1 kW biogas plant have been determined

TABLE III.
GENERIC 1 KWH LEAD-ACID BATTERY SPECIFICATIONS

Properties	Ratings
Nominal voltage	12V
Round trip efficiency	80%
Lifetime throughput	800 kWh
Maximum charging current	16.67 A
Maximum discharge current	24.33 A

to be 3 000 $, 1 500 $, and 0.1$/hr [22], respectively. The lifetime of the generator has been fixed at 20 000 hours operating. The minimal charge ratio has been supposed by 50% capacity.

F. Modeling Storage of Energy System

The power storage is one of the most critical component of integration systems generated by different renewable energy sources. A 12V general-purpose lead-acid battery with 1 kWh of energy storage is provided to assure extremely reliable service and economical operation. Specifications are given in Table III. The capital costs, replacement costs, maintenance costs, and life of the battery are 300 000$, 300 000$, 10.00$/years, and 10 years, respectively.

G. Energy Converter Model

Universal system converters are provided to rectify the AC generator outlet to DC, which is much less expensive than a bi-directional convertor. Consider capitals, replacements, maintenances, durability, and efficiency of the converter are 250$, 250$, 10$/year, 5 years, and 95%, respectively [23].

VII. EVALUATION CRITERIA OF THE SYSTEM

This part is reserved to evaluate the electricity production. There are different elements that affect the cost, and those cost. The cost is expressed in kWh/MWh, and typically include the capital, the discount rate, subsidy, and operating cost like fuel, maintenance, etc. The costs of a decentralized energy system need to be standardized or levelized. The mathematical representations for various costs and emissions will be discussed in the bellow.

A. Economic Criteria

1) Net present cost

The Homer program calculates the total NPC by adding up the sum of the discounted future cash flow for every year in the lifetime of the project. The NPC total, it's an economic output in HOMER software and allows for the ranking all the systems configuration in the optimum result, also calculated a total annualizes, and discounted energy costs. A mathematical representation of the NPC is described by (6).

$$C_{NPC} = \frac{C_{TAC}}{f} \tag{6}$$

where C_{TAC} presents the sum of annualized costs and f is the capital recovery factor.

2) Levelized cost of energy

Levelized cost of energy (COE) present the minimal price at which power has to be delivered to the end users in order to achieve break even over the lifetime of the project, and expressed in ($/kWh). To determine the COE from HOMER software, we simply to take the annualizes costs of power generation (total annualizes costs less for the cost of serving the thermal charge) and divided by the total electric load being served. It is the mean system operating cost to produce one kilowatt-hour of power. COE is defined as the ratio of the total annualize systems cost to the total available power generation of the system per year [24]. A mathematical equation for COE is described by (7).

$$COE = \frac{C_{a,tot} - C_{boiler} H_{serv}}{E_{serv}} \tag{7}$$

where $C_{a,tot}$ presents the total annualized costs of the system ($/year), C_{boiler} presents the boiler marginal costs ($/kWh), H_{serv} presents the total thermal charge served (kWh/year), and E_{serv} presents the total electrical charge served (kWh/year).

3) Cost of operation

The operating costs are the estimated value of every cost and revenue other than initial capital cost. The HOMER software displays operating costs in an optimization result list. To calculate the operating cost, we use (8).

$$C_{op} = C_{an,tot} - C_{an,cap} \tag{8}$$

where C_{op} is a sum of annualized costs of the system ($/year), and $C_{an,cap}$ is a total annualized capital costs ($/year).

4) Initial capital costs

The capital costs of the components are the total installed costs of component at the beginning of the project.

5) Renewable fraction

A renewable fraction is the portion of the energy supply to the loads that are derived from renewable energy source. The HOMER software calculates a renewable fraction using (9).

$$f_{ren} = 1 - \frac{E_{nonren} - H_{nonren}}{E_{serv} + H_{serv}} \tag{9}$$

where E_{nonren} presents the nonrenewable electrical production (kWh/year), $E_{grid,sales}$ presents the energy sold to the grid (kWh/yr) (included in E_{serv}), H_{nonren} presents the nonrenewable thermal production (kWh/year), E_{serv} presents the sum of electrical charge served (kWh/year), H_{serv} presents the sum of the thermal load served (kWh/year).

VIII. RESULTS AND DISCUSSIONS

HOMER software analyzes the engineering practicability, and life cycle cost of the virtual plant for every year, and test the inputs for the given time period. Simulation capacity is long-term to Homer. Optimization, and sensitivity analysis are performed to find the simulation capacity with user specified classes. The less costs for the virtual power plant depend on the total net costs. The optimization is performed on

TABLE IV.
OPTIMAL SIMULATED ELECTRICAL COMPONENT

Specification Model	**Component**	**Unit**	**Best Hybrid System Per Model**					
			Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
System architecture	PV Array (TrinaSolar300TSM-300PA14)	kW	62.6	69.2	79.5	119	-	-
	Wind Turbine (Generic 10 kW)	Number	1	-	1	-	6	15
	Biogas (Generic Biogas Genset)	kW	5	5	-	-	5	-
	Pumped Hydro (10kW Generic)	kW	11	11	11	11	11	11
	Tidal turbine (AR2000)	Number	1	1	1	1	1	1
	Converter	kW	18.3	16.7	20.8	22.8	18.7	37.8
	Battery	Number	100	120	208	224	336	728
	Dispatch strategy	LF or CC	LF	LF	CC	CC	CC	CC
Cost	COE	$	0.403	0.413	0.458	0.484	0.740	1.29
	NPC	$	314.846	322.628	357.454	377.675	577.651	1.01M
	Operating cost	$/year	11.206	12.711	12.940	15.114	19.666	32.018
	Initial capital	$	169.985	158.303	190.169	182.292	323.419	593.740
Power production	PV Array	kWh/year	94.087	104.097	119.518	178.434	-	-
	Wind Turbine	kWh/year	23.366	-	23.366	-	140.197	350.492
	Biogas	kWh/year	8.590	11.350	-	-	12.160	-
	Tidal Turbine	kWh/year	20.792	20.792	20.792	20.792	20.792	20.792
Capacity factor	PV Array	%	64.1	76.4	73	89.6	-	-
	Wind Turbine	%	15.9	-	14.3	-	81	94.4
	Biogas	%	5.85	8.33	-	-	7.02	-
	Tidal Turbine	%	14.2	15.3	12.7	10.4	12	5.6

TABLE V.
FINANCIAL ANALYSIS SUMMARY

Component	**Capital ($)**	**Replacement ($)**	**O&M ($)**	**Fuel ($)**	**Salvage ($)**
Hydraulic	80 000	0	31 026,04	0	0
Tidal Turbine	14 000	4 463,30	34 904,29	0	−251 536
Battery	30 000	26 781,44	12 927,52	0	−3 348,96
Biogas	15 000	5 497,79	12 856,42	5 611,94	−769,21
Power Converter	5 476,39	2 323,49	2 359,87	0	−437,30
PV Array	7 508,99	0	8 089,39	0	0
Wind Turbine	18 000	5 738,53	2 585,50	0	−3 234,03

the basis of these inputs, and the table results. During optimization, HOMER considers the profile of every generator based on the specifications of the user.

In this sense, Table IV presents six the most efficient system architectures and their respective costs. Six the inputs to the model of design have been provided as follow:

- Model 1:PV+WT+Bio+Bat+Hy+TT
- Model 2: PV+Bio+Bat+Hy+ TT
- Model 3: PV+WT+Bat+Hy+TT
- Model 4: PV+Bat+Hy+TT
- Model 5: WT+Bio+Bat+Hy+TT
- Model 6: WT+Bat+Hy+TT

Table IV indicates the component details, and a technical, economical specification for the optimal hybrid systems in all the model.

We can see that the optimum solution composed of 62.6 kW photovoltaic plants, a 10 kW WT plant, a 5 kW biogas generator, 100

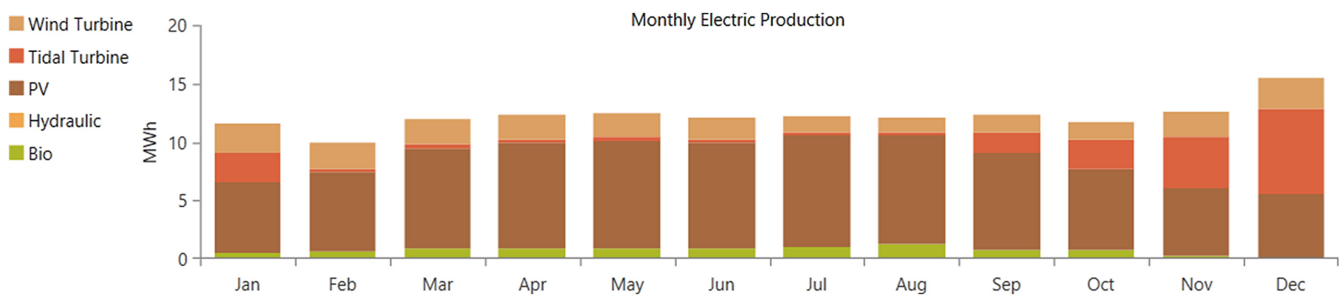

Fig. 7. Monthly average electrical outputs from the optimal configuration system.

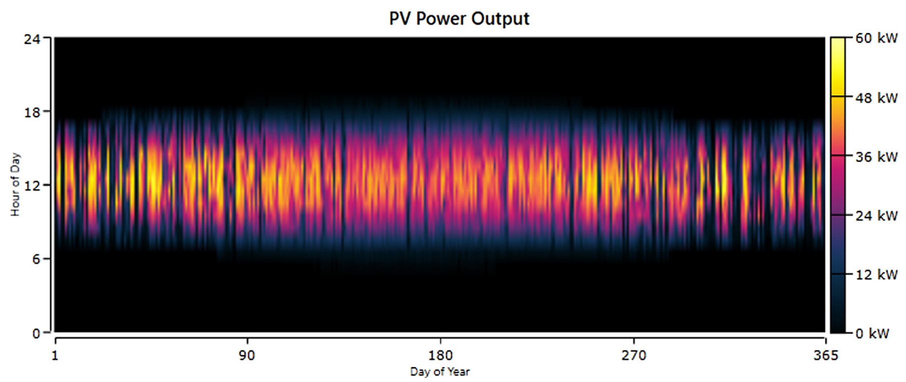

Fig. 8. The PV array output.

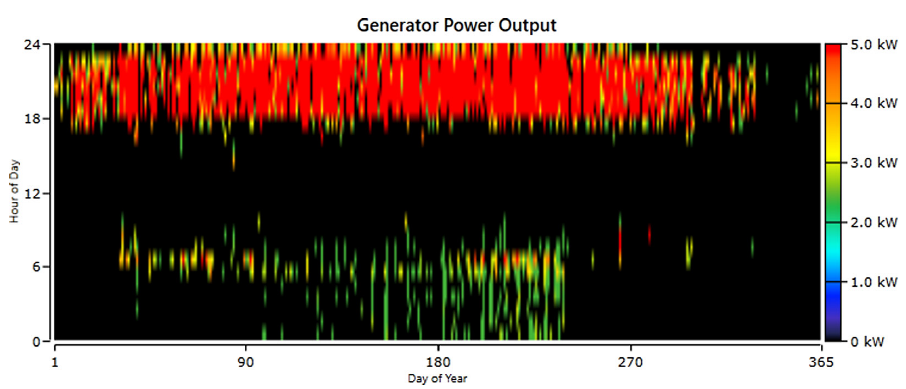

Fig. 9. Biogas generator output.

batteries, an 11 kW pumped hydroelectric storage, a 1 tidal turbine, and an 18.3 kW generator bidirectional converters with one load following dispatch strategies. All sources are presented. Its costs of power (COE) and its total NPC was 0.403$ and 314,846$ respectively, and the renewable fraction is 100%.

The assessment of the virtual power system in term of investment, operation, also maintenance cost is shown from Table V. The capital costs in the system are owned by the hydraulic system power is higher, and the operation and maintenance costs. A total cost of the systems over the life for the project is calculate at 314,846$ based on this assessment.

Figure 7 presents the monthly contribution of the virtual power system (all sources used in the system) throughout the year. The HOMER Pro indicated that the energy supplied by PV was 64.1%, the energy supplied by WT was 15.9%, the energy supplied by TT was 14.2%, and the biogas produced was 5.85%.

The production of the photovoltaic generator all year long, presented in Figure 8, shows that the photovoltaic power production occurred from 06:00 a.m. to 06:00 p.m. and was most likely to peak (55.7 kW) from 10:00 a.m. to 2:00 p.m. In addition, the total yearly photovoltaic electricity production is 94.087 kWh/year, which corresponds to a system capacity factor of 17.2%.

Figure 9 demonstrates the performance of the biogas plant throughout the years. It has been very likely that the generator would be turned on from 06:00 p.m. till midnight. Also, the biogas producer was able to supply its maximum electrical power (5 kW) from 06:00 p.m. to 00:00 a.m. The yearly electricity generation of the biogas production was 8.590 kWh/year, which is a system capacity factor of 19.6%.

Figure 10 presents the energy and the production profile from the converter for a period of 1 year with a capacity factor of 13.3% for the inverter and 0.862% for the rectifier. Fig. 11 shows the state of load of the battery storing station for 1 year.

A randomly selected week's energy situation of generation and consumption in 1-year period of a VPP operation is given in Fig. 12. In Fig.12, the PV power production, wind turbine power, tidal turbine

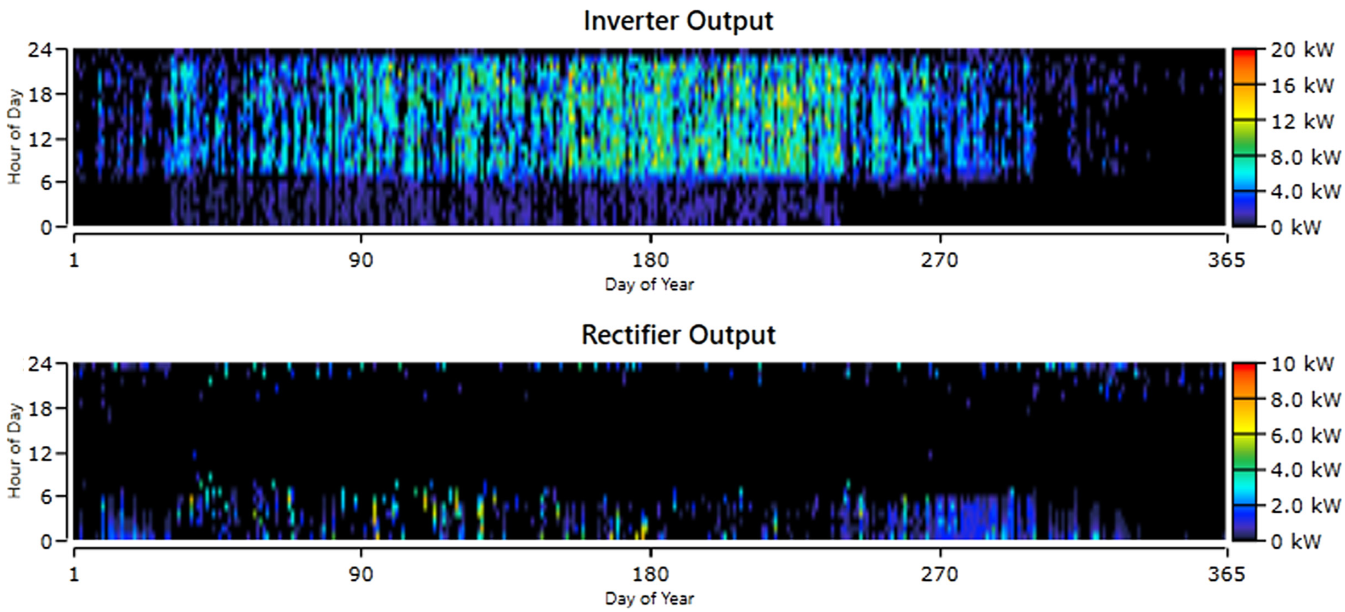

Fig. 10. The energy output profile of converter during period of 1 year.

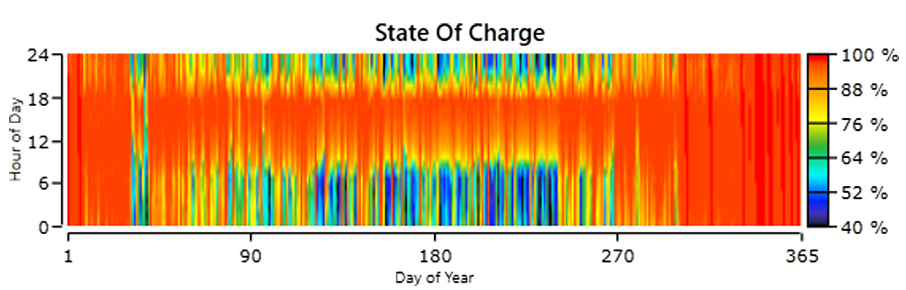

Fig. 11. State of charge of the pumped-hydro storage station.

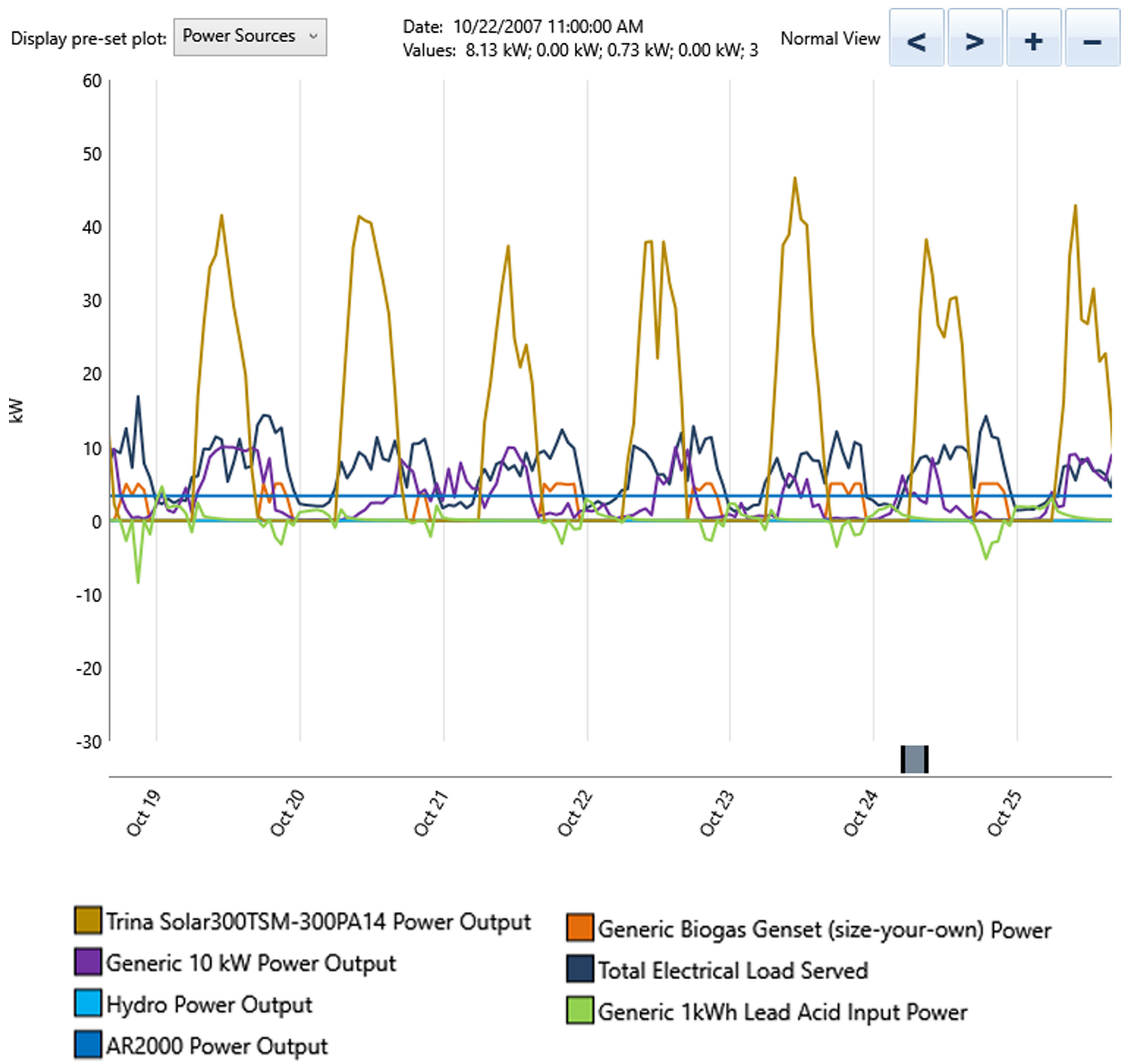

Fig. 12. One-week energy generation–consumption graph of the virtual power plant.

power, load, and the amount of load energy are presented. When all the sources of the VPP production are more than just the uptake, the energy is provided to the charge alone of a VPP system, and excess power is sent to the utility grid. When PV production is below the consumption, necessary energy is bought from the network. In this operating strategy, the battery is used.

IX. CONCLUSION

This study provides a detailed overview of how the potential of renewable energies can be realized in Tunisia with optimal design and is a comparison study of real data for Djerba Island. The study compared six categories, and how it can be beneficial to Djerba Island to address the frequent power outages and disruptions and to encourage the utilization of renewable energy sources in these communities.

In this study, a proposed VPP consists of a photovoltaic energy plant, a wind energy plant, a tidal energy plant, a hydropower system, a biogas generator, and an energy storage system based on battery bank designed to supply power for the island of Djerba, Tunisia. Yet, the optimal for dimensioning and operating this additional system should be done properly so that maximum benefit can be obtained. We find an optimal sizing of all components based on the available supplied irradiation in the study area, wind turbine, water turbine, biomass, water pressure, and charge data. The study also provides projected economical and environmental analyses of system based on the actual electrical load of Djerba Island over a period of 1 year.

HOMER software can be utilized to analyses a variety of structure of electrical energy systems, and is useful for calculating costs, and in the scheduling of virtual power plant where microgrid. With appropriate scheduling, and dimensioning, it may be possible to provide power to the island's community in Tunisia. In this sense, a 62.6 kW PV power source, 1 wind turbine, 1 tidal turbine, 5kW biomass generator, 11 kW hydro pump, 8.109 kWh/year energy storage unit are optimal for the chosen charge profile. The effect of virtual power plant sources degradation demand increase, grid outage, and diesel fuel price increase were studied in a PV-wind-tidal-hydraulic-biomass virtual power plant generator-batteries-inverter combination. When the effects of those factors are included in the system, the resulting increase in were observes over a baseline system. With NPC is 314.846$, the discounted COE is 0.4031$, and the operating cost is 11.205.61$, and the renewable fraction is 100%. It is expected that the systems VPP will be more economical with the further developing of the power will be more economical with further development of renewable energy and the decrease in component costs.

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