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Electrification of Egyptian army camps in remote areas using renewable energies: An Application of HOMER in New Valley

Original Article

Ahmed M. Selim[1], Naglaa K. Bahgaat[2], Azza G. Haggag[3]

[1,3]Architecture Department, Modern Academy for Engineering and Technology, Cairo,
[2]Communications and Electronics Engineering Department, Faculty of Engineering, Canadian International College (CIC), El Shiekh Zayed, Egypt

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Corresponding Author:

Ahmed Mohamed Selim, Architecture Department, Modern Academy for Engineering and Technology, Cairo, Egypt, **Tel:** 01028282427, **Email:** ahmed.selim@eng.modern-academy.edu.eg

Abstract

Egypt's government has strived to develop the electrical sector in the five past years. Nevertheless, the border regions and remote areas (RAs) are still suffering from a lack of access to electricity.This study aims to propose the optimum hybrid technology system by using Renewable Energy Resources (RER)to obtain the necessary electricity for army camps (battalions) in (RAs) and focusing onNew Valley as a case study. In this respect, the technologies for providing electricityby (RER) were discussed. Then, the (RER) potentials for army camps in (RAs) wereidentified based on the climatic zones in which the five sectors of the Egypt army forcesarelocated. The meteorological data were allocated forNew Valley. As well, the architectural design principles and specifications were assigned for the (battalion). Therefore, the electrical profile was estimated for it. By HOMER Pro software, three hybrid technology scenarios were determined through the simulation and the optimization process. Finally, based on the concluded scenarios from HOMER Pro. Statistical analysis was performed using the comparative method to allocate the optimum scenario.This scenario was the third scenario that uses a diesel generator with PV panels and Wind turbines. It is worth noting that the study limitation is to provide the demand for electricity for ordinary jobs, excluding the (battalion) military function.

I. INTRODUCTION

Egypt has significant progress in the electricity sector field to confront the rapid urbanization and economic growth.Where the demand for electricity extremely increased between 1500 to 2000 megawatts per year in the last 5years[1]. Nevertheless, the border regions and places that arefar from civilization are still suffering from a lack of access to the major service and utilities (clear water and electricity).In urban studies, these areas were defined as remote areas (RAs)[2]. In fact, (RAs) are normally out of government grid electrification coverage. Thus, to overcome this challenge, "Off-Grid Electrification" (OGE) is considered the optimum solution to electrify these areas depending on renewable energy resources (RER). Where it is probably neither economically nor technically viable to rely on traditional grid electrification in these regions[3].

From another hand, the energy sector in Egypt has many achievements in the field of (RER). In 2022, Egypt's electricity production from thermal plants reached 80% with a capacity of 162,092 GWh, and from renewable energy 20% with a power of 8663 GWh (12% of which was from wind energy, 2 % solar energy, and 6% hydro energy)[4].

More specifically, army camps are vital settlements for military missions with specific geographic locations[5], most of them are located in border areas or(RAs) for security purposes. Moreover, army camps may be constructed for a specific function or multi-purposes functions. These functions specify the type of base camp to be Intermediate Staging Bases (ISB) or Forward Operating Bases (FOB). It affects the type of required facilities to support appropriate operations. The FOB can be tactical, logistics or training bases[6]. Therefore, providing an electricity source for it is a critical issue. Additionally, reliance on a single off-grid energy source isn't sufficient tacticity.

Based on that, and to overcome this challenge, hybrid systemsare considered the magic key[7]. Where, the hybrid system supports the combination of different energy resources, whether renewable or power generators that are used in mini-grid networks.

This research aims to propose the optimum hybrid technology system to obtain the necessary electricity for army camps (battalions) in border areas or (RAs) according to three parameters:geographical location, the climatic zone, and the actual demand for the electricity for the ordinary jobs and excluding the battalion military function.Hybrid Optimization Model for Electric Renewables (HOMER) software was used as the analytical tool to proposethe hybrid systems and to apply a technical and economic comparison between the specifications of systems used in different regions.

II. LITERATURE REVIEW

II.1 Renewable Energy Resources (RER) and (OGE)

Recently, seventeen goals were adapted to achieve sustainable development at the 2015 UN summit under the title "(Transforming our World: Sustainable Development Plan 2030)". The new agenda focused on promoting affordable and clean energy (goal 7)[8]. From this point of view, most countriesturned to (RER) to achieve this goal based on their needs, limits, level of technology, and social systems[9]. Renewable energy relieson producing energy from naturally replenished sources instead of traditional sourcessuch as fossil fuels. (RER)can be used for electricity generation, water heating, cooling, and transportation[9].

In this respect, sun and wind are considered the most important of (RER) in the middle east and north Africa to provide clean energy. More specifically, the use of Solar Cells / Photovoltaic cells(PV), concentrated solar power (CSP), and Wind turbine technologies can generate electrical power (GP) depending on the type of the system, and location[1] as illustrated in (Table1).

Table 1: (RER) generation sources

	System Description	Location	GP (Watts per unit)
Solar Energy	Type:Solar Cells / Photovoltaic (PV) cells. Technology: convert Global Horizontal Irradiance (GHI) of sunlight into a direct electric current.	• Rooftop • Isolated central plants	According to cells array module (One cell can produce 2 watts) Average GP from 250 to 400 watts
	Type :Concentrated solar power (CSP). Technology:converts Direct Normal Irradiance (DNI) into solar thermal energy by using mirrors. Electricity is generated when the concentrated light is converted to heat.	• Central plants	According to cells array module
Wind Energy	Type: Wind turbines and transformer. Technology: Electricity is generating when turbine blades rotated around a rotor. Varied in sizes and capacity, affected by wind speedat certain height. While transformer converts DC to AC.	• Rooftops	Small turbines: GP from 500 to 1000 watts
		• Stand alone	Small independent turbines: GP up to 2 MW
		• Stand alone	Large independent turbines: generate electricity up to 3 MW or more.

Meanwhile in, Off-Grid Electrification (OGE) is not limited to the electrical power generation process by (RER).Where, (OGE) consists of the following main components[15]: Energy generation source (stand-alone units), Energy storage units (batteries), and Backup units (like Glycerol fuel cell)[16]. Additionally, (OGE) is classified according to energy capacity, coverage area, and the number of beneficiariesasshown in (Table 2).

Table 2: Characteristics of the OGE applications

	Mini-grids	Micro-grids	Stand-alone
Energy capacity	<10MW	< 100kW	< 20 kW
coverage area	8 to 49 km2	3 to 8 km2	< 1 km2
Number of beneficiaries	10.000 to 100.000	1000 to 10.000	Usually, 1 to 1000
Size	Communities	Communities	remote small communities/ Individual buildings

I. II.1.1. Renewable Energy Resources in Egypt

Egypt is a country with high potential in terms of (RER). The percentage of (RER)represents 20% of electricity production sources in 2020[4]. According to the plans of the New and Renewable Energy Authority (NREA), it is expected to increase the proportion of renewable energy to 42% by 2035. In fact, electricity production by (RER) is linked to the climatic reigns in Egypt. Where,The Housing and Building Research Center (HBRC) divides Egypt into eight different climatic zonesas illustrated in Figure(1)[17]. Each zone has its own unique resources. However, solar and wind energy remain the dominant resources in most zones as shown in Figure 2.

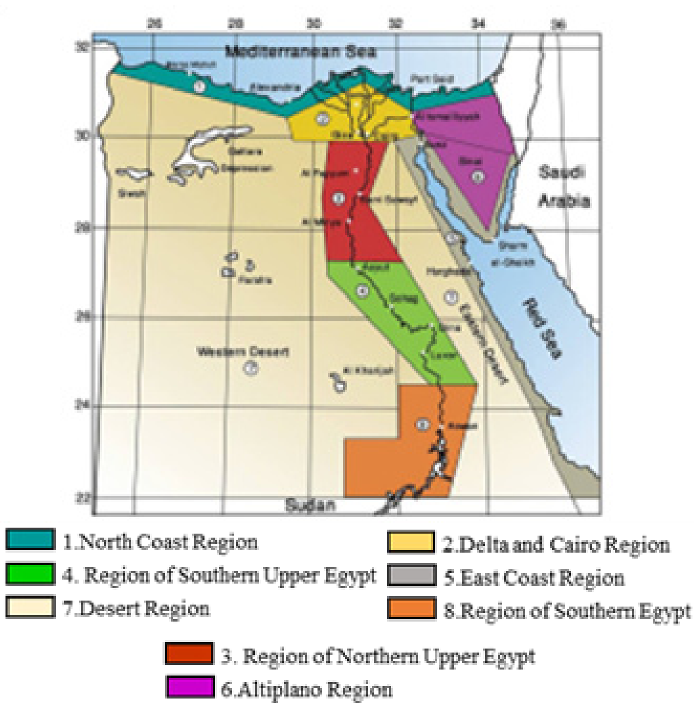

Fig. 1: HBRC classification of climatic zones

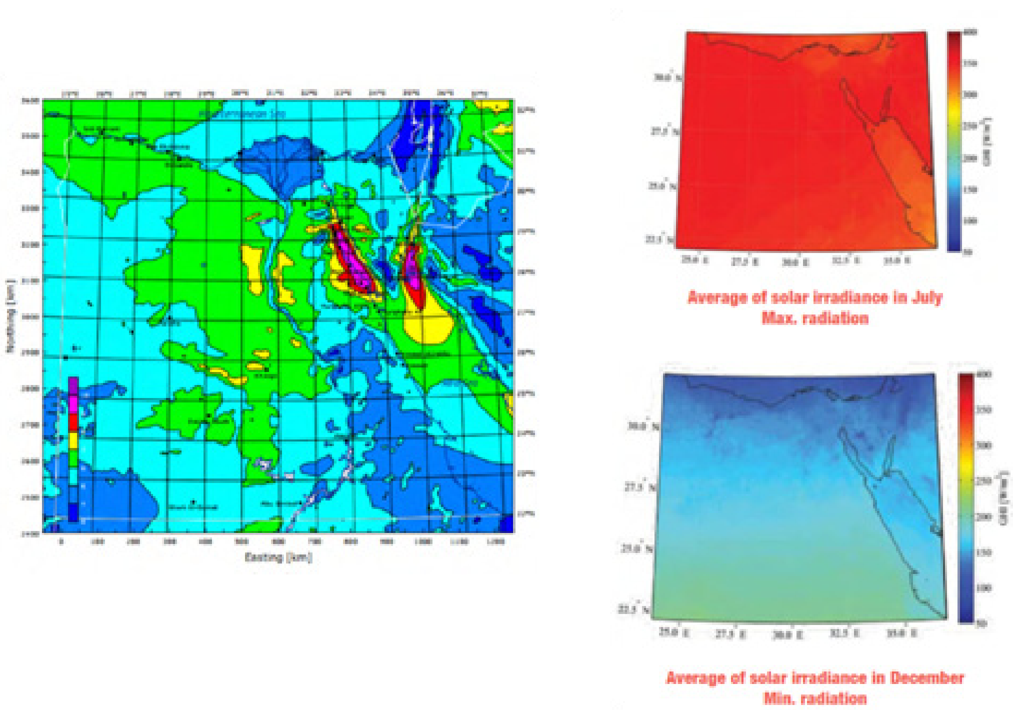

Fig. 2: Average wind speed and solar brightness

The New and Renewable Energy Authority (NREA)has set up several power generation projects using (RER)[18], and has proven their effectiveness and high capabilitiesas illustrated in (Table 3).

Table 3: The power generations projects using (RER)

	Off-Grid Remote Areas	Climatic zone	Existing Mega Projects	RER		Capacity
				S	W	MW.
1	North and South Sinai	East canal zone	Projects under feasibility study			
2	Matroh, Salloum	West Region				
3	Northern coast, Ras Elhekma.	North Region				
4	The coasts of the Gulf of Suez and the Red Sea, Nouba, Aswan, Qina, New Valley, Natroun Valley, El-Wahat	South Region	Gebel El-Zeit Wind Complex			580
			Zaafarana Wind Complex			545
			Ras Ghareb			260
			West Bakr			250
			Gulf Of Suez (under construction)			250
			PV Benban			1465
			PV Plant KomOmbo			26
			Kuraymat solar thermal power-CSP			140

These mega projects, whether existing or under construction, are connected to the national electricity network, as they are national projects. Butthere are many other off-grid projectsusingsolar energy (PV panels) spread in the Western Desert in the areas of Farafra, Abu Minqar, Darb Al-Arbaeen and Siwa, as well as in the Eastern Desert in the areas of Marsa Alam, Halayeb and Shalateen[18].

II.1.2. Army camps in (RAs) and the potential (RER)

Egyptian army forces are deployed to protect its land through service and combat battalions. Each battalion is located in a climatic zone and hasthe potential of (RER). More specifically, army camps are vital settlements for military missions with specific geographic locations[5], most of them are located in border areas or (RAs) for security purposes. In fact, providing electricity source for it is a critical issue, not only for providing the quality of life of officers and soldiers, but also for the security and stability of the battalions to perform their tasks, including control, monitoring, communication with surrounding points, warning, and other military tasks. Therefore, (OGE) by using (RER) according to the army camp location can provide electricity for these camps. In this regard, New Valley is considered both a border area and (RAs). It represents a focal point for the Egyptian army force to protect the southern and western borders. The meteorological data for New Valley can be described as shown in (Table 4).

Table 4: The meteorological datafor New Valley.

Regions	Solar power for PV(W/M2)	Solar power for CSP (W/M2)	Wind speed: M/S	Average daily temperature
New Valley	200 - 350	290 - 370	5.5 at 50 M height	34o C

II.2. Army camps classification and architectural design

Army camps are physical locations designed to sustain and protect deploying forces. It is one of the vital components of military missions in various regions[5]. Armycamps are graduallyclassified in terms oftheir size into Platoon, Company, Battalion, and Brigade. Additionally, it can be tactical, logistics, or training bases [22]. The architectural design of army camps is governed by four main principles including scalability, sustainability, standardization, and survivability whatever the purpose ofit. Subsequently, there are many factors for planning and designing army camps (battalion) as illustrated in (Table 5)[23], such as:

- Determining the type and function of the camp.
- Expected base camp population (according to camp size).
- Anticipated lifetime span.
- Level of services (Basic, Expanded, or Enhanced).
- Commander operation plans.
- Environmental factors.

Table 5: Specifications of the battalion.

Scope	Classification	Analytical Description
Construction standards	Semi-permanent (Enduring type)	Building and facilities are designed and constructed to serve a life expectancy of less than 10 years and can be expanded to 25 years with maintenance and upkeeping of facilities.
Army camp size[24,25]	Battalion	• Population 1000 occupants. • Area without standoff 600,000m2. • Dimensions 500x 1200, Parameter length 3400m.
Level of services[26]	Enhanced	Improved to operate at optimal efficiency and sustained operations for a long duration. Services are flexible, durable, nearly self-sustaining, and primarily implemented through contracted support.
Utility planning[27,28]	Water	50 gallons /person day.
	Electricity	3.5 kilowatts/person.
	Wastewater	40 gallons/person day.
	Solid waste	10 pounds/person day.

II.2.1. Army camp (Battalion) energy needsprofile

The energy needed for operating an army camp (Battalion)is defined as the needed energy for providing training, accommodation, andsustaining military forces and weapons platforms. In addition to the energy demanded for tactical systems[29]. The energy demand of the battalion can be estimated based on the planning and design factors, life cycle requirements, consumption sources, and operating hours[30]. In this regard, an electrical energy profile was calculated excluding the battalion military function based on the population of occupants (1000) person, and the electrical demand per person (3.5 kilowatts/person) as illustrated in (Table 5).

II.2.2. The current Situation ofenergyresources for(Battalions) in Remote Areas

Due to the distribution of the Battalionsin many areas, whether connected to the electricity network or not, as well as in remote areas. The power grid of these camps consists of three components[15]:

• A power source (e.g., generator, power plant, batteries).

• Distribution system (power distribution panels, power cables, transformers).

• Consumption sources (such as air conditioners, lighting,and communication equipment).

In terms of power generation sources, most basecamps are powered by individual generators. These generators are usually inside a containeras shown in Figures3 (a)and (b). It generates energy either for a specific building (like billeting) or a specific equipment (such as refrigerators or air conditioners), or for a group of facilities (such as multiple billeting areas).

Fuel oil is often used as an energy source[31]. It is often not supplied in pipelines connected to a distribution network but is brought to the site by a tanker wagon or tanker truck. These vehicles are often prime targets for enemy forces' attacks in high-risk regions.The operating costs of military camps and their facilities are going high, especially in hot climatic conditions where the requirements of air-conditioned workplaces and other mission-related areas are critical. Several NATO countries are trying to reduce their main dependence on fossil fuels, and some are also considering a zero-carbon footprint during their military activities in the near future[32]. So, the need for RER, especially solar and wind energy is increasing as an available resource in most of Egypt and theArab world regions.

Fig. (3a): Electricity generator inside a safe container in military base camp

Fig. (3b): Generator serves multi spaces inmultiple areas

II.3. HOMER Software as a tool foroptimizing hybrid system viability

"Hybrid Optimization Model for Electrical Renewables"(HOMER) is a simulation analysis software. It is the global standard for optimizing microgrid design in all sectors, from villages to military camps. It has been used by more than 250,000 system designers and developers in over 190 countries[33]. Developed originally by the National Renewable Energy Laboratoryto work as a design and investment decision tool for selecting the optimal configuration, size, placement, and dispatch of the multiple energy sources feeding the off-grid energy system[34]. Three powerful capabilities characterize the program, Simulation, Optimization, and Sensitivity analyses. During simulation, the software attempts to simulate a viable system for all possible combinations of equipment that are considered. Through the optimization process, the best possible design and configurations were obtained, and the system can identify the least-cost options for microgrids or other distributed generation electrical power systems. Other sensitivity analyses identify the impact of variables such as wind speed, fuel costs, etc., and alert how the optimal system changes according to these variables by comparing thousands of possibilities[33, 35].This study is related to the design, simulation, and optimization of a PV, and wind turbines as the main (RER) for generating electricity in military rural areas using HOMER software.

II. METHODOLOGY

This study was divided into three sections as illustrated in Figure 4:

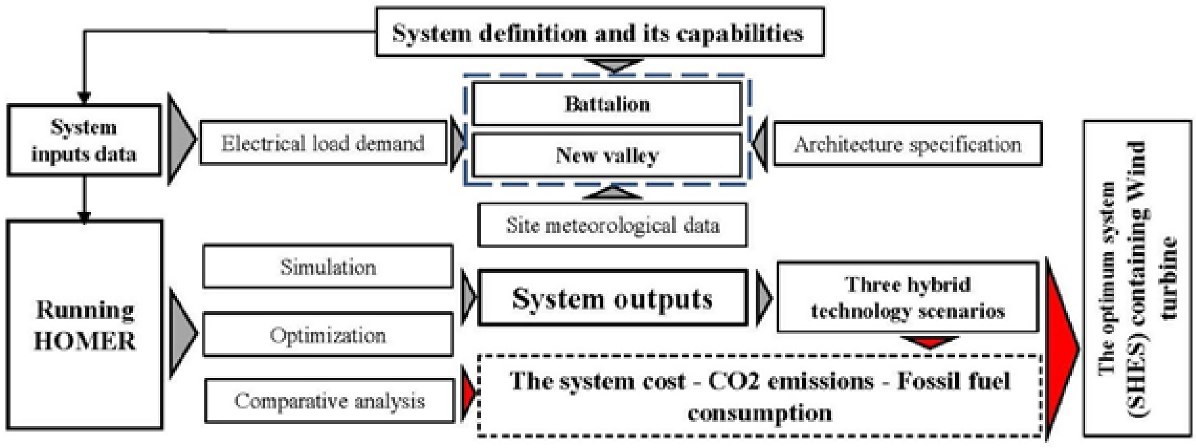

Fig. 4: Study framework by HOMER Pro

III.1. The first section:

"desk-based research", and by using the inductive method, the study discussedthe Renewable Energy Resources (RER)applications and focused on solar and wind energy. (RER) in Egypt was identified. Then, the (RER) potentials for army camps in (RAs) were identified based on the climatic zones in which the five sectors of the Egypt army forces are located. The meteorological data were allocated for New Valley. As well, the architectural design principles and specifications were assigned for the (battalion).Therefore, the electricaldemandwas estimated based on the population of occupants (1000) person, and the electrical demand per person.

III.2. The second section (by HOMER Pro):

Based on the previous data identified in the first section, itwas used as input to HOMER software.Two steps were achieved as follows:

• The simulation process was performed under load profiles of the Battalion for 1000 persons, in thesouth region New Valley.The electrical power capacity was sized for 3.5 KW/ person, considering 10% overload and 10% expansion for the future. HOMER Pro is used to search for the most cost-effective system configuration in terms of net present cost (life cycle cost). Particularly, the optimization algorithm in the HOMER Pro searched for the most effective system configuration by comparing the electric and thermal energy demand that the system can supply.

• The optimization process was implemented to sort and filter designed systems according to the defined criteria. There are three scenarios deducted. The first contained the battalion with only a diesel generator.The second scenario contained a diesel generator works with the photo voltaic station (PV) panels and converter to convert the DC power into AC and anenergy management system (EMS) that actively monitors and manages base camp equipment and zones as shown inFigure (5). The third scenario is done by using adiesel generator with PV panels and adding awind station to the system and also using a converter and EMS as shown in Figure (6).

III.3.The third section:

Based on the concluded scenarios from HOMER Pro. Statistical analysis was performed by using the comparative method to allocate the optimum scenario.

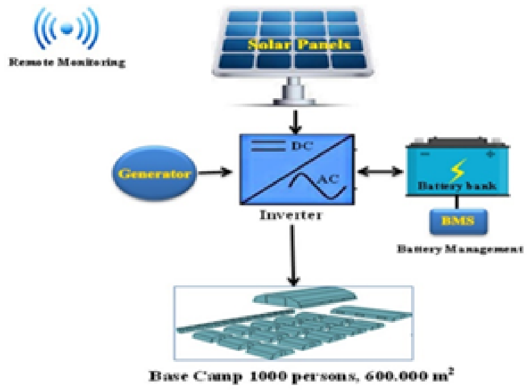

Fig. 5: The SHES system with PV panels

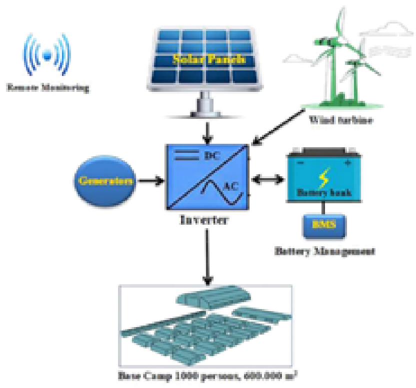

Fig. 6: The SHES system with PV panels and wind turbine

III. RESULTS

Regarding the simulation process by HOMER Pro. Three scenarios were concluded as illustrated below:

I. IV.1. Using traditional diesel generator

This model consists of a diesel generator CAT-400kVA-50Hz-PPto feed the loads in the camp, which is estimated at 3.5 kW/Person. The generator works for approximately 10 years.Specific Fuel Consumption was 0.314 L/ kWh, with mean electrical efficiency 32.4%, Figure 7 a, b and c illustrates the monthly and daily fuel used to generate the electrical energy consumed in the camp and the monthly electrical production of the Diesel generator, while Table 6 discusses the results for this model.

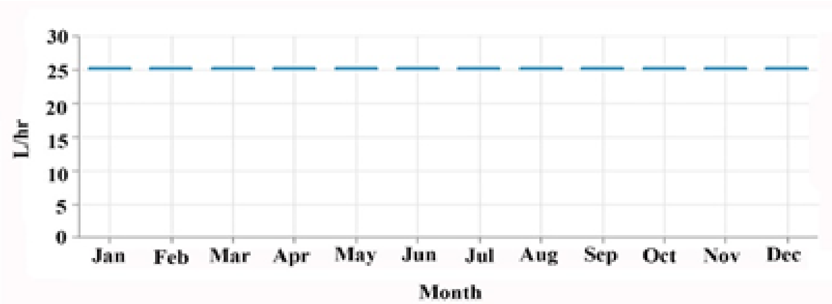

Fig. (7a): Monthly fuel consumption of the diesel generator

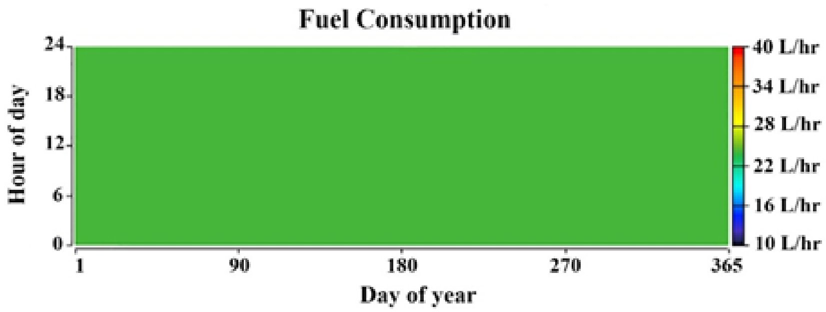

Fig. (7b): Daily fuel consumption of the diesel generator

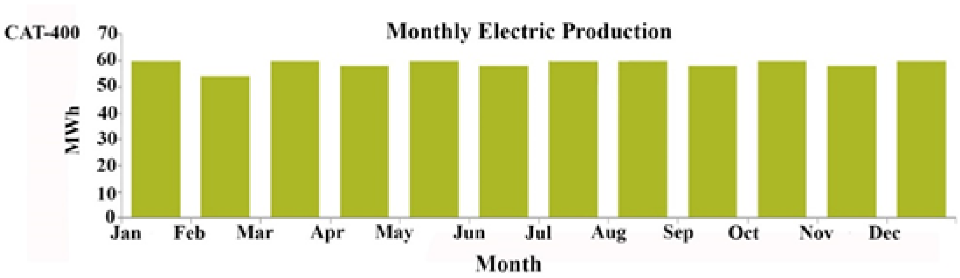

Fig. (7c): The monthly electrical production of the Diesel generator

Table 6: Homer Pro. Output values for diesel generator only

Quantity	Values	Units
Electrical Production	700,800	kWh/yr
Mean Electrical Output	80.0	KW
Total fuel consumed	219,822	L
Avg. fuel per day	60	L/day
Specific Fuel Consumption	0.314	L/Kwh
Fuel Energy Input	2,163,049	kWh/yr
Mean Electrical Efficiency	32.4	%
System cost	2,841,753.28	$
Carbon Dioxide	580,220	kg/yr
Carbon Monoxide	877	kg/yr
Unburned Hydrocarbons	6.59	kg/yr
Particulate Matter	0	kg/yr
Sulfur Dioxide	1,442	kg/yr
Nitrogen Oxides	3,179	kg/yr

II. IV.2. Smart Hybrid Energy System (SHES)

The SHES is designed to work in stand-alone mode or connected to the local grid. The SHES combines into the system of the following technologies:

• 21% efficiency (SPR-X21-345- BLK) photovoltaic (PV) array. It's important to note that the PV array would have employed larger systems and has high initial costsconsidering the army power requirements for continuous transportation the PV system was sized to sufficiently cover the peak electric loads except for cooling; thus, only systems up to 100 kW were considered.

• Energy storage is used to overcome the intermittent nature of renewable energy sources. Excess energy is stored in batteries[36]. On the other hand, when there is a high demand for energy or during night periods and there is no sunlight, the batteries are discharged but the permissible limit of discharge is observed. The different types of batteries were observed, and the least expensive and most efficient type was selected, select BASF NAS lithium-ion battery with large capacity (1250 kWh), long duration hours (4.4 h), (286.1 kW max) discharge output, and long-lifetime (20 years or 6,250,000 kWh).

• Inverters are used to transform the direct current (DC) produced from PV into (AC) current as the base camp loads areneeded[37,38].

• A diesel generator CAT-400kVA-50Hz-PP was integrated into the system as a continuous power source to ensure provides the necessary energy for the camp at any time.

• Energy management system was integrated (EMS) for monitoring, managing and controling base camp equipmentto ensure system stability.

The detailed of the power system generation of the SHES was illustrated in Table 7. The output power shows that the PV produced 16.2% of the power consumed.As well, Figure 8 presents the monthly power consumed according to the SHES system.

Table 7: The production of the electrical power energy for the SHES system

Production	Quantity KWh/year	Percentage %
PV array (SunPower X21-335-BLK)	709	16.2
Diesel generator (CAT-400kVA-50Hz-PP)	3,680	83.8
Total	4,389	100

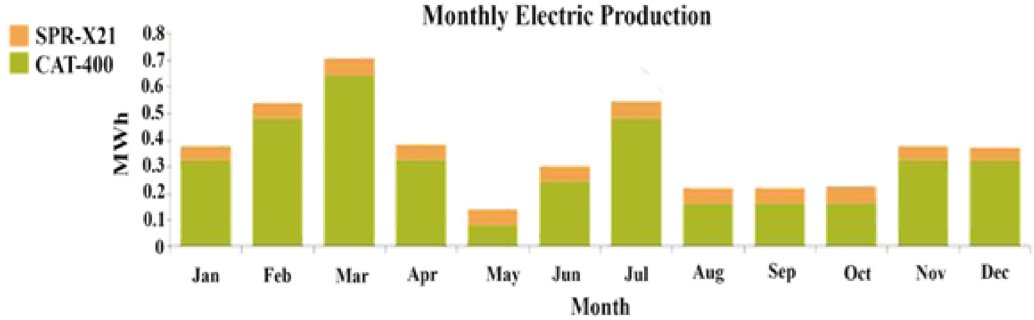

Fig. 8: Themonthly electrical production of the system

Additionally, Table 8 shows the consumption of diesel fuel according to the operation of the generatorto produceelectrical power. While Figure 9 presents the monthly fuel consumption.

Table 8: Diesel fuel consumption

Quantity	Value	Unit
Total fuel consumed	1.154	L
Average fuel per year	3.16	L/day
Average fuel per hour	0.132	L/hour
Specific Fuel Consumption	0.314	L/kwh
Number of batteries used	3	battery

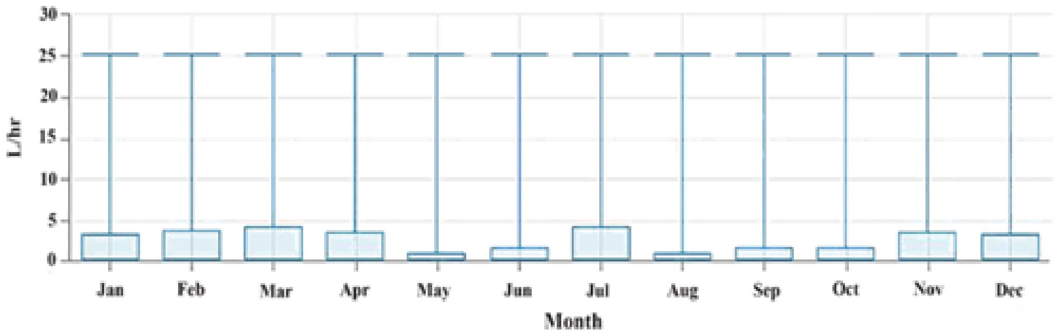

Fig. 9: The monthly diesel fuel consumed

The optimum number of Battery used in the optimum result of Homer Pro. are three with discharging capacity levelspresents in Figure 10a, while Figure 10b presents the daily discharge, and Figure 10c shows the monthly battery discharging according to the power produced.

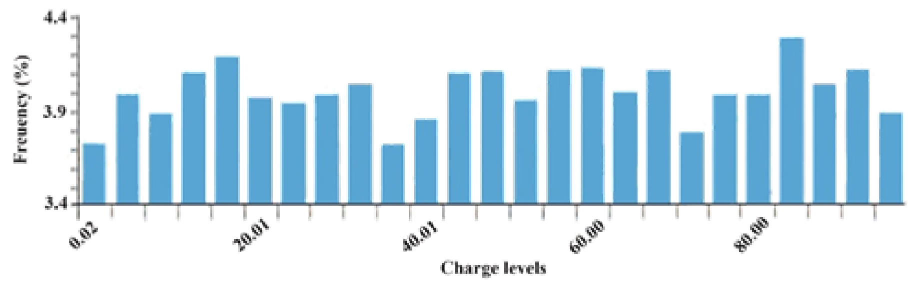

Fig. (10a): Battery power discharge level

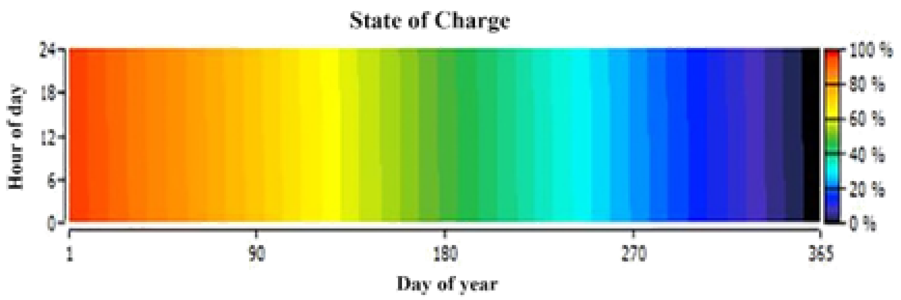

Fig. (10b): Daily Battery power discharge level

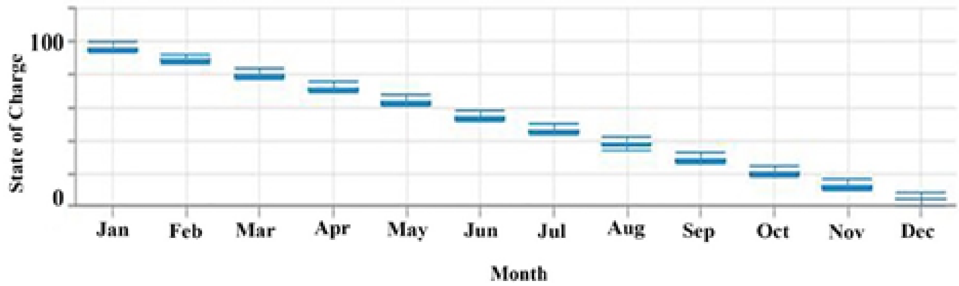

Fig. (10C): Themonthly battery discharge

It is noted that the optimal solution for using energy in this model requires the use of three batteries, which are considered the highest price in this system compared to the price of fuel and solar cells, taking into account the change in the price of fuels and products according to the place and time of setting up the camp.The following Table 9 shows the expected prices in this case, which shows that the greatest cost was for the batteries.It should be noted that the cost may change depending on the location of the camp and the prices of components and equipment in the country.

Table 9: The estimation of the cost of the energy system

Component	Fuel cost	Total $ / year
BASF NAS® Battery	0	$1,383,712.40
Diesel Generator (CAT-400kVA-50Hz-PP)	$14,922.45	$14,922.45
PV panels (SUNSYS PCS² IM 200kVA TL)	0	$247.10
Total system cost	-	$1,398,881.95

IV.3 Smart Hybrid Energy System (SHES) containing Wind turbine

In this model, the possibility of multiple sources of new and renewable energy is studied. A wind turbine can be added in addition to the solar energy system. In this case, it is possible to take advantage of the characteristics of both systems and save a greater amount of energy while retaining the diesel generator for use in the event of a camp move or for more assurance of saving electrical power and power system stability[39]. Using AWS HC 1.8kW Wind Turbine, with a rated capacity of 1.8 kW, 3.4 m with the same model used in the previous system.

Noting the use of the homer program to predict the best system in energy production and taking into account the amount of diesel fuel used, which results in polluting emissions to the environment. It has been noted that the optimal use of energy sources is as follows in Table 10.

It was found that the optimal use of energy sources was by using wind turbines and the solar energy system only and the number of batteries to store energy without using the generator, which means not using diesel fuel and preventing environmental pollution resulting from its use in addition to saving money. Table 11 presents HomerPro. Output values for PV array, Wind turbine, and diesel generator.

Table 10: The optimum power sources of the system

Production	Quantity kWh/year	Percentage %
PV array (SunPower X21-335-BLK)	709	12.6
Diesel generator (CAT-400kVA-50Hz-PP)	0	0
Wind turbine (AWS HC 1.8kW Wind Turbine)	4.933	87.4
Total power	5.642	100

Table 11: Homer pro. Output values for PVarray, Wind turbine and diesel generator

Quantity	Value	Units
Total fuel consumed	0	L
Number of batteries used	1	
System cost	461,765.36	$
Carbon Dioxide	3.047	kg/yr
Carbon Monoxide	4.61	kg/yr
Unburned Hydrocarbons	0.0346	kg/yr
Particulate Matter	0	kg/yr
Sulfur Dioxide	7.57	kg/yr
Nitrogen Oxides	16.7	kg/yr

Figure 11 shows the monthly electrical production by the SHESsystem. Figure 12a presents the battery charge levels. while Figure 12b shows the daily charge level and finally Figure 12c presents the monthly state of charges.

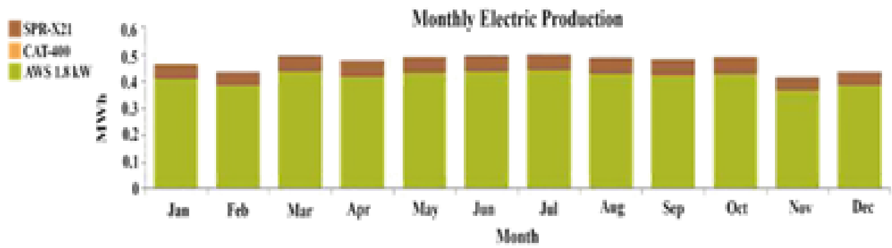

Fig. 11: The monthly electrical production by the SHES system

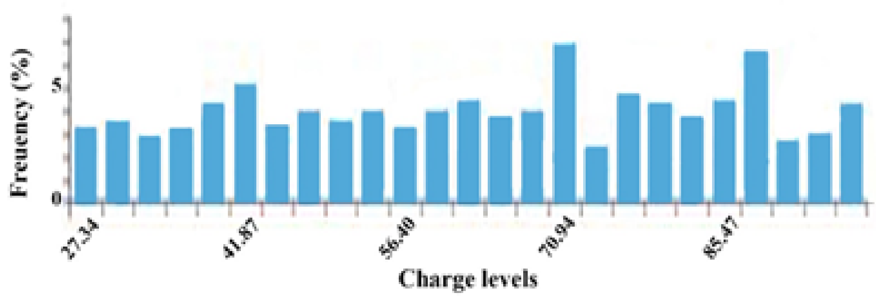

Fig. 12a: the battery charge levels

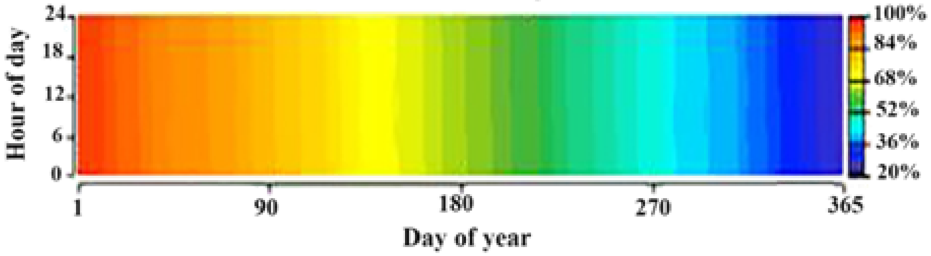

Fig. 12b: The daily battery charge level

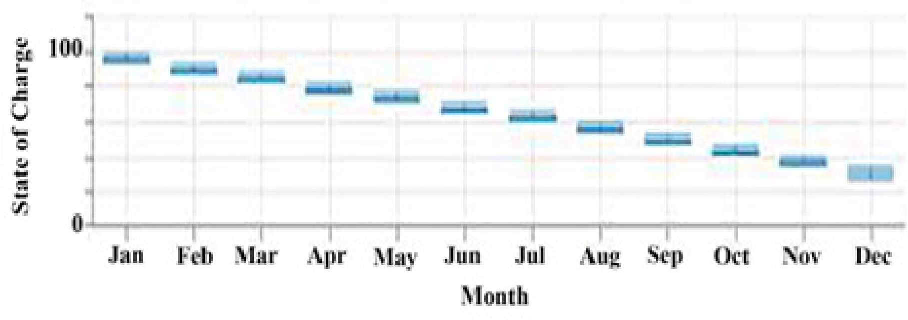

Fig. 12c: the monthly state of charges

V. DISCUSSION

Three scenarios have been studied to provide a camp consisting of 1000 people with electric powerdemand. Based on comparing the cost, CO_2 emissions, and fossil fuel consumptionthat summarized in the following Table 12 and 13 and Figure 13. It is possible to reach the optimal solution that ensures the stability of the selected system, savings,andthe cheapest and least used diesel fuel, thus reducing the environmental pollution. This scenario is the third scenario that uses adiesel generator with PV panels and a wind turbine.

Table 12: The Summary of simulation results for the various scenarios of power systems

Production	Technology	Percentage %
Base system	Diesel generator CAT-400kVA-50Hz-PP only	The electrical power production is700,800 kWh/yr. Diesel fuel was 219,822 L and the used fuel per day was 60 L / day. While the fuel production cost was 2,841,753.28 $The use of fuel cause the environmental pollution.
Smart Hybrid Energy System (SHES):	Combination of Sun Power X21-335-BLK plus diesel generator CAT-400kVA-50Hz-PP and store the residual electrical power by threeBASF NAS lithium-ion batteries and inverter	12.6% of power was produced by PV array.So, the amount of fuel used was reduced,which means that the environmental pollution also was reduced compared with the first scenario,and the total cost of the system reduced to be 1,398,881.95 $ it was saved about 51% of all costs.Also, the cost of batteries and all the system saving this value.
Smart Hybrid Energy System (SHES) adding a wind turbine	PV array (SunPower X21-335-BLK), Diesel generator (CAT-400kVA-50Hz-PP), Wind turbine (AWS HC 1.8kW Wind Turbine), battery to store the residual power, and inverter	The optimum system was producing all electrical power from renewable energy and zero diesel fuel was used.So,the polluting emissions to the environment. The electrical power used by PV was 12.6% and the remaining power produced by Wind turbine using one battery only to store the residual power, so the cost of this system is 461,765.36 $which saving about 83% compared with thebase system and about 67 % compared with a smart hybrid system using PV only.

Table 13: Comparison between different pollutant emissions in giving scenarios

Pollutant emissions	Diesel Generator	Diesel Generator with PV	Diesel Generator, PV, and wind turbine
Carbon Dioxide	580,220	0.134	0
Nitrogen Oxides	3,179	16.7	0
Sulfur Dioxide	1,442	7.57	0
Carbon Monoxide	877	4.61	0
Unburned Hydrocarbons	6.59	0.0346	0
Particulate Matter	0	0	0

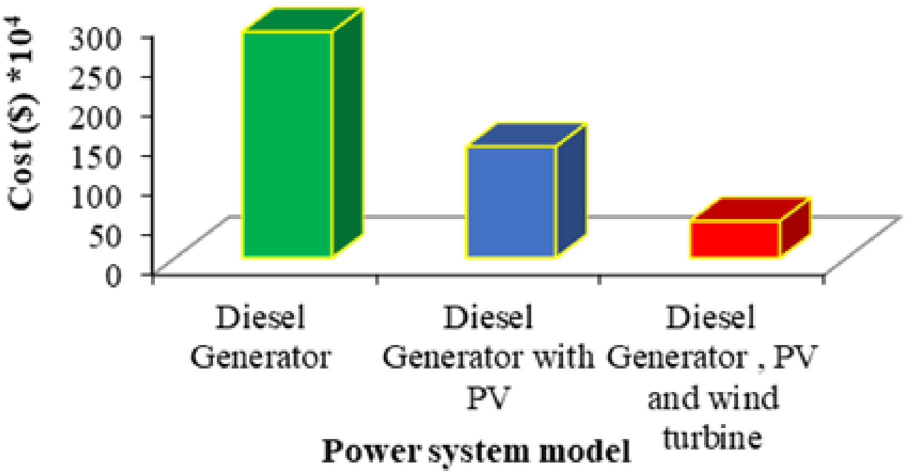

Fig. 13: Comparison between the cost of different power systemsscenarios

In addition, although the third scenario is considered the most economical alternative. The large size of the wind turbine may be a fundamental reason for revealing the location of the combat military battalions on the front line, especially in the border areas, thus targeting them from the hostile forces, whether by air forces or artillery is easy. Therefore, the second scenario, which depends on (PV) panels is the ideal solution for use in combat battalions on the front line.

In this vein, and to achieve maximum camouflage and concealment of (PV) panels to became part of the building. There is a modern technology for these units that can be installed on the building's facades in various shapes, sizes, patterns, and colors called "Mimic Design Facade Modules[40,41] or invisible building integrated photovoltaic (BIPV)[42]. as shown in Figure (14). More specifically, the advantages of this technology can list as:

- The panel with dimensions of (1 x 0.60 m) provides 220 watts peak wp/panel. Therefore, the efficiency of these panels is 60- 85 percent more than the roof-top types[42].
- It can be installed in the existing facades without the need for special requirements,
- The life span and the maintenance of these units are higher than the conventional types,
- The variety of shapes, sizes, patterns, and colors support the architects to provide innovative solutions without being restricted to fixed sizes or shapes[43].
- It can be invisibly incorporated into a façade.

Fig. 14: (PV) wall panels

VI. CONCLUSION

This study has presented a Smart Hybrid Energy Systemfor Egyptian army camps (battalions) in remote areas using (RER). Where, New valley was taken as a case study for applying this approach. The HOMER pro. software was used to estimate the optimalpower generation model for the battalions.A simulation and optimization process were carried out based on identifying the potential (RER) represented in wind and sun energies, the meteorological data, the architecture specifications, and the electrical demandof the battalion in the study area.

In the relevant context, three scenarios were deducted from the simulation process. The first relied on adiesel generator. The secondincluded a diesel generator with (PV) panels. The third scenario was done using adiesel generator with PV panels and awind turbine. Subsequently during the statistical analysisbased on comparing the cost, CO2 emissions, and fossil fuel consumption. The optimal Smart Hybrid Energy System for this case was the third scenario using a diesel generator CAT-400kVA-50Hz-PP, (SPR-X21-345- BLK) photovoltaic (PV) array, BASF NAS lithium-ion battery with a large capacity (1250 kWh), long duration hours (4.4 h), (286.1 kW max) discharge output and long-lifetime (20 years or 6,250,000 kWh), and AWS HC 1.8kW Wind Turbine, with rated capacity 1.8 kW, 3.4 m.

Finally, it is worth noting that the study limitation is to provide the demand for electricity for ordinary jobs, excluding the (battalion) military function. On the other hand, this approach supportsbattalions to perform their tasks, including control, monitoring, and communicationusing a hybrid model that relies on a multi-energy resource. Where reliance on a single off-grid energy source isn't sufficient tacticity.Notably, the study methodology can be applied to evaluate the optimum uses of (RER) for the otherborder areas and (RAs) in the future researches.

Abbreviations:

(CSP) Concentrated Solar Power
(DNI) Direct Normal Irradiance
(EMS) Energy Management System
(FOB) Forward Operating Bases
(GHI) Global Horizontal Irradiance
(GP) Generated Electrical Power
(HBRC) Housing and Building Research Centre
(HOMER) Hybrid Optimization Model for Electric Renewables
(ISB) Intermediate Staging Bases
(NREA) New and Renewable Energy Authority
(OGE) Off-Grid Electrification
(PV) Photovoltaic
(RAs) Remote Areas
(RER) Renewable Energy Resources
(SHES) Smart Hybrid Energy System

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