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Feasibility Assessment of a Hybrid PV/diesel/Battery System to Supply Required Electrical Energy of a Residential Complex in South of Iraq

A Thesis Submitted as a Partial Fulfilment Requirements of MSc Degree

By

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1. INTRODUCTION

- The electrical grid and lack of equipment is one of the worst of the legacy of Iraq from previous decades; until 2017the electricity supply did not exceed 12 hours per day in most part of country. This acute shortage in the processing of electric power caused the adoption of the Iraqi citizen on the personal and joint generators, which fueled with diesel and gasoline

1. INTRODUCTION

- Renewable energy sources – which are available in abundance all around us, provided by the sun, wind, water, waste, and heat from the Earth – are replenished by nature and emit little to no greenhouse gases or pollutants into the air. Versatile renewable sources, found it around us, cheaper, healthier, creates new jobs, makes economic sense are six reasons why accelerating the transition to clean energy is the pathway to a healthy, livable planet today and for generations to come.
- **The primary goal for this research is will recommend another ideal mixture solar/diesel/battery framework on to covering the interest load of a country, especially in the desert place of south of Iraq.**

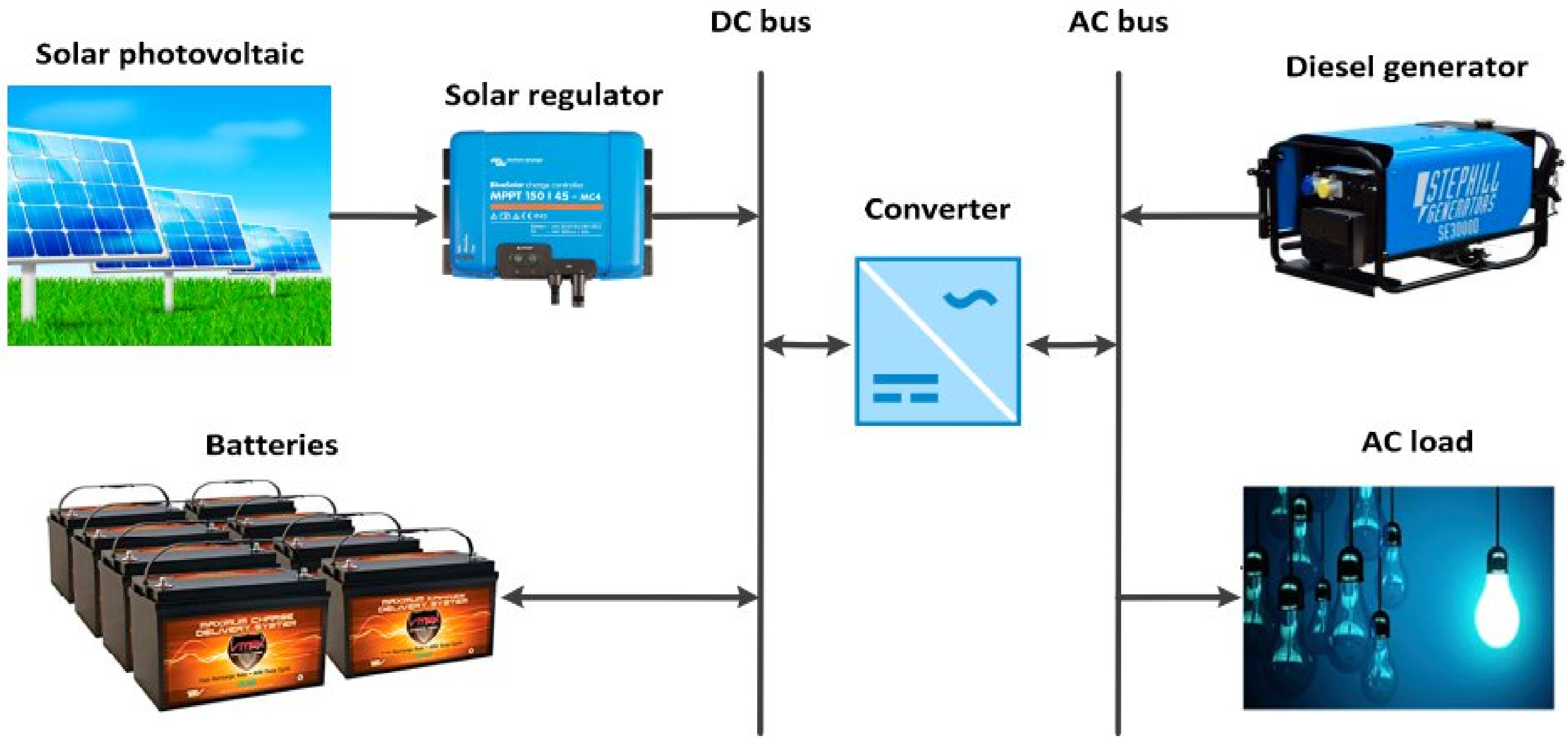
2. ASSUMPTION

- The following assumptions will be tested in this study:
- Due to the nature of the dessert, it has large area and the distances among population centers, the expected cost for the fuel to power the generator and the capital cost of the PV array system is primarily increased. Therefore, an optimization analysis is used to find the best possible hybrid power system configuration based on the desired constraints at the lowest total net present cost.
- To meet the desired electric load with high renewable energy required, the expected size, operation constraints and control of HRES will become more complicated.

3. Objectives

- The following objectives are pursued in this study:
- - Introducing a suggested configuration for the Hybrid PV/Diesel/Battery energy System (HRES).
- - Applying the proposed model on a practical case study in desert of Samawah -Iraq.
- - Investigating the problems of rural areas to develop a viable and sustainable energy system.
- - Identifying the key factors affecting the feasibility assessment of a HRES to supply required electrical energy.
- - Investigating new technologies has created opportunities based on hybrid system architectures.

4. Mathematical model of HES: PV, battery and diesel generator

- Figure below shows the foremost aspects of the hybrid system which it shows PV panel ,battery ,inverter ,diesel engine and load.
- 

4.1 Solar photovoltaic (PV) cell model

- The maximum power output from the PV cell, power of PV can be calculated as in equation

$$P_{PV} = P_{r-PV}\left[\frac{G}{G_{ref}}\right]\left[1 + kT\left(T_C - T_{ref}\right)\right] \dots \dots$$

P_{PV}: output power from the PV cell.

P_{r-PV}: rated power at reference conditions.

G: solar radiation in kW/m^2

G_{ref}: solar radiation ($1000\ W/m^2$) at reference.

kT: Temperature coefficient of maximum power

T_C : Cell temperature

T_{ref}: temperature reference

4.2 Battery Bank model

- The battery capacity, $C(t)$ at a point in time t,
- is calculated as in equation .

$$C(t) = C(t-1) - \eta_{batt}\left(\frac{P_{B(t)}}{V_{BUS}}\right)\Delta t \ldots\ldots\ldots\ldots\ldots.$$

$P_{B(t)}$ is as in (3.3)

$$P_{B(t)} = E_g(t) - E_l(t) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..$$

Where:

$C(t)$: battery capacity

$C(t-1)$: battery capacity at previous increment

η_{batt}: battery efficiency

4.3 **Diesel generator (DG)** model

The diesel generator is an energy conversion system from fuel to electricity with a conversion efficiency of, η_{DG} so that it can described as in equation

$$E_{DG} = \eta_{DG} E_{ff} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

A linear model has been assumed for the fuel consumption rate (F) in liters/hour of operation by the DG [25, 26] given in equation

$$F = (0.246 x P_{out}) + (0.08415 x P_{Ngm}) liters/hour..$$

The fuel cost, C_{fuel} can be calculated using the formula as in equation

$$C_{fuel} = C_{diesel} F(R_s) \ldots\ldots\ldots\ldots$$

5. **Optimal design criteria of HES model**

- 5.1 **Problem formulation**
- The objective function here is an economic function that is constrained in technical or reliability function. The problem was modeled according to the loss of power supply probability (LPSP) and total annualized cost system (ACS). The ACS is given in equation

$$ACS = CC_{an} + RC_{an} + MC_{an} + FC_{an} + EC_{an} \dots \dots \dots$$

Where:

CC_{an}: annual capital cost of each of the component

RC_{an} : annual replacement cost

MC_{an}: annual operation and maintenance cost

FC_{an} :annual fuel cost

EC_{an} :annual emission cost generated from DG

5. Optimal design criteria of HES model

$$LPSP = \frac{\sum(P_L - P_{PV} - P_{SOC_{min}} + P_{DG})}{\sum P_L} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

P_L : total load demand

P_{PV} : output power from the PV cell.

$P_{SOC_{min}}$: min state of battery charging

P_{DG} : output power from the diesel generator.

LPSP: Loss of Power Supply Probability: is the ratio between the energy shortage and total energy demand of the load for a long period of time . this function have been used in this task to determine experiencing insufficient power supply when HES configuration is unable of satisfy the load demand. The value of LSPS ranges from zero to one. In this project, minimum value is 0.25 , and maximum value 0.9.

6. Constraints

- In order to solve the optimization problem, all the constraints must be satisfied .
- Power balance constraint,

$$P_{PV}(t) + P_{BATT}(t) + P_{DG}(t) \geq (1 - R)P_L(t) \ldots$$

- Battery capacity constraint,

$$SOC_{min} \leq SOC(t) \leq SOC_{max} \ldots \ldots \ldots \ldots \ldots$$

- Non – negativity constraints,

$$0 \leq N_{PV,P} \leq N_{PV,Pmax}$$

$$0 \leq N_{BAT,P} \leq N_{BAT,Pmax}$$

7. Optimization Procedure

- The first case takes place after calculate PV power and check power demand, if the output PV power is higher than the load power, the PV feeds the load resulting in excess power. In this case, the excess power will be damped if the battery is fully charged. In the case where the battery is not fully charged, the excess PV power is used to charge the battery. The generator also does not work in this case.

7. Optimization Procedure

- The second case is when the output PV power is equal to the load power. Here, the PV power meets the load demand, the batteries do not draw any energy, and the generator stays off. In this case, no excess power exists.

7. Optimization Procedure

❖ The last case is when the PV power is lower than the load power. The two possible subcases are as follows:

- If load demand = min of capacity of PV and DG, the generator works to feed the net load (load minus renewable power). The generator provides only enough power to satisfy the net load without charging the battery. It is important to mention that if the minimum generator loading output power is higher than the net load, the generator works to feed the load and the excess power from the PV charges the battery.
- If load demand > min of capacity of PV and DG, a cost of discharging the battery is computed and compared with the cost of turning on the generator that operates only to serve the net load. If the battery discharging cost is higher than the cost of turning on a generator, then the battery would not be discharged while the generator runs and produce enough power to meet the load demand without charging the battery. Otherwise, the battery

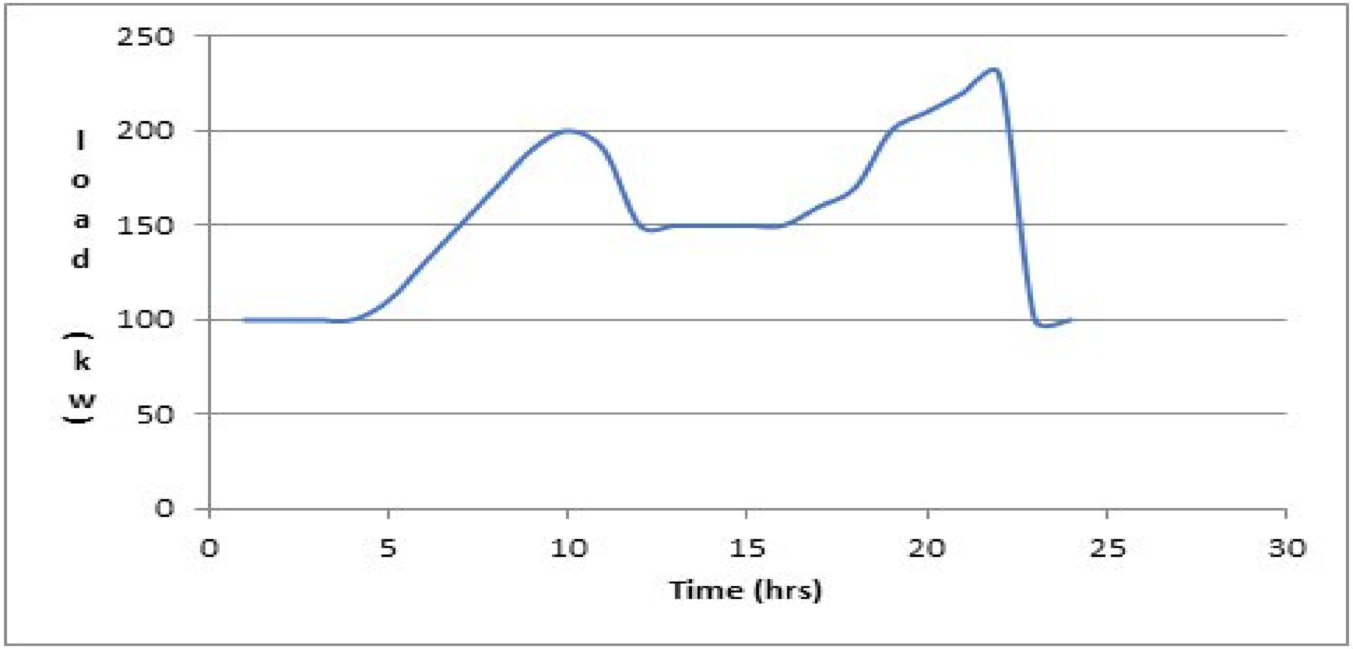
8. SOFTWARE

Genetic algorithm (GA) was utilized in this simulation to determine the optimal configuration. GA is very flexible and has better efficiency than classical methods. The three decision variables considered are number of PV array, number of battery bank, and the diesel generator. GA based MATLAB m-file code was developed to determine the best chromosome in final generation to obtain the optimum configuration of HES in this case.

9. SIMULATION RESULTAS

. Data acquisition of study area

Data for load demand was obtained through the use of questionnaires. The daily load profile for the case study as shown in figure



9. SIMULATION RESULTAS

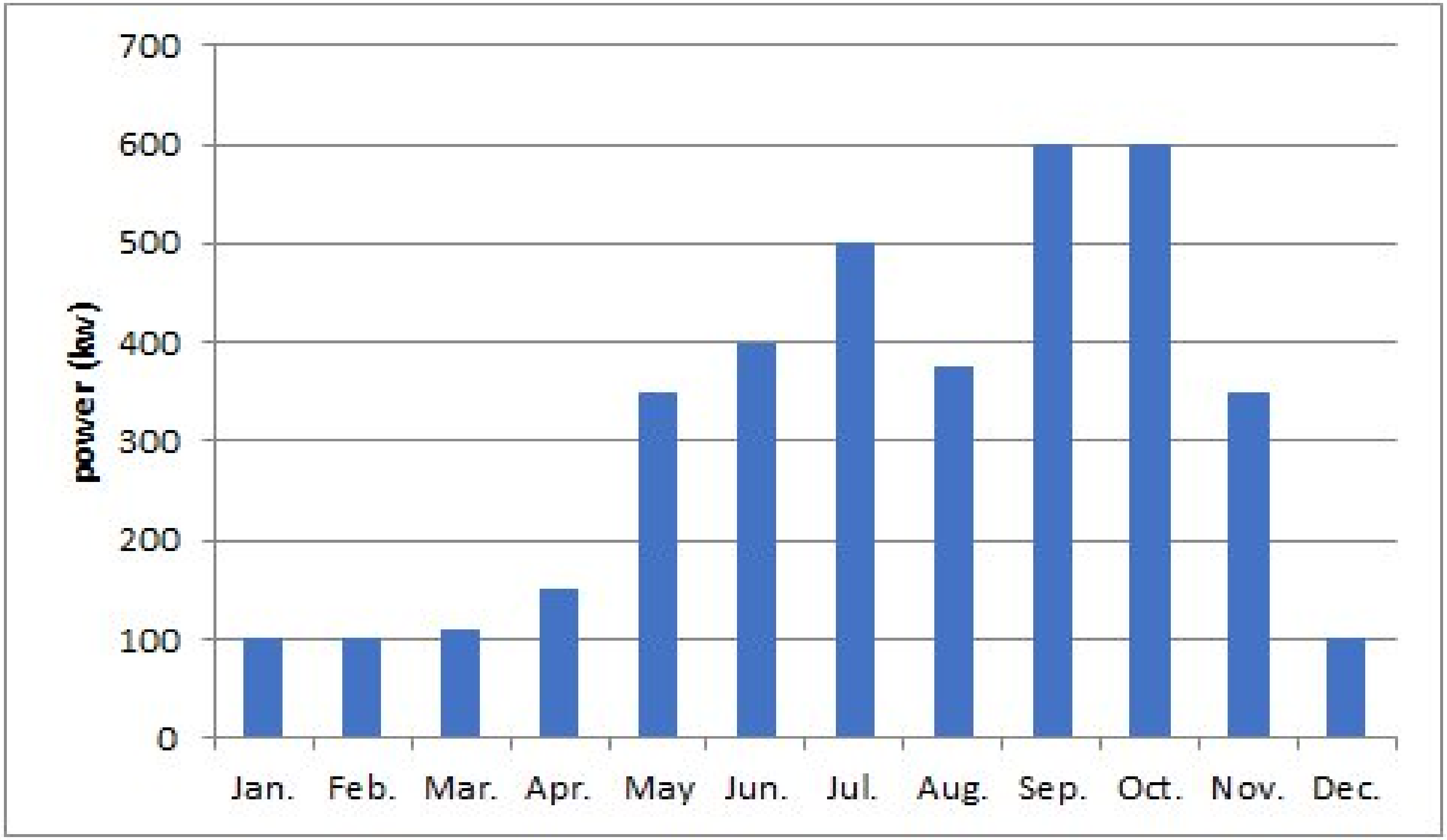


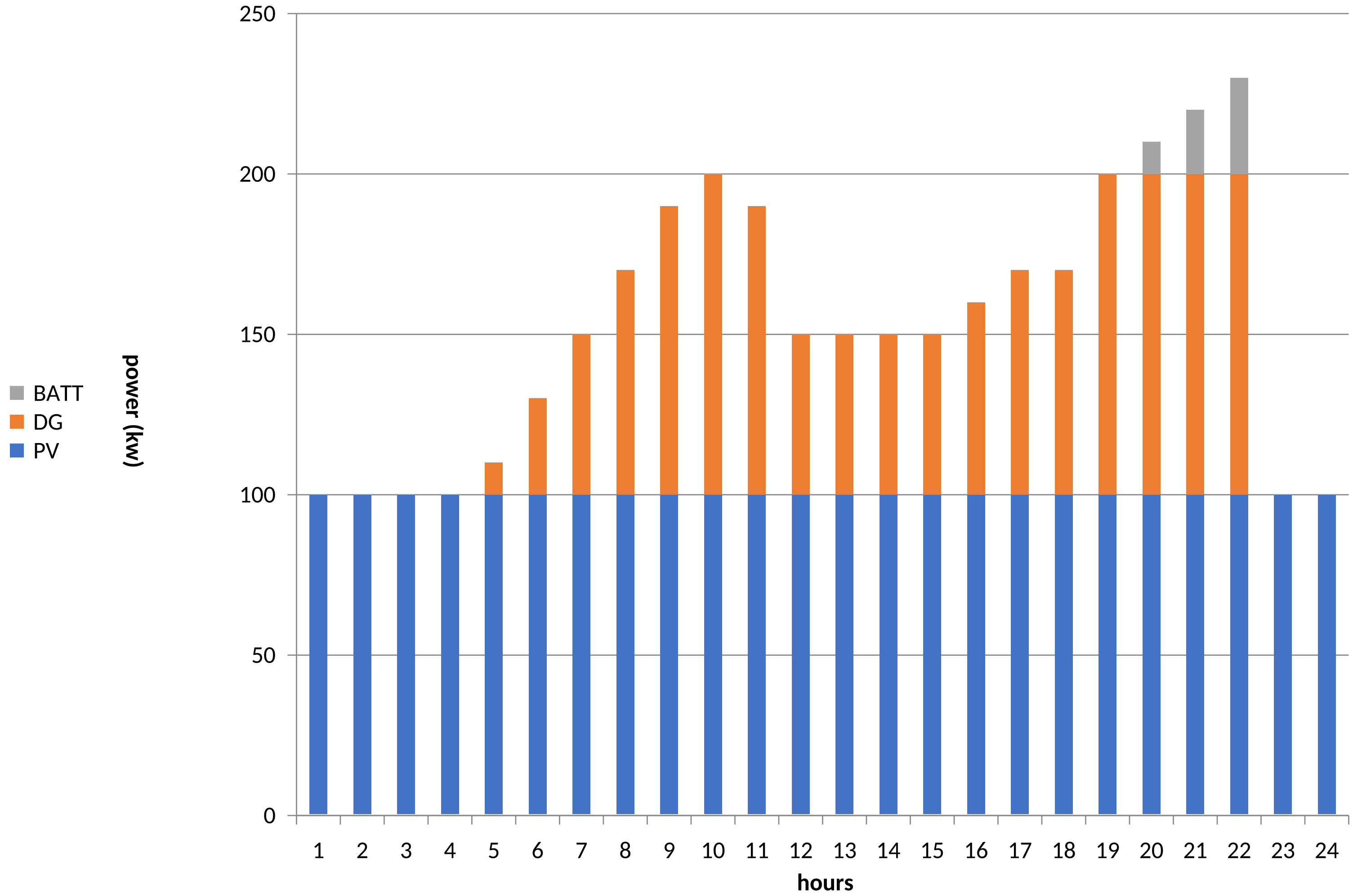
Figure (4.4): monthly average load demand

10. Conclusion of Feasibility Study

An optimization analysis is used to find the best possible HES configuration based on the desired constraints at the lowest total net present cost. The proposed system is composed of solar PV system, Diesel generator, batteries, converter, and controller. A description of the selected parts for the hybrid power system is summarized in tables (4.1) and (4.2).

Figure (4.5) shows the total electrical production from hybrid power system. The PV contributed 100.483kWh/year and 70.999kWh/year from DG and 29.123kWh/year from battery bank. The percentage of contribution of components as 58% from PV, 41% from DG, and 1% from battery bank.

The best configuration was obtained with a combination of 100Kw PV array, 50kW Diesel generator, 144 batteries (4 batteries in series and 36 string in parallel)



BATT
DG
PV
power (kw)
250
200
150
100
50
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
hours