Economic Study for a Lebanese Hybrid Wind/Diesel system

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Abstract---**In Lebanon, a hybrid wind-diesel system or PV-diesel is used to supply the need of electricity in some cases when the public electricity is cut off. In large cases batteries are used for storage. This paper treats this method of storage. Economic study and evaluation of an electricity project for a Lebanese small workshop.**

Keywords-renewable energy; wind turbine; batteries; chemical energy storage

I. INTRODUCTION

In our country Lebanon, the Electricity Of Lebanon EOL, which is the public company responsible for supplying electrical power for the users, cannot supply all needs 24/24, thus there are multiple cut offs each day for several hours in almost all regions. This causes a major problem for companies, offices and factories that need electrical power the whole day, the solution was to use diesel generators when the public electricity is cut off.
The increase of the fuel cost causes a problem, and the users find the wind-diesel systems a fine solution to limit the electricity bills. The normal storage system is the chemical storage using batteries, which are easy to use, relatively cheap and don’t need large maintenance cost, but on the other hand the recycling of the batteries causes a big problem for this technic.

II. SYSTEM UNDER CONSIDERATION

The studied system is a small sawmill workshop containing multiple equipment such as: dry kilns, planer, molder, shaper, router, trim saw & boaring machines.

This workshop is supplied by two three phase electrical sources:

- The ELO connected to a counter and breaker of 35 A.
- A 12 KVA diesel-generator with a breaker of 30 A.

The daily consumption is shown in figure 1. The consumption graph describes the variation of the current versus time (in hours).

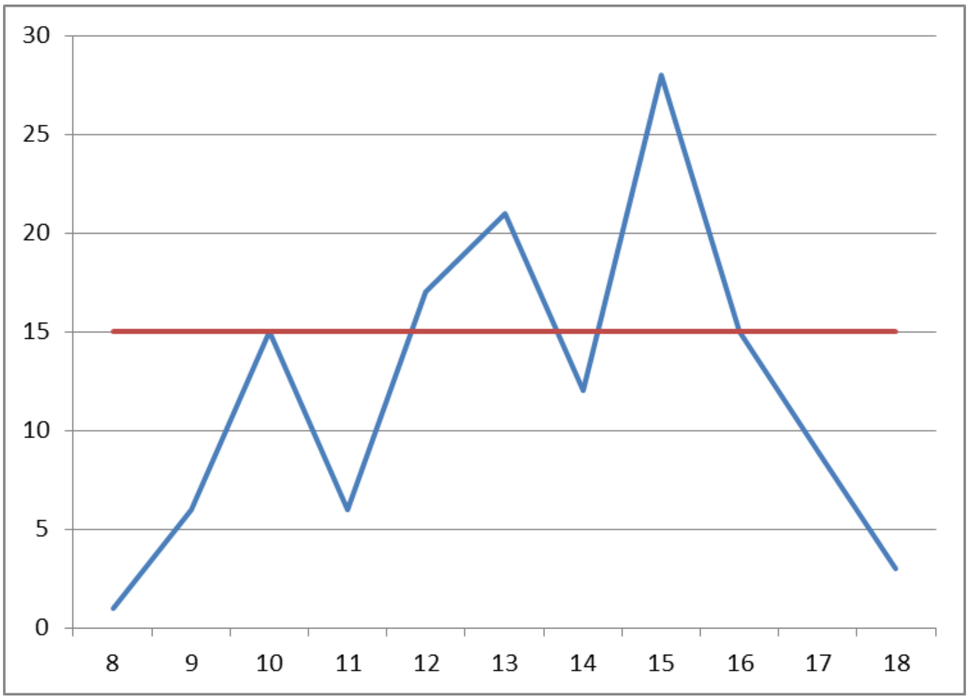

Figure 1: Daily workshop consumption.

In this study, some hypotheses are suggested:
(A1) The daily workshop consumption is taken as repetitive,
(A2) The maximum current demand is 30 A,
(A3) The 1/2 of the maximum current demand (24 A) is provided by the EOL or by a diesel generator,
(A4) The 1/2 of the maximum current demand (24 A) is supplied by a hybrid renewable system.

For our new system which is a hybrid wind-diesel system coupled with the ELO, we can consider that the thresholds consumption by the ELO and the by the diesel generator are supposed fixed on 15 A. The remaining consumption, above this threshold is provided by wind turbine.

Thus, a hybrid wind-diesel system is installed to provide the energy demand. This system should be associated with an energy storage system or device and an inverter.

We can find, from figure 2, that the daily excess of the consumption power, P_{de} is equal to 20000 Wh. Then the hourly excess of the consumption power, P_{he} , for 10 hours is equal to :

P_{he} =20000 Wh / 10 h = 2000 W

This power is used when sizing the wind turbine.

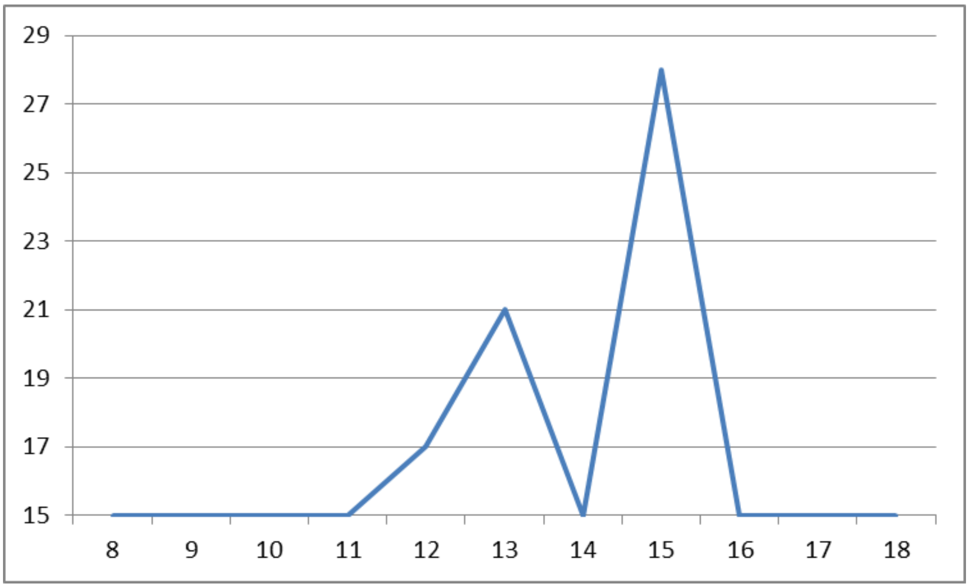

Figure 2: Daily consumption provided by wind power

III. SIZING THE RENEWABLE ENERGY HYBRID SYSTEM

III.1 Sizing of the wind turbine

The choice of the wind turbine depends on its power, the available wind speed and the allowed space that can be used. However, the power of the wind turbine (P_{WT}) can be calculated from the following equation:

$$P_{WT} = P_{de} / N_{hw}$$

Where N_{hw} designs the average of the daily number of hours for witch the wind turbine is functioning.

N_{hw} is estimated to be close to 5 hours for the location where the wind turbine will be installed. Thus, the chosen wind turbine is one of power equal to 4 kW. Of course, because of the output voltage of this wind turbine that is equal to 48 V, it is important to use a rectifier, ac-dc converter, to connect the wind turbine to the 48 V dc bus.

III.2 Sizing of the inverter

The choice of the most suitable inverter, which had to supply the excess of the load demand, has a primary criterion depending on the load consumption. Therefore, it is essential to have some notions on the power consumption and its calculation. The inverter is characterized by its instantaneous power, Pinv(t), its maximum power, Pmax-inv, and its efficiency, ηinv. The calculation of Pmax-inv is based on the maximum power absorbed by the load. According to Fig. 3, the load maximum power, Pmax-load, is:

$$\text{Pmax-load} = 3 \times 220\ \text{V} \times 15\ \text{A} = 9900\ \text{VA}$$

Thus, the required inverter, which is connected to the 48 V dc bus and having an efficiency of 0.8, has a power of 12 kVA.

IV. ELECTRIC STORAGE TECHNOLOGY

The fundamental idea of the energy storage is to transfer the excess of power (energy) produced by the power plant during the weak load periods to the peak periods. Initially, electricity must be transformed into another form of storable energy (chemical, mechanical, electrical, or potential energy) and to be transformed back when needed. The stored energy should be quickly converted on demand and used in a wide variety of electric applications and load sizes. There exist different Energy Storage Systems (ESS) technologies; some of them are well studied and developed, while others are just emerging and waiting for new hardware technologies to make them cost-effective. [2].

Electrical energy can be stored in different ways. A number of major electric storage technologies are:

- Pump hydro power
- Compress air energy storage (CAES)
- Batteries
- Flywheels
- Super conducting magnetic energy storage (SMES)
- Super Capacitors
- Hydrogen storage

V. ELECTRICAL ENERGY STORAGE AS CHEMICAL ENERGY

1. *Principle*

Energy stores in battery due to reactions generated in electrochemical components of the battery while charging.
Based on demand, reserves chemical reactions lead to electricity flow of the battery to the grid. Nowadays using of this technology has become very popular. There are different types of battery such as: Lead-acid batteries, Ni-Cd Batteries, Li-ion batteries, Nas Batteries and etc. that are being used in grids by considering their characteristics and the girds condition.

2. *Sizing of the accumulators*

As the dc bus is fixed to 48 V, the required A.h for the excess power consumption is:

$I_{Bat} = P_{de} / V_{out} = 20000\ Wh / 48\ V = 416\ Ah$

Thus, for a 200 A.h accumulator of 12 V output voltages, three parallel columns of 4 batteries connected in series are required. It is assumed that the efficiency of these 12 batteries is about 70%.

VI. ECONOMICAL ASPECT AND COMPARATIVE SURVEY

Total cost

We will consume that the life time for the wind turbine is 20 years, so we will calculate the total cost based on this assumption. The life time of the batteries is 4 years, so it will be replaced 5 times.

Item	*Cost (in USD)*
2kW wind turbine	5000
Batteries (12×200 Ah) (replaced 5 times)	18000
Inverter	6000
Installation	1500
Maintenance	1500
Total cost	**32000 $**

We can see that the compressed air energy storage and the electrochemical energy storage have almost the same economical prices, with little benefit for the electrochemical energy storage. But we must not let this little difference in total cost hide very important issues as:

- The recycling of the batteries is very pollutant
- The electrochemical storage is not efficient for high energy storage.

VI.1 Compound annual growth rate:

Compounded Annual Growth rate (CAGR) is a business and investing specific term for the smoothed annualized gain of an investment over a given time period. CAGR is not an accounting term, but remains widely used, particularly in growth industries or to compare the growth rates of two investments because CAGR dampens the effect of volatility of periodic returns that can render arithmetic means irrelevant. CAGR is often used to describe the growth over a period of time of some element of the business, for example revenue, units delivered, registered users, etc.

Since in our case we don't have revenues, thus we can't find the CAGR.

VI.2 Net Present Value (NPV):

In finance the **net present value** (**NPV**) of a time series of cash flows, both incoming and outgoing, is defined as the sum of the present values of the individual cash flows of the same entity.

VI.3 Time value of money:

The time value of money is the value of money figuring in a given amount of interest earned over a given amount of time. The time value of money is the central concept in finance theory.

For example, $100 of today's money invested for one year and earning 5% interest will be worth $105 after one year. Therefore, $100 paid now or $105 paid exactly one year from now both have the same value to the recipient who assumes 5% interest; using time value of money terminology, $100 invested for one year at 5% interest has a future value of $105.

VI.4 Return on Investment (ROI)

The internal rate of return on an investment or project is the "annualized effective compounded return rate" or "rate of return" that makes the net present value of all cash flows (both positive and negative) from a particular investment equal to zero.

The ROI= Total investment/ annual gain

The daily excess of the consumption power, P_{de} is equal to 20000 Wh. If we consider that the half was provided by EDL and the other half was provided by the generator (before the installation of the wind turbine). Thus electricity bills will be as:

30 A of the generator costs 600$/month, but with the new system we only need 15A from the generator and that will cost 300$/month, so the saved cost is 300$/month.

Also, we need 10000Wh/day from EDL, the cost by EDL is 45 USC/kWh so the cost will be 45 USC X 10 = 4.5 USD/day ➔ 4.5 X 30 = 135 USD/month. So the total cost will be 435$/month ➔ 5220$/year.

ROI = 32000/5220 = 6.13 years = 6 years and 2 months.

Thus the system can payback its price only after ~ 6 years, which is a short time in regard the life time which is 20 years

VI.5 CO_2 Saved:

If we consider that generating 1kWh of power needs an equivalent of 0.3 kg of CO_2, thus we can calculate CO_2 saved, which can be calculated by:

CO_2 saved = 20*365*0.3= 2.19 ton of CO_2 are saved each year.

But we cannot forget that the batteries are difficult to be recycled.

VI.6 Social impact:

In Lebanon we don't have wind turbine industry or chemical batteries industry, but this project and similar projects increase the trading of the wind turbines and the batteries in Lebanon.

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