ALGORITHM SIZING FOR A SYSTEM WITH RENEWABLE ENERGY SOURCES CONNECTED TO THE NETWORK

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Abstract - Steadily increasing demand of electricity and social interest for global environmental concern has necessitated an urgent search for alternative energy sources to meet the energy requirements. This fact makes renewable energy resources very attractive for many applications. Wind and solar energy sources are considered as viable option for future electricity need, particularly for rural area electrification. Wind and solar resources in an adequate combination can overcome their disadvantage. These are unpredictable and dependent on weather and climate. A major concern in sizing a system of electricity using renewable energy sources is the correct choice of system components, which can satisfy the load demand in economic point of view. For this purpose the authors, using linear programming, presents the optimal sizing algorithm for such a system. For this study it was used Matlab software.

Keywords: renewable energy sources, algorithm sizing, linear programming, Matlab software.

1. INTRODUCTION

Hybrid renewable energetic systems are systems that integrate more than one renewable energy sources. As they are time, environment and site dependant, one expects that their judicious and complementary combination may overcome some limitations which are inherent to every individual system used alone. Hybrid systems may also reduce the need for energy storage which is very costly and space consuming. In this context, the topic of optimizing the integration of renewable energy sources in a complementary way is a very interesting but a challenging one both scientifically and technologically. [1]

Renewable energy resources like solar and wind offer clean and economically competitive alternatives to conventional power generation where high wind speed and high solar radiation are available. For meeting the energy demand, PVwind hybrid power generating systems can be beneficial in enhancing the economic and environmental sustainability of renewable energy systems. [2]

While planning, designing and constructing a hybrid energy system, the problem becomes complex through uncertain renewable supplies, load demand, non-linear characteristics of components and the fact that the sizing and operation strategies of hybrid systems are interdependent. This calls for an optimized hybrid energy system with the objective of minimizing the life cycle cost while guaranteeing reliable system operation. [3]

The authors aim to do the sizing, taking into account the above mentioned, a hybrid with renewable energy sources. For this sizing it is used linear programming.

2. GRID CONNECTION OF WIND TURBINES AND SOLAR PANELS

Voltage levels that can be connected with groups / wind power and photovoltaic systems to public electricity networks are shown in Figure 1.

Usually, individual generating units (wind or solar) with rated power up to about 500 kW can be connected to low voltage networks.

Because the the rated power of a wind farm (group consisting of wind turbine and generator) is currently still relatively low (usually between 0,5 MW and 3 MW, although, currently, are produced wind units with rated power of 5 MW, 6 MW and even 7,5 MW). Due to economic reasons and due to the need to increase the production of electricity with the help of wind, more wind units are grouped in so-called "parks", "farms" or wind plants (with one or more wind units/groups located in a same site and connected through an internal network of MT, of the wind farm). [4]

Wind energy system. It typically consists of:
(1) a wind turbine, which converts the energy in the wind into mechanical energy;
(2) an electric generator, which converts the mechanical energy into electricity;
(3) a tower, which supports the turbine-generator set above the ground to capture higher wind speeds;
(4) a control system used to start and stop the wind turbine, and to monitor the proper operation of the machinery.

The main specifications that define a wind turbine model are the power curve and the response factor. The power curve is a graph of power output versus wind speed at hub height; it is a function of the turbine design and is specified by the turbine manufacturer. The turbine response factor is a measure of the relationship between the variability of the wind and the variability of the resulting electrical power. A wind turbine will have a cut-in wind speed at which the turbine starts to generate power, a rated wind speed, at which it starts to generate rated power, and a high-wind cut-out wind speed at which it is shut down for safety. [5]

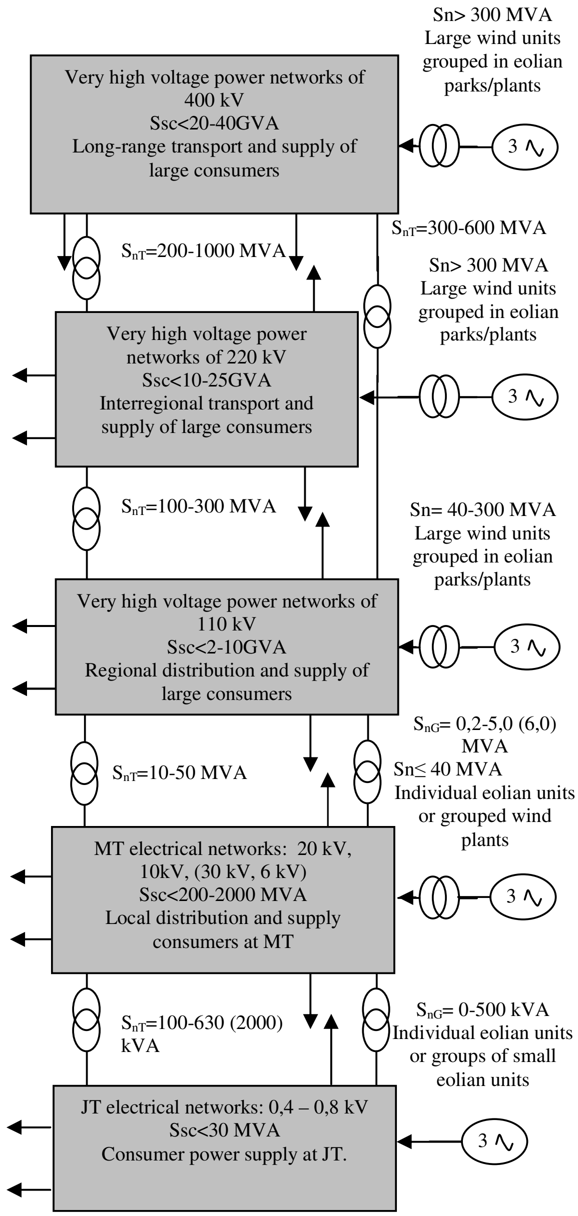

Fig. 1. Connection to electric networks of eolian units/plants according to their nominal power. [4]

Due to the alternation of day and night and change of the weather, there exist instability shortcomings in electric energy production when using PV or wind power alone. It not only affects normal energy consumption but also results in batteries being discarded too early. At present, the cost of batteries during the lifetime of wind generator and PV module has occupied fairly large part of the total cost of PV or wind generating systems. How to prolong the operating lifetime of batteries has become a big problem. By using PV/wind hybrid power generation, effective charge time of the batteries can be increased remarkably, so that the operating lifetime of the batteries is prolonged and the electricity production cost decreased. PV/wind hybrid power generation acting as an energy production mode has attracted more and more attention, and has been used more and more widely. [6]

3. MODELS FOR ENERGY SYSTEMS

3.1 Model for solar panels

In the proposed method, system operation is simulated for one year, with a time step of 1 h. The maximum power of the PV panel for one day i ($1 \le i \le 365$) and for an hour t ($1 \le t \le 24$), $P_M^i(t,\beta)$ (W), is calculated using the specifications of the PV module under conditions of standard testing (STC, cell temperature = 25 °C and solar radiation = 1 kW/m^2), provided by the manufacturer, and the conditions of irradiation and ambient temperature according to the following equation:

$$P_M^i(t,\beta) = N_s \cdot N_p \cdot V_{oc}^i(t,\beta) \cdot I_{sc}^i(t,\beta) \cdot FF(t) \quad (1)$$

$$I_{SC}^i(t,\beta) = \left\{ I_{SC,STC} + K_I \left[T_C^i(t) - 25^o \right] \right\} \cdot \frac{G^i(t,\beta)}{1000} \quad (2)$$

$$V_{oc}^i(t) = V_{OC,STC} - K_v \cdot T_C^i(t) \quad (3)$$

$$T_C^i(t) = T_A^i(t) + \frac{NCOT - 20^o C}{800} \cdot G^i(t,\beta) \quad (4)$$

where: $I_{SC}^i(t,\beta)$ is the short circuit current of the module PV [A], $I_{SC,STC}$ is the short circuit current under STC [A], $G^i(t,\beta)$ is global irradiation [W/m^2], incident on the PV module placed at tilt angle β [^{o}], K_I is the short-circuit current temperature coefficient [A/^{o}C], $V_{OC}^i(t,\beta)$ is the open-circuit voltage [V], $V_{OC,STC}$ is the open-circuit voltage under STC [V], K_v is the open-circuit voltage temperature coefficient [A/^{o}C], $T_A^i(t)$ is the ambient temperature [^{o}C], NCOT is the Nominal Cell Operating Temperature [^{o}C], provided by the manufacturer and $FF(t)$ is the filling factor. [6]

The value $G^i(t,\beta)$ is calculated using daily solar radiation on the horizontal plan. The tilt angle of PV module can be selected by the system designer to be constant during the year, β, or a variable angle β_1 coresponding to the months of January to April (number of days 1-104) and from september till december (days 290-365) and β_2 corresponding to the rest of the year.

The solar characteristics of the analized region are summarized in Table 1:

Table 1. Solarization values of the region[9]

Months	Clearnes Index	Dailiy Radiation Wh/m^2/d	Months	Clearnes Index	Dailiy Radiation Wh/m^2/d
Jan	0.408	1.510	Jul	0.550	6.190
Feb	0.456	2.340	Aug	0.551	5.480

Months	Clearnes Index	Dailiy Radiation Wh/m²/d	Months	Clearnes Index	Dailiy Radiation Wh/m²/d
Mar	0.449	3.240	Sept	0.512	4.060
Apr	0.463	4.340	Oct	0.453	2.600
May	0.505	5.530	Nov	0.406	1.630
Jun	0.523	6.060	Dec	0.384	1.260

3.2 The model for the wind turbine

There are three main factors which determine the power output of a whole wind energy conversion system, i.e., the power output curve of a chosen wind turbine, the wind speed distribution of a selected site where the wind turbine is installed, and the hub height of the wind tower.

The most simplified model to simulate the power output of a wind turbine can be described by:

$$P_{WT} = \begin{cases} P_r \dfrac{\left(v^2 - v_{cin}{}^2\right)}{v_{rat}{}^2 - v_{cin}{}^2}, & v_{cin} < v < v_{rat} \\ P_r, & v_{rat \le v < v_{cou}} \\ 0, & v \le v_{cin} \;\; and \;\; v \ge v_{cou} \end{cases} \qquad (5)$$

Where: P_r is the rated electrical power; V_{cin} is the cut-in wind speed; V_{rat} is the rated wind speed; and V_{cou} is the cut-off wind speed. For small-scale wind turbines, the cut-in wind speed is relatively smaller, and wind turbines can operate easily even when wind speed is not very high.

In order to calculate the wind speed, V at the desired WG installation height H, which is usually different from the height corresponding to the wind speed input data, the exponential law is used:

$$v = v_{ref} \cdot \left(\frac{H}{H_{ref}}\right)^{\alpha} \qquad (6)$$

Where: v_{ref} is the reference (input) wind speed (m/s) measured at height H_{ref} (m) and α is the power law exponent, ranging from 1/7 to 1/4. In this article the considered value of α is 1/7. [7]

Table 2 shows the monthly average wind speed for the considered region, the wind speed being measured at 10 m.

Table 2. Wind speed data available in the study area[9]

Months	Temperature [°C]	Mean Monthly Wind Speed [m/s]
January	1.9	3.500
February	2.0	4.000
March	5.1	4.100
Aprilie	9.9	3.500
May	15.1	3.300
June	19.7	3.100
July	22.0	3.300
August	22.0	3.400
September	18.5	3.900
October	13.2	4.200
November	7.0	3.800
Decembrie	3.1	4.000
Annual Average	11.7	3.67

The system components data are given in Table 3 and Table 4.

Table 3. Wind turbine characteristics

Tzpe Wind Turbine	Entegrity eW 15
H (m)	25
P_r (kW)	100
V_{cin} (m/s)	5
V_{rat} (m/s)	13
V_{cou} (m/s)	25
Diameter (m)	15

Table 4. PV module characteristics [8]

Type PV module	KYOCERA KD240GX-LFB
Maximum Power (Pmax)	240 (+5%／−3%)
Maximum Power Voltage (Vmpp)	29.8V
Maximum Power Current (Impp)	8.06A
Open Circuit Voltage (Voc)	36.9V
Short Circuit Current (Isc)	8.59A
Max System Voltage	600V
Temperature Coefficient of Voc	−1.23x10-1 V/℃
Temperature Coefficient of Isc	3.18x10-3 A/℃

3.3 The Load Model.

The hourly load demand, $P_{load}(t)$, determines the requirements of power supply from the hybrid system. The loads can be DC or AC. It is assumed a load profile varying over the observation interval time.

Figure 2 shows the variation of load for one day of the each month.

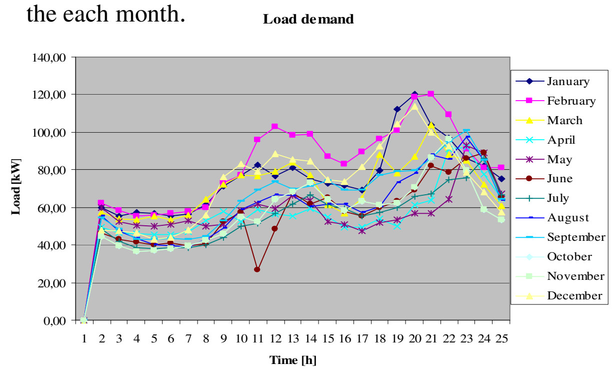

Fig. 2. Load demand for one day of the each month

4. THE PROPOSED LP MODEL

The proposed methodology is based on the solution of an optimal resource allocation problem by means of a Linear Programming (LP) approach. The classical LP problem consists of the determination of the decision variable vector *x* minimizing a linear objective function *F(x)*[10]:

$$\min_x F(x) = \sum_{i=1}^{n} f_i \cdot x_i \qquad (7)$$

subject to linear equality constraints:

$$A_{eq,i} \cdot x = B_{eq} \qquad (8)$$

and to linear inequality constraints:

$$A_i \cdot x \leq B \qquad (9)$$

For this article, the linear programming problem looks like this:

Case 1:

Minimizing a linear objective function *F(x)*:

$$\min_x F(x) = 6764 * N_1 + 147000 * N_2 \qquad (10)$$

$$\begin{aligned} &3547 * N_1 + 258904 * N_2 \geq 566480 \\ &N_2 \leq 2 \\ &N_1,\ N_2 \geq 0 \end{aligned} \qquad (11)$$

Where: N_1 is the number of modules PV, N_2 - the number of wind turbines.

PV module consists of 10 panels of KYOCERA KD240GX-LFB type which costs 6764 $. This price includes all equipment necessary to connect to the network. Depending on the weather data previously presented this system produces 3547 kWh/year.

The wind turbine produces for the considered location 258904 kWh/year and it costs 147000$.

One of the constraints of the sizing program is that the number of wind turbines $N_2 \leq 2$

Following the simulation with the help of Matlab Software results:

N1	N2	F(x) [$]
14	2	388696

Case 2:

Minimizing a linear objective function *F(x)*:

$$\min_x F(x) = 6764 * N_1 + 147000 * N_2 \qquad (12)$$

$$\begin{aligned} &3547 * N_1 + 258904 * N_2 \geq 566480 \\ &N_1,\ N_2 \geq 0 \end{aligned} \qquad (13)$$

In this case it was not applied any constraints on the number of wind turbines.

Simulation results are the following:

N1	N2	F(x) [$]
0	3	441000

5. CONCLUSION

This article was made by using linear programming, sizing a system with renewable energy sources. Of the two cases analyzed it is observed that the minimum objective function is obtained in case 1. In order to accomplish the sizing using linear programming, it have been used the data for a period of one year. Due to the variation of primary energy sources it is necessary a connection to the network of the system to ensure uninterrupted supply of electricity to the consumer group. In the situation analyzed the group of consumers need 566480 kWh/year. The electrical network is used as a back-up system.

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