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Optimum autonomous wind–power system sizing for remote consumers, using long-term wind speed data

J.K. Kaldellis*

Laboratory of Soft Energy Applications and Environmental Protection, Mechanical Engineering Department, TEI Piraeus, Pontou 58, Hellinico 16777, Athens, Greece

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Abstract

The usage of autonomous power-systems is one of the most successful ways to treat the electrification requirements of numerous isolated consumers, not only in Greece but also worldwide. Such an autonomous system comprises a micro-wind converter and a battery storage device, along with the corresponding electronic equipment. Considering the high wind potential of several regions in our country, an integrated study is carried out, based on long-term wind-potential experimental measurements, in order to determine the optimum configuration of a stand-alone wind power system. The proposed solution "guarantees" zero load rejections for all the 4-year period examined. For this purpose, two separate calculation approximations are developed, presenting almost similar results. Of course, the application of the "WINDREMOTE II" numerical code based on detailed measurements, gives almost analytical results concerning the energy autonomy and the operational status of the autonomous system components. Finally, by introducing preliminary financial aspects, it is possible to determine the optimum system dimensions on a minimum first-installation cost. © 2002 Elsevier Science Ltd. All rights reserved.

Keywords: Autonomous wind power system; Optimum system sizing; Remote consumers

1. Introduction

In the beginning of the 21st century, almost every one of the European Union habitants has access to a continuous electricity supply, although this is not the case

* Tel.: +30-1-9619972; fax: +30-1-5450962.
E-mail address: jkald@teipir.gr (J.K. Kaldellis).

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Nomenclature

C_{bat}	battery's purchase cost
C_{elec}	electronic equipment's cost
CF	wind-turbine's capacity-factor
C_{WT}	wind-turbine's ex-works price
DOD_L	maximum battery depth of discharge
E_{tot}	electricity consumption for a given time period
$E_{tot}{}^{*}$	total annual electricity demand
f	first installation cost coefficient
$f(V)$	wind-speed probability density function
h	calm-spell duration
h_o	selected hours of autonomy
IC_o	autonomous system's initial cost
$N(V)$	wind-turbine's power curve versus wind speed
N_o	wind-turbine's nominal (rated) power
N_{max}	maximum wind-power required
N_{min}	minimum wind-power required
N_p	consumption peak load demand
n_c	battery's maximum operation cycles
Q_{max}	maximum battery-capacity
Q_{min}	minimum battery-capacity
U	battery's operation-voltage
V	wind-speed value
V_c	wind-turbine's cut-in speed
V_F	wind-turbine's cut-out speed
y	annual number of calm spells
Δ	technical availability
Δt	time-period in hours
η^*	energy-transformation coefficient
η_s	storage-system's efficiency
ω	wind-turbine's mean power coefficient

for all the planet's population. However, in spite of this technological achievement lasting for the three former decades, there still is a small part ($\approx$500,000) of the EU residents who have not direct access to a local utility network [1]. In Greece, mainly due to the existing peculiar topography and the large number of small islands, there are more than 50,000 remote consumers [2], which could be conceivably doubled once the existing country houses, shelters, telecommunication stations, lighthouses and remote military stations are taken into consideration.

The decision of not being grid-connected is commonly compulsory, either due to local electrical network scarcity in the area (e.g. tiny islands and mountainous areas) or due to the prohibitively high connection cost (e.g. 8000–11,000 Euro/km) [3].

On the other hand, in many of these isolated regions a high quality wind potential exists all over the year, mainly characterized by remarkable annual mean wind speeds and relatively limited calm spells. On top of that, during the last 20 years, wind-power technology has achieved an outstanding maturity status, while an astonishing improvement has taken place in the battery construction and electronic equipment sectors.

Taking into account all the above-mentioned information, it is a common belief [4] that by using autonomous wind power systems, there is an excellent opportunity to face the electricity demand requirements of remote consumers, contributing thus to a significant improvement of their life quality-level.

2. Position of the problem

The problem to be solved in the present essay concerns the electricity demand fulfilment of a typically remote consumer (4–6 member family), under the precondition of a rational investment cost. The proposed solution takes advantage of the existing wind potential of the area investigated: thus a small (micro) wind converter may be used. Additionally, three representative weekly electricity consumption profiles are selected—after an extensive local-market survey—on an hourly basis [5], being also depended on the year period analyzed (winter, summer, other). The data used are based on information provided by the Greek National Statistical Agency, concerning the electricity-demand profile of selected representative households. In Fig. 1, the most viable electricity-load demand profile is presented, for the typical family adopted, during a representative winter and summer week. According to the consumption profile approved, the annual peak load "N_p" is set at 3.5 kW, while the weekly electricity-consumption varies between 80 kWh and 100 kWh.

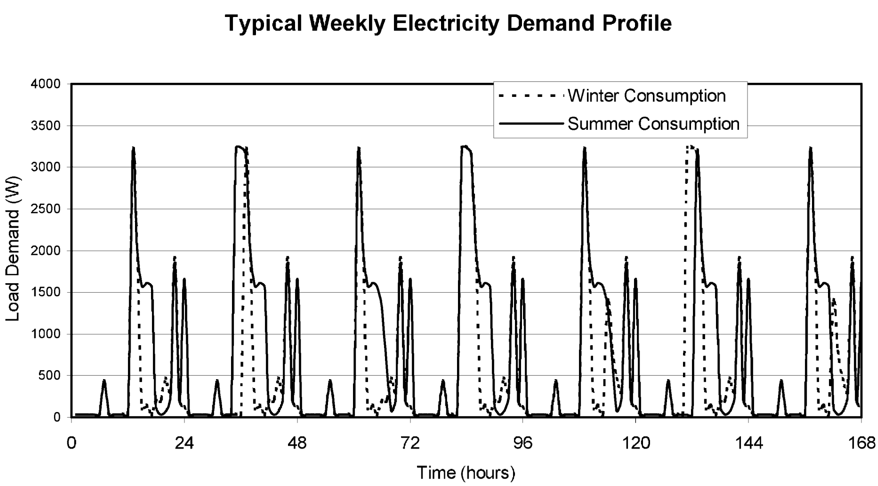

Fig. 1. Typical electricity demand profile of the remote consumer analyzed.

Summarizing, the total electricity consumption for every month of a year is given in Table 1. The electricity consumption in association with the available wind potential values remain the main inputs defining the appropriate size of the system wind turbine.

Consequently, due to the stochastic behaviour of the wind, the existence of an energy-storage system [6] (in the present case a lead-acid battery row) able to match the electricity demand of the consumer and the energy output of the wind turbine is absolutely necessary. More precisely, the battery capacity is one of the parameters strongly affecting the energy autonomy of the stand-alone system, influencing also the operational cost of the installation.

3. Proposed configuration-system sizing

In order to meet the electricity demand of remote consumers, an integrated autonomous wind-power system is devised [7], similar to the one in Fig. 2. Hence, the proposed system comprises:

(i) A small wind converter
(ii) A lead acid battery storage system
(iii) An AC/DC rectifier
(iv) A DC/DC converter
(v) A UPS (uninterruptible power supply)
(vi) A DC/AC inverter

Table 1
Four-year analysis results for Kithnos Island[a]

Kithnos			1st year			2nd year			3rd year			4th year		
Month	E_{tot} (kWh)	Temp. (°C)	$\overline{V}$ (m/s)	ω	$\leqslant N_o$ (kW)	$\overline{V}$ (m/s)	ω	$\leqslant N_o$ (kW)	$\overline{V}$ (m/s)	ω	$\leqslant N_o$ (kW)	$\overline{V}$ (m/s)	ω	$\leqslant N_o$ (kW)
January	335	11.5	7.69	0.39	2.89	8.98	0.47	2.40	8.65	0.45	2.50	8.28	0.43	2.62
February	303	11.9	9.48	.50	2.25	8.40	.44	2.56	8.62	.45	2.50	7.87	.40	2.81
March	325	12.8	7.30	0.38	2.87	6.44	0.32	3.41	7.30	0.38	2.87	7.04	0.36	3.03
April	315	16.0	5.51	0.27	4.04	5.56	0.27	4.04	4.78	0.23	4.75	3.68	0.15	7.28
May	325	19.6	5.63	0.27	4.04	6.21	0.31	3.52	5.02	0.25	4.37	4.40	0.20	5.46
June	410	24.2	4.21	0.19	7.50	3.64	0.15	9.50	3.71	0.15	9.50	5.63	0.27	5.28
July	424	26.5	4.52	0.21	6.78	6.06	0.30	4.75	5.05	0.26	5.48	4.84	0.24	5.94
August	424	26.2	8.07	0.42	3.39	6.86	0.35	4.07	6.23	0.31	4.60	6.28	0.31	4.60
September	315	23.5	7.20	0.37	2.95	5.11	0.25	4.37	7.22	0.37	2.95	6.26	0.31	3.52
October	325	20.0	5.08	0.25	4.37	5.38	0.26	4.20	6.76	0.34	3.21	7.24	0.37	2.95
November	324	16.4	6.32	0.32	3.52	6.27	0.31	3.63	9.37	0.49	2.30	8.24	0.42	2.68
December	335	13.2	9.02	0.48	2.35	7.52	0.38	2.96	7.93	0.41	2.75	6.36	0.32	3.52

[a] E_{tot} (electricity consumption per month), Temp. (monthly mean temperature), $\overline{V}$ (monthly average wind speed), ω (mean power coefficient value for each month), N_o (wind turbine rated power).

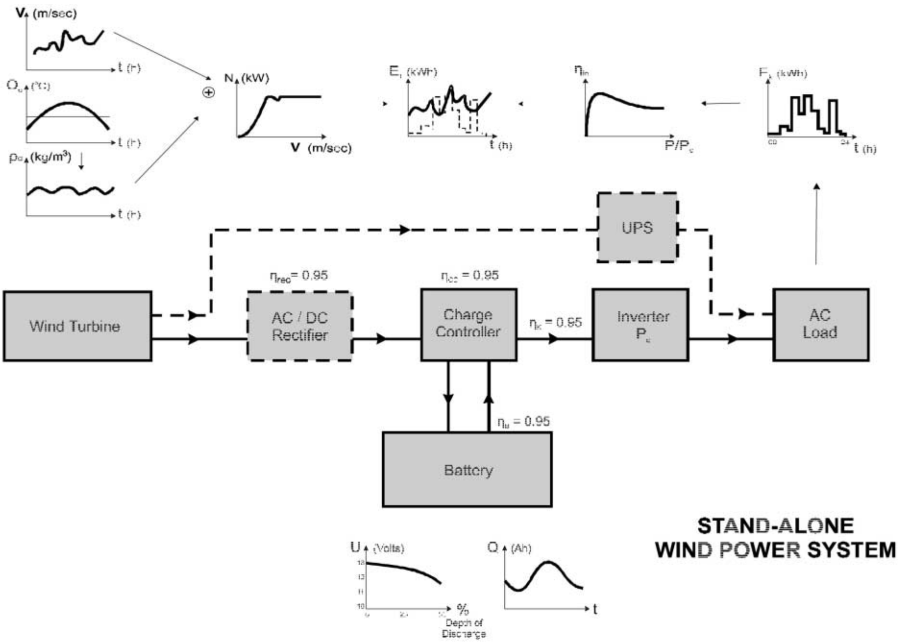

Fig. 2. Proposed autonomous wind-power system.

More specifically, the micro wind-converter (rated power "N_o") is connected either to the AC load via a UPS or to a battery row via a rectifier and a battery charge controller. The case that the wind turbine generates direct current (although similar to the one analyzed) is not examined here. The rated power of the selected wind-turbine depends on the system electricity demand, the available wind potential and the operational characteristics of the machine [8]. Keep also in mind that the wind-turbine output curves are given at standard-day conditions, without air humidity. Thus, in real day conditions, the ambient temperature and pressure along with the relative humidity are used to obtain the real air density and the corresponding wind-turbine output [9].

More precisely, using also the data of Table 1, the nominal power "N_o" of the machine is:

$$N_{\min} = E_{\text{tot}}(\Delta t)/(\Delta t \cdot CF) \leqslant N_o \leqslant E_{\text{tot}}(\Delta t)/(\Delta t \cdot CF \cdot \eta^*) = N_{\max} \tag{1}$$

where "$E_{\text{tot}}(\Delta t)$" is the system electricity consumption (increased by 20% to take into account future changes) for the examined period "Δt"–in h–(e.g. 1 month or 1 year), "CF" the capacity factor of the installation for the same time period and "η^*" the energy transformation coefficient, expressing the portion of the wind energy produced and stored via the battery system, which finally satisfies consumption [6,10]. Note also that the power output of the proposed wind-turbine should be big enough to face the maximum (peak) load demand "N_p" of the system, without using the inverter.

Bear in mind that the capacity factor is the product of the technical availability "Δ" with the mean power coefficient "ω" of the installation, i.e.

$$CF = \Delta\omega \tag{2}$$

More precisely, "ω" can be computed [11] as:

$$\omega = \int_{V_c}^{V_F} \frac{N(V)}{N_o} f(V)\mathrm{d}V \tag{3}$$

with "V_c" and "V_F" the corresponding cut-in and cut-out wind speeds of the wind-turbine analyzed, while "$N(V)$" is the corresponding power curve (Fig. 3) versus wind speed "V" and "$f(V)$" is the wind speed probability density function at the hub height describing the local wind potential for the time period "Δt". In cases that no detailed wind speed data exist for the area under investigation, the well-known Weibull distribution "$f(V)$" is used [12]. However, this is not the case in the proposed analysis, since the calculations are based on available experimental data of the wind potential for various regions of Greece [13].

Additionally, the system includes a battery row, of "$Q_{\max}$" capacity, selected to be sufficient to store the energy produced during the windy days, for usage during the calm spells. The battery size is defined by the autonomy hours "h_o" of the system, the total annual energy demand "E_{tot}*", the efficiency of the storage system "η_s" and the maximum permitted depth of the batteries discharge "DOD_L" [14]. Selecting a $U = 24$ or 48 V battery operation voltage, the maximum battery capacity (in Ah) is given as:

$$Q_{\max} = \left(\left(h_o E^{*}_{tot}\right) / (8760\eta_s DOD_L U)\right) \tag{4}$$

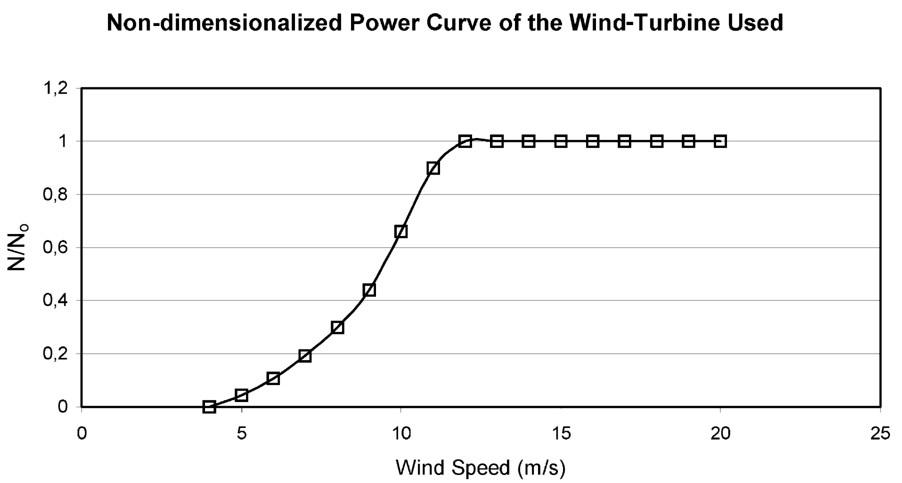

Fig. 3. Non-dimensionalized power curve for the wind turbine used.

In any case, the battery capacity "Q" varies between Q_{min} and Q_{max}, where:

$$Q_{min} = DOD_L \cdot Q_{max} \tag{5}$$

while the "DOD_L" value is strongly related to the life duration (operational cycles-"n_C") of the batteries, e.g.

$$DOD_L \cdot n_c \approx 1500 \text{ to } 1800 \tag{6}$$

The AC/DC rectifier and the battery charge controller size-definitions are based on the wind turbine and the battery operational characteristics (e.g. "N_o" kW, $U = 24$ or 48 V, charge rate "R_{ch}" in A, where the charge current numerical value must not exceed 20% of the storage capacity value). Similarly, the UPS characteristics depend on the maximum load demand "N_p" and the service time (e.g. 2 min), along with the operational voltage (e.g. 220–240 V).

Finally, the size of the inverter is selected [7] to fulfil the maximum load demand of the consumption "N_p", including a safety coefficient. In Fig. 4, a typical inverter efficiency profile is presented, as a function of the relative electrical load covered by the device.

Recapitulating, during the long-lasting operation of the proposed stand-alone system, the following situations may appear:

a. The power demand "N_D" is less than the power output "N_w" of the wind turbine, ($N_w > N_D$). In this case the energy surplus ($\Delta N = N_w - N_D$) is stored via the rectifier and the battery-charge controller. If the battery is full ($Q = Q_{max}$), the residual energy is forwarded to low-priority loads.
b. The power demand is greater than the power output of the wind turbine, ($N_w < N_D$), which is not zero, i.e. $N_w \neq 0$. In similar situations, the energy deficit ($\Delta N = N_D - N_w$) is covered by the batteries via the DC/DC converter and the DC/AC inverter. During this operational condition, special emphasis is laid on the two electricity production subsystems management plan.
c. There is no energy production (e.g. low wind speed, machine non available ($\Delta = 80\%$)), i.e. $N_w = 0$. In this case, all the energy demand is fulfilled by the battery-DC/DC controller-DC/AC inverter subsystem, under the condition that $Q > Q_{min.}$ In cases (b) and (c), when the battery capacity is near the bottom limit, an electricity-demand management plan should be applied; otherwise the load would be rejected.

4. Wind-potential analysis

Kithnos is a small island (1700 habitants, area of 94 km^2) in the Aegean Sea, located approximately 60 km southeast of Athens. The topography of the island is typically Aegean, i.e. gentle slopes, absence of flat fields, low mountains and sparse

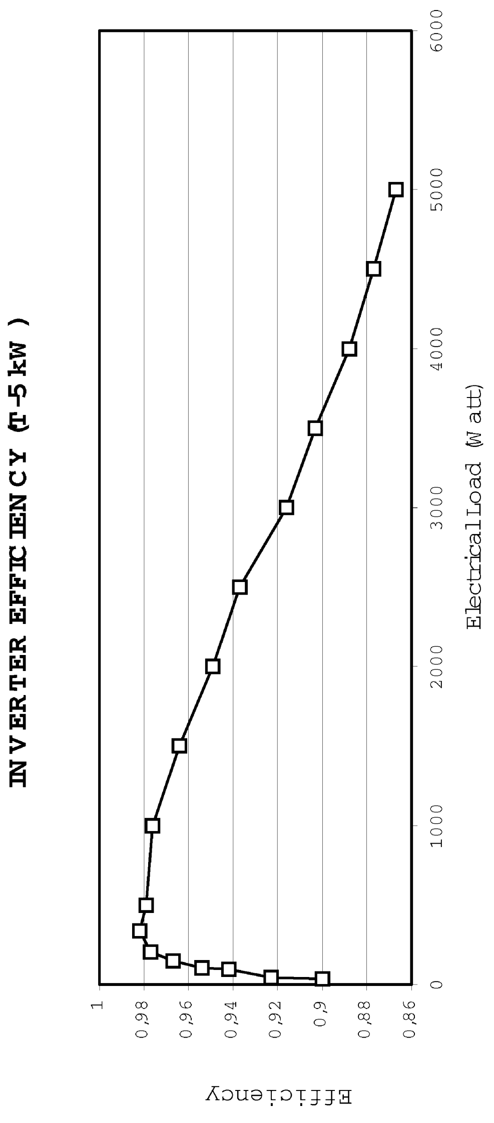

Fig. 4. Typical 5 kW inverter efficiency evolution.

vegetation. Its major village is Hora Kithnou with 800 habitants, and the main economic activities of the local society are agriculture, merchant marine and tourism. Due to the insufficient infrastructure (e.g. road network), there are many isolated consumers with no access to the local electrical grid. The island has an outstanding wind potential, since in several locations the annual mean wind speed approaches 7 m/s, at 10 m height.

Using the available wind speed data [13] for a relatively long (4 years) period, it is possible to create the experimental 4-year wind-speed probability density function distribution "$f(V)$" see (Fig. 5a). In Fig. 5(b) and (c), we present the corresponding "$f(V)$" distribution for the worst (April of the 4th year) and the best (February of the 1st year) month of the period examined (see also Table 1), concerning the available wind potential.

In Fig. 6, the monthly average wind speed is cited along with the corresponding velocity frequency curves for the 4-year period analyzed. The numerical monthly average wind-speed values for each year analyzed are also given in Table 1. As it is obvious from these results, the minimum wind speed values appear in Kithnos mainly during the end-of-spring, beginning-of-summer period (i.e. April, May and June); therefore, the selected wind turbine size should strongly depend on the wind potential characteristics of this period.

Finally, for stand-alone systems, further detailed data are necessary to guaranty the energy autonomy of the installation. In similar applications, the annual duration of calm spells without a break is very important, as it indicates the period to be covered by storage systems. Hence, after a thorough analysis of the available detailed wind-speed values [15], it is possible to estimate the calm-spell phases ($V \leqslant 5$ m/s) for Kithnos island for the complete period investigated (Fig. 7). Accordingly, an analytical function is also used to simulate the relation between the annual number of calm spells "y" and the calm spell duration "h", thus:

$$y = \frac{\alpha}{h^{\beta}} \tag{7}$$

where $\alpha = 60.2$ and $\beta = 0.948$.

5. System sizing—1st-order approximation

Small wind turbines used for electricity production start operating (cut in speed) at a wind speed approximately 3–5 m/s, Fig. 3. In order to obtain an unambiguous picture, the monthly mean wind speeds are also calculated for the complete time period analyzed (Table 1), along with the monthly frequency curves; see for example Fig. 6. Subsequently, using the available experimental probability density function distributions for every month (e.g. Fig. 5) of the 4-year period under investigation, the minimum acceptable nominal power of the wind turbine selected is predicted using Eqs. (1)–(3), according to the following relation:

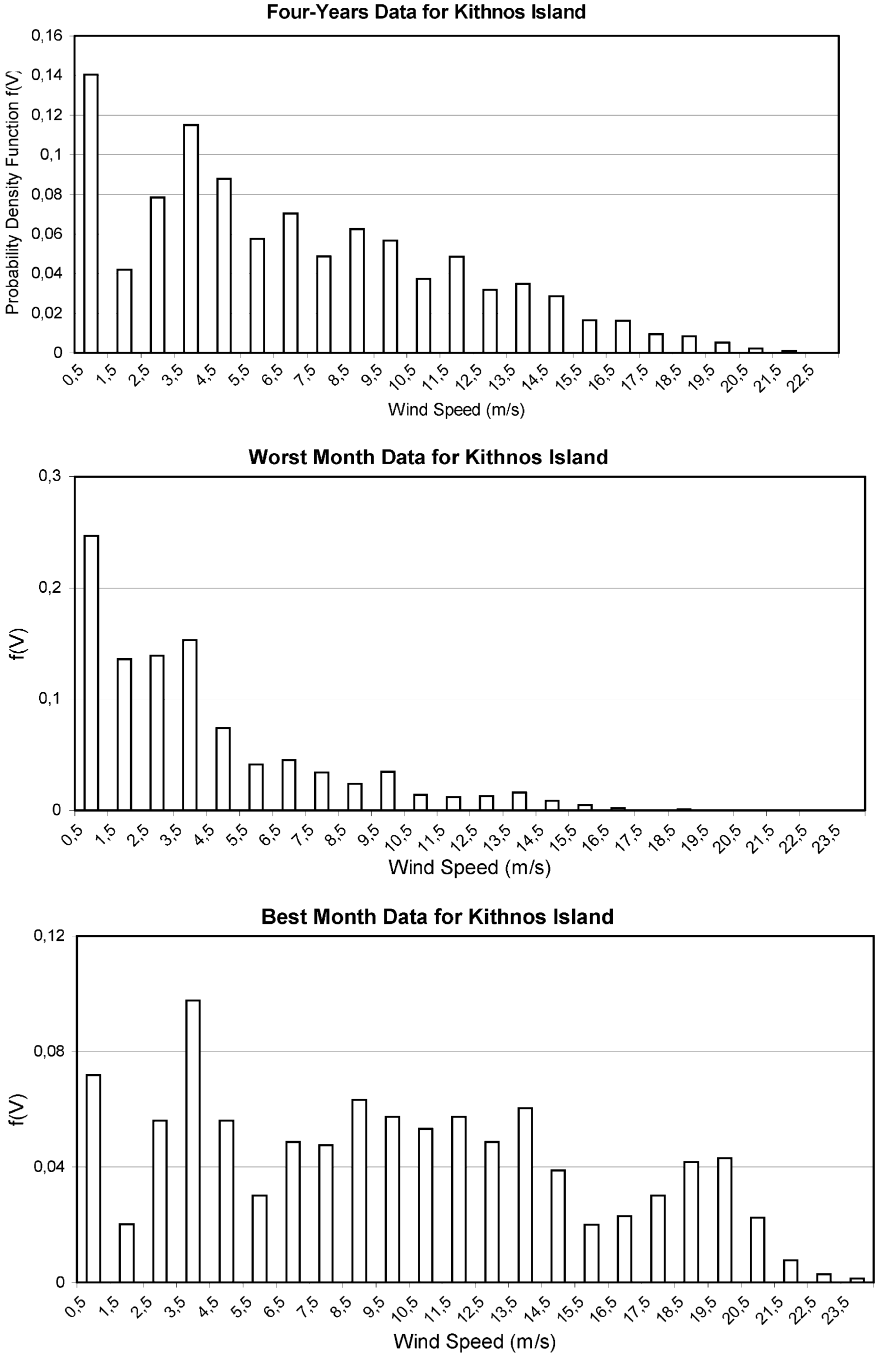

Fig. 5. (a) Four-year wind potential characteristics. (b) Worst month wind potential characteristics. (c) Best month wind potential characteristics.

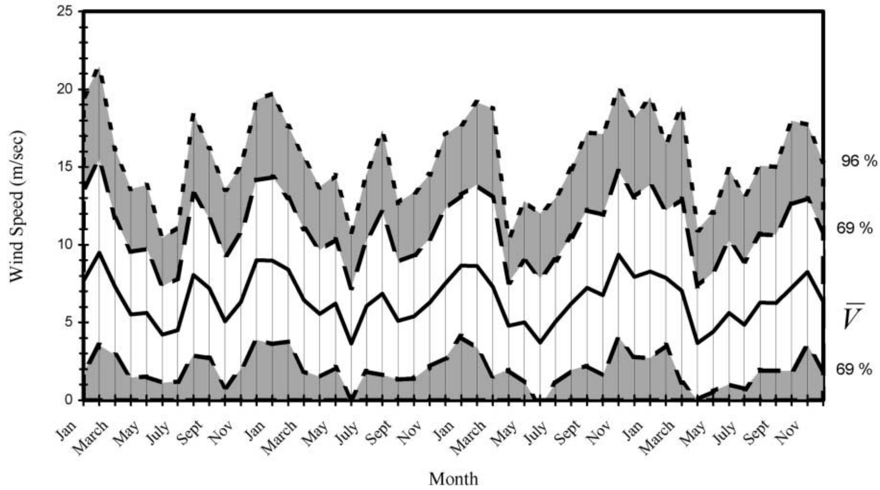

Fig. 6. Long-term monthly mean values of Kithnos wind speed.

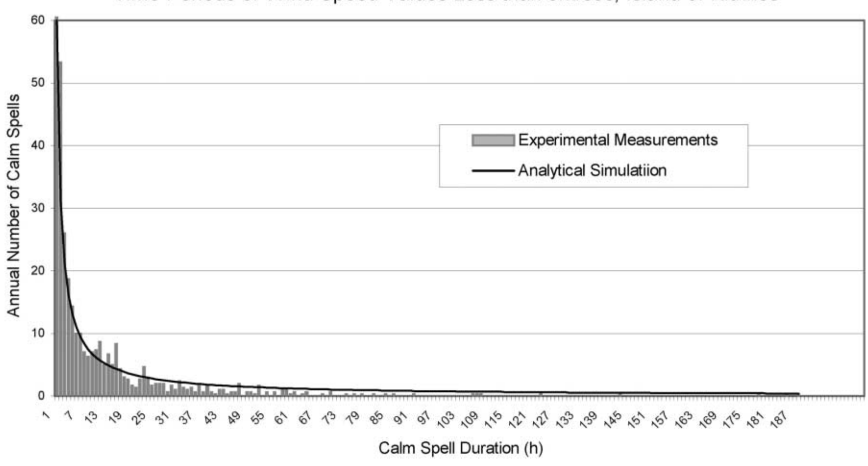

Fig. 7. Long-term calm spell periods for Kithnos Island.

$$N_{\mathbf{o}} = \max\left[\max_i N_{\max_i}, N_{\mathrm{p}}\right] \tag{8}$$

Hence, the resulting nominal power for Kithnos Island is set equal to 9.5 kW.

Consequently, taking into account the above-presented investigation, it is concluded that an 180 h calm spell appears at least once per year in the area of Kithnos, while there is a 95% possibility that the calm spell does not exceed the 140 h per year. Summarizing, the maximum acceptable calm spell (180 h) may be used to define the minimum battery size, in order to avoid the load rejections of the stand-alone system. Thus, with ($\eta_s = 0.8$, $DOD_L = 75\%$, $U = 24$ V) from Eq. (4) one gets $Q_{max} = 7200$ Ah.

Recapitulating, according to the 1st-order approximation analysis, based on monthly wind speed data, the proposed stand-alone system consists of a small wind converter of 10 kW, an AC/DC rectifier of 10 kW, a UPS of 5 kW/240 V/2 min, a DC/AC inverter of 5 kW/240 V/50 Hz and a battery storage system of 7200 Ah/24 V. The exact battery size is selected according to the expected maximum calm spell duration, resulting from the long-term analysis of the local wind potential.

6. System sizing—2nd-order approximation

As mentioned above, the main purpose of the present study is to estimate the appropriate dimensions of a stand-alone wind-power system for every remote consumer sited on Kithnos Island, under the condition that detailed wind speed (along with ambient pressure–temperature–humidity) data exists. The two governing parameters used during the optimization procedure are the rated power "N_o" of the wind turbine and the battery maximum size "Q_{max}". To confront similar problems, a computational algorithm "WINDREMOTE-II" was devised [16]. The developed numerical code is used to carry out the necessary parametrical analysis on an hourly energy production-demand base.

More precisely, for each pair of "N_o" and "Q_{max}" values the "WINDREMOTE-II" algorithm is executed for the specific time-period selected (e.g. 1 month, 6-months, 1 year or even 4 years), while emphasis is laid on obtaining zero-load rejection operation.

If this is not achievable, the battery size is increased and the calculation is performed again, up to the case that the no-load rejection condition is fulfilled, i.e. $Q^* = \min\{Q_{max}\}$. Next, another wind-turbine size is selected and the calculations repeated. Thus, after the integration of the analysis a (N_o–Q*) curve is predicted under the no-load rejection restriction (Fig. 8). To get a clear-cut picture, keep in mind that for every pair of (N_o–Q^*) values the stand-alone wind power system is energy autonomous for the period investigated.

More precisely, in Figs. 9–12 the computational results of "WINDREMOTE-II" algorithm are presented for 4 successive years for Kithnos island. In the same figures, the "100 annual permitted load rejection curves" are also given for comparison purposes. As expected, according to the numerical results obtained, the battery size is significantly increased as the rated power of the selected wind turbine is decreased. This increase is much more abrupt for relatively small wind-turbines ($N_o \leqslant 5$ kW), while the battery size shows an asymptotic behaviour for wind-turbines of the order of 10 kW.

Additionally, the no-rejection (N_o–Q^*) curves for every year analyzed do not present similar distributions, since, for small wind-turbines, the 4th year examined

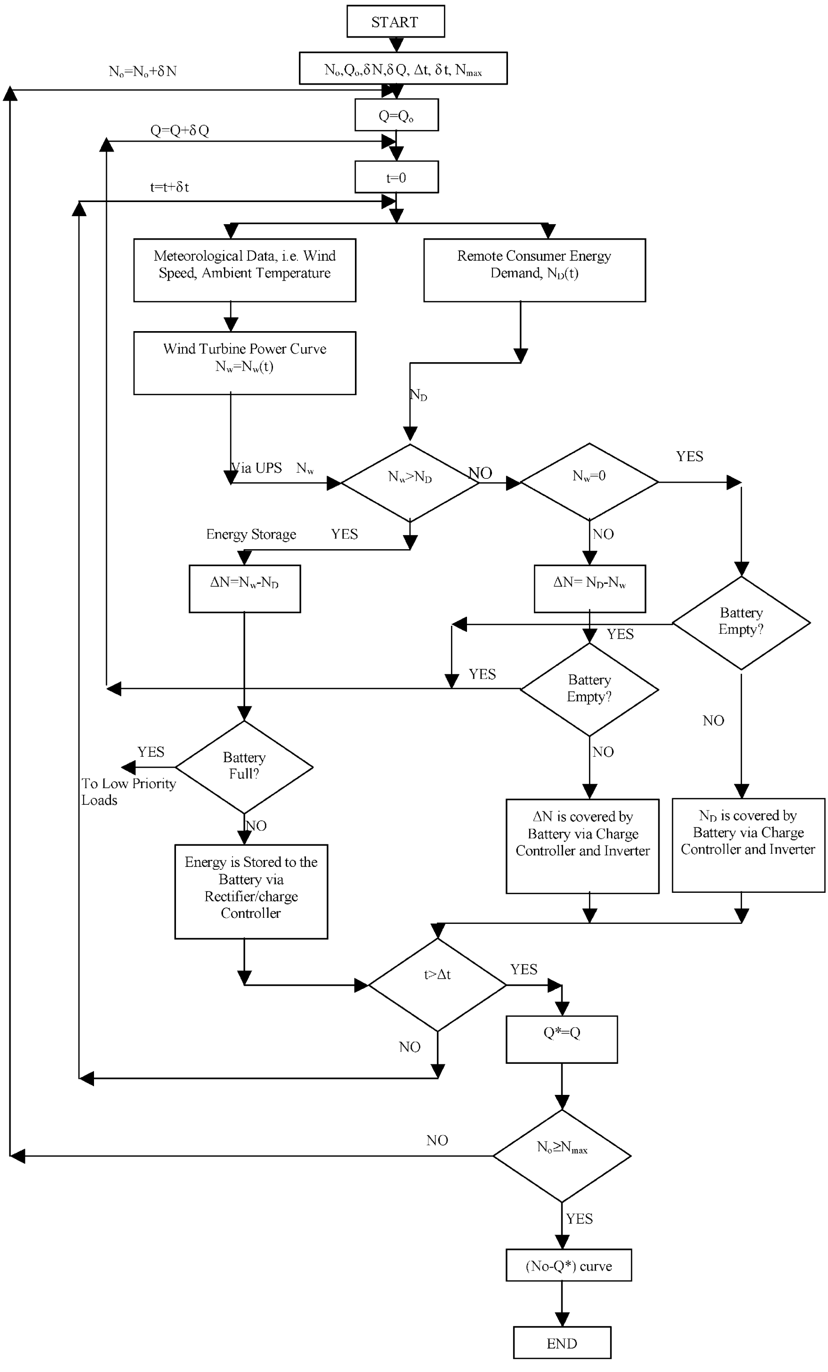

Fig. 8. WINDREMOTE-II algorithm.

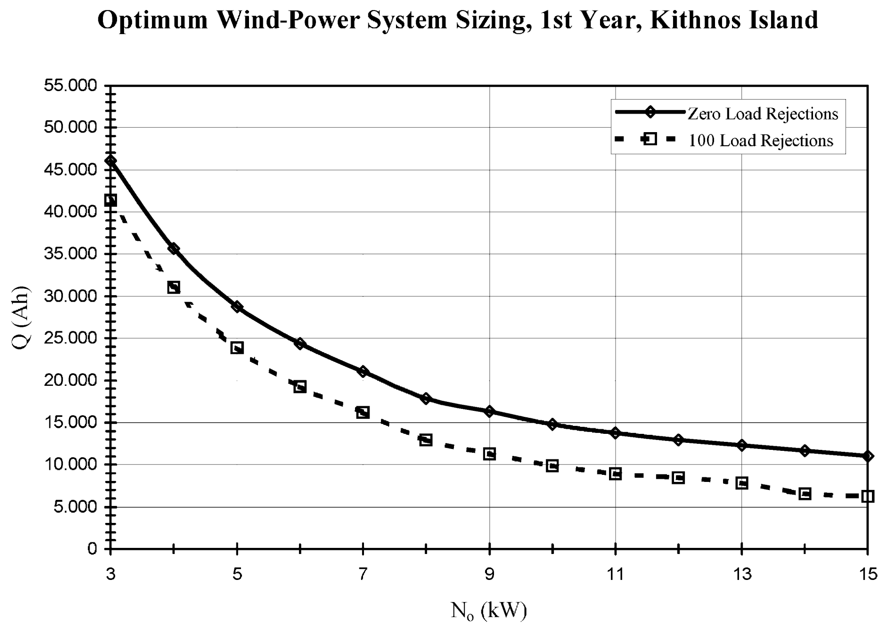

Fig. 9. Battery storage capacity requirement versus wind-turbine rated power (1st year results).

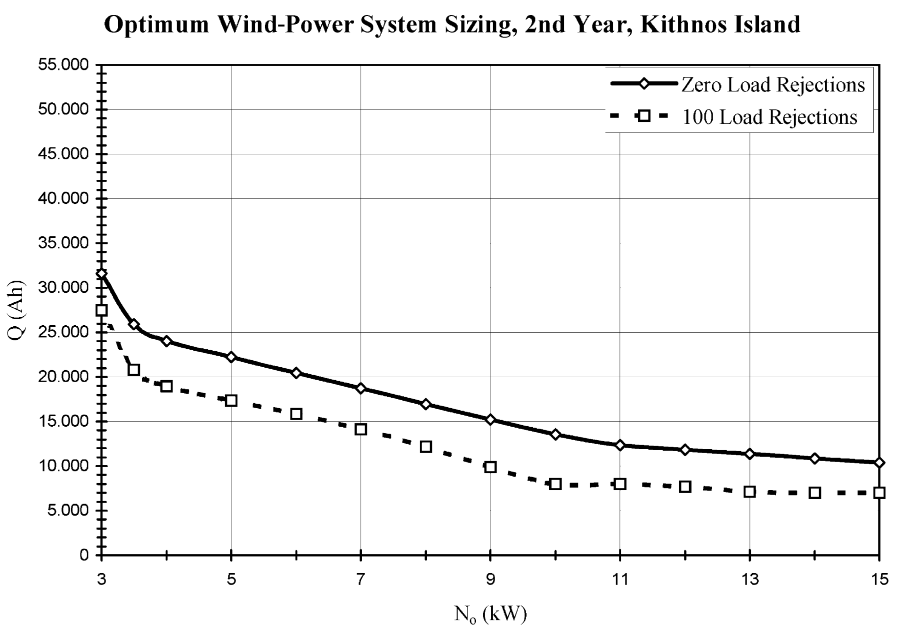

Fig. 10. Battery storage capacity requirement versus wind-turbine rated power (2nd year results).

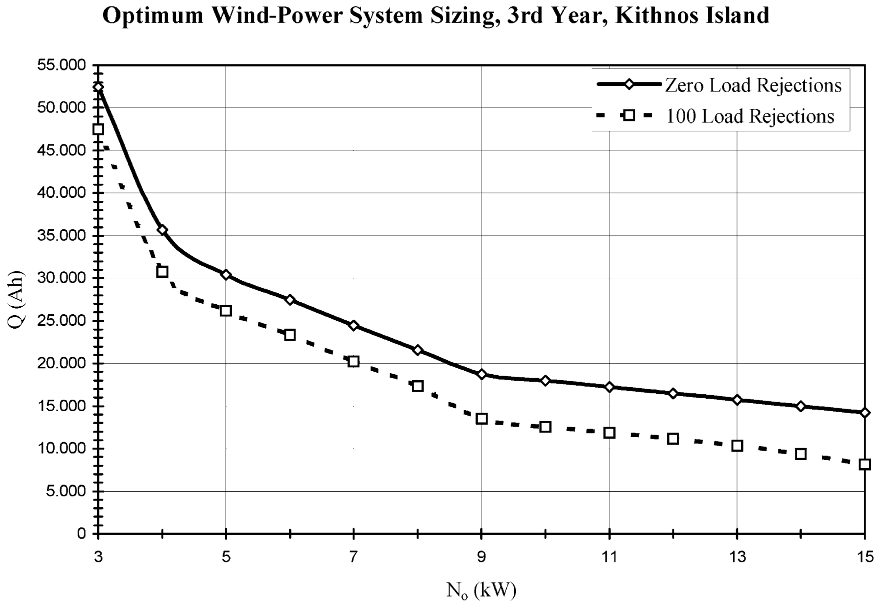

Fig. 11. Battery storage capacity requirement versus wind-turbine rated power (3rd year results).

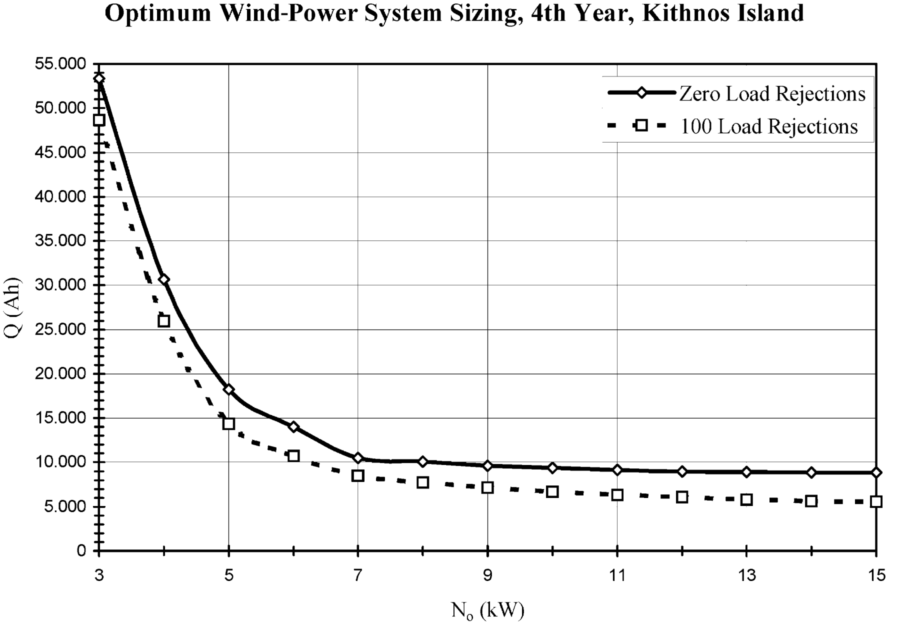

Fig. 12. Battery storage capacity requirement versus wind-turbine rated power (4th year results).

imposes the largest battery-storage capacity. On the contrary, for bigger wind converters, the 3rd year results seem to dominate the battery capacity values. Finally, the windiest year seems to be the 2nd one, taking into consideration the quite small battery capacity needed to guarantee whole year energy autonomy.

Another interesting conclusion drawn from Figs. 9–12 is the substantial decrease in storage requirement, provided that a reasonable number of annual load rejections is acceptable. This "Q*" value decrease is relatively limited for the small wind converters adopted ($N_o \leqslant 5$ kW); approaching significant values (up to 35% decrease) in cases that "N_o" exceeds the 10 kW.

In order to obtain a complete picture of the problem analyzed, the four "annual no-load rejection (N_o–Q^*) curves" are grouped in Fig. 13, along with the corresponding solution 4-year distribution. According to the numerical results obtained, the 4-year autonomy curve encloses the corresponding annual profiles, thus the 4-year autonomy curve is defined on the basis of the worst annual case, or for every "N_o" value the battery size "Q_{opt}" is given as "$\max\{Q_i^*(N_o)\}$", where "i" refers to the year analyzed, taking integer values between one and four.

Similarly, for comparison purposes, the 1st-order approximation solution is placed in the same figure. As is clear, the 1st-order approximation solution is not validated by the analytical results, since the corresponding battery size is almost 40% of the optimum value given by the "WINDREMOTE-II" numerical code. This remarkable discrepancy may be attributed to the fact, that a load rejection will most likely be realized during two or more successive calm spells, even though the battery is sized enough to face the electricity demand of the major calm spell of a whole year. More precisely, in cases where there is not enough time between successive calm spells to recharge the energy-storage system, the real duration of the worst

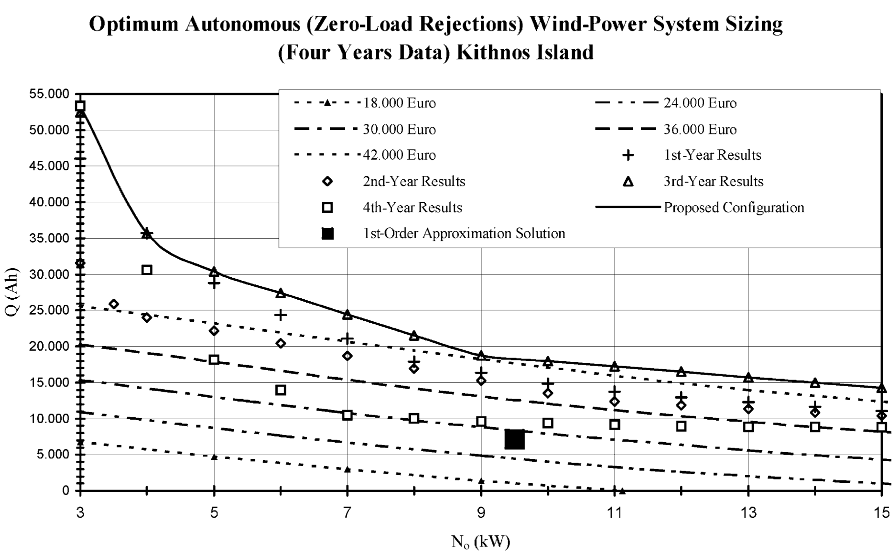

Fig. 13. Calculation results comparison for the entire period analyzed, Kithnos Island.

calm spell may be almost equal to the sum of the above mentioned successive time-periods. On the other hand, the 1st approximation solution gives a reasonable estimation of the optimum size of the proposed stand-alone wind-power system (especially for "N_o"), although it is not possible to ensure a completely autonomous operation of the installation.

Integrating the present analysis, it is interesting to introduce (not in detail) the influence of the first installation cost on the optimum configuration selected. More precisely, according to previous analysis by the authors [17], the initial cost "IC_o" of the investment under investigation can be approximated as:

$$IC_o = C_{WT} + C_{Bat} + C_{elec} + f * C_{WT} \tag{9}$$

where the wind turbine (ex-works) cost for small wind converters ($N_o \leqslant 100$ kW) is given [18] as:

$$C_{WT} = \left(\frac{a}{b + N_o^x} + c\right) N_o \qquad (\text{in Euro, for } N_0 \leqslant 100 \text{ kW}) \tag{10}$$

($a = 8.7 \times 10^5$; $b = 621$; $x = 2.05$; $c = 700$, [18])

and

$$C_{Bat} = c_b * Q_{max} \qquad (\text{in Euros}) \tag{11}$$

Note that "c_b" is slightly dependent [7] on the battery capacity, while for the local market–after a market survey concerning lead-acid batteries–essential values may be approximated by the following semi-empirical relation:

$$c_b = 5.0377/Q_{max}^{0.0784} \tag{12}$$

Additionally, the first installation cost coefficient "f" (excluding the cost of electronic equipment) is relatively small for micro wind-turbines, e.g. $f = 0.15$ [19]. On top of that, the cost of the remaining electronic equipment is a function of the peak-load demand (UPS Inverter, i.e. $A = A(N_p)$), while it also depends on the wind-turbine size (rectifier, charge controller). Thus, since the maximum electricity demand of the remote consumer is prescribed, the following simplified relation is valid [16] for the Greek market:

$$C_{elec} = A + B * N_o \qquad (N_o \geqslant 1 \text{ kW}) \qquad (\text{in Euro}) \tag{13}$$

with $A = 2200$ Euros and $B = 380$ Euros/kW.

Recapitulating and substituting Eqs. (10)–(13) into Eq. (9), one gets:

$$IC_o = \left(\frac{a}{b + N_o^x} + c\right)N_o * (1 + f) + c_b(Q_{max}) * Q_{max} + A + B * N_o \tag{14}$$

Consequently, according to Eq. (14), the installation initial cost is a function of "N_o" and "Q_{max}", i.e.

$$IC_o = IC_o(N_o, \ Q_{max}) \tag{15}$$

By drawing the corresponding initial cost constant-value curves in Fig. 13, it is possible to estimate the optimum (minimum initial-cost) solution, which guarantees energy autonomy of the remote consumer for the 4-year period examined. Of course, since the optimum solution is strongly dependent on the slope of the initial cost (IC_o=constant) curves, a more detailed investigation is necessary, taking into consideration the current values and opportunities of the European market. In any case, the resulting optimum autonomous solution for Kithnos Island is based on a 9.5 (or 10) kW wind converter and on an 18,000 Ah–24 V battery row. Accordingly, the first installation cost is approximately 42,000 Euros, if the 40% Greek State subsidy is taken into account [18,19].

For comparison purposes, it is interesting to repeat that the grid connection cost is almost 10,000 Euros/km, while the proposed wind based autonomous system is offering enough electricity for at least 20 years, with minimum maintenance and operation cost (excluding the battery replacement every 5–7 years), independent of oil prices and with fundamental environmental and social benefits.

7. Conclusions

The optimum dimensions of an autonomous wind-power system are defined for a representative island in the Aegean Sea, using extensive wind-speed data. The results obtained are based on experimental measurements and operational characteristics by the autonomous system components manufacturers. For this purpose, two separate computational approximations are developed. The first one, based on monthly mean-velocity values, calm spells and velocity frequency curves, estimates with reasonable accuracy the necessary parameter values for the proposed configuration, but it does not guarantee the no-load rejection constraint for all the period examined.

Subsequently, the second method, based on detailed wind-speed and ambient temperature-pressure time series, predicts—via the "WINDREMOTE II" numerical code—the corresponding wind-turbine size and battery capacity that ensures the remote system's energy autonomy. Additionally, according to the results obtained, the 1 year data based analysis is not enough to provide long-term energy autonomy of the system: thus at least 3–5 years extensive data are needed.

Finally, although the economic behaviour investigation is not the purpose of the present analysis, it is demonstrated that the proposed wind-powered energy autonomous system is the best solution to meet the electricity demands of the vast majority of remote consumers', especially in high wind-potential locations. On top of that, subsidization possibilities either by local authorities or via European funds should greatly increase the economic attractiveness of similar wind energy applications.

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