CALCULATION OF INSTALLATIONS

INTRODUCTION

Ortronic® is a unique technology and our advantage obligates us to consider as our first objective the fully satisfaction of the users of our systems.

The only possibility for a Ortronic® system user to do not be fully satisfied with their functioning, is that the system power is lower than the minimum needed power for guarantee his fully satisfaction.

All above mentioned justifies completely the necessity of paying the maximum attention to everything that we say about the calculation of installations.

CALCULATION OF INSTALLATIONS

The purpose of the calculation is guarantee the good functioning of the installation and then, the fully satisfaction of the user.

With the same purpose, which must not be changed, there are the two following ways to do the calculations:

Fast calculation of an installation: Based in our own experience and in the technical characteristics of our converters, unique in the market, that have great advantages as their efficiency, over 97%, for any output power, in all the models.

Detailed calculation of an installation: Based in the measurements taken by a high precision net analyzer.

Both ways of calculation guarantee the good functioning of the installation and they have the following differences:

1 Fast calculation of an installation.

With the fast calculation we avoid the net analyzer, its installation and the necessary days to take the measurements.

On the other hand, the size of the converter could be a little higher, this will benefit the security of the installation and the possible installation extensions, without any kind of problem.

Detailed description point by point:

1.a Turn on the needed receivers, including the receivers with motor, until reach the 50% of the total power of the installation.

1.b With an Amp meter, measure the current and calculate the RMS power.

1.c Multiply the RMS power by 8 to obtain the starting power.

1.d Choose a converter whose starting power is the nearest higher to the calculated starting power.

Taking under consideration that the Ortronic® converter efficiency does not depend on the output power, under a technical point of view, always is better to install higher powers than needed.

1.e To calculate the size of the storage batteries bank multiply the RMS power, paragraph 1.b, by 8 and divide the result by 264, you obtain the ampere-hour of each of the 22 batteries, choose the nearest capacity with a maximum difference of 10% if it exists, if not, choose the nearest higher capacity. **The fast calculation finishes at this point.**

2 <u>Detailed calculation of an installation.</u>

With the detailed calculation it is essential the high precision net analyzer, its installation, the necessary days to take the measurements and the delay on the quotation presentation.

The detailed calculation, under a technical point of view, is more complete, more professional and it is also the best way of showing the great advantages of the Ortronic® converters in comparison with the PWM.

If you want to calculate with accuracy the needed power, proceed as follows:

Must be understood as exact calculation of an installation, to define the needed technical requirements of its principal components, such us:

2.1 The converter.

2.2 The battery charger.

2.3 The storage batteries bank.

For calculation purpose, we will call '**Receiver**' to all type of apparatus which use the electrical energy to work, and we divide them in two big groups: '**Resistive**' and '**Inductive**'.

3 <u>Variables to calculate, for each receiver:</u>

3.1 Effective Power.

3.2 Starting power.

3.3 Transients Peak Power.

3.4 Daily consumption, expressed in Watts-Hour-Day (WHD).

3.5 Energy losses or gains.

For making the calculations, with guaranteed success, it is essential to have a clear knowledge of the following concepts: Power, Energy, Effective Power, Peak Power, Starting Power and Transients, for that purpose, please click on the following link, **Some Basic Electricity Concepts**.

In these following paragraphs, we analyze all the technical characteristics whose results depend of the technology utilized at their manufacture.

4 THE CONVERTER

It is the most important component of an installation and also the one which most affects to its good functioning.

The efficiency of an installation depends, principally, on the converter efficiency, which depends on the technology utilized at its manufacture.

Nowadays, the converters that exist in the market, of power higher than 4 kW, are manufactured with one of the two following technologies:

4.1 Pulse Width Modulation, PWM.

4.2 Ortronic® technology, developed and patented by Juan Ortigosa.

In order to understand in a better way, the influence of the technology in the converter functioning, we analyze the No-Load Consumption (NLC) and the Energy Losses due to the Converter Efficiency (ELCE) in the following paragraphs.

4.3 The No-Load Consumption (NLC) of the PWM converters:

NLC must be understood as the energy consumed by the converter when there is not any receiver connected at its output.

In Ortronic®, we have selected a 24 kW RMS PWM converter that is a very common power for real installations with air conditioning.

If you do not have a similar converter, you could use a graphic that represents the efficiency depending on the output power at the converter that should be given by the converter manufacturer.

It is very easy to measure the NLC, you only have to measure the DC current at the input of the converter and multiply it by the DC Volts at the converter input.

In this case, the NLC measured at the PWM converter was 1163 Watts-hour.

4.4 The NLC at Ortronic® converters.

The Ortronic® converters NLC is lower than 3 Watts-hour, for all models, this consumption comes from the battery that energizes the digital heart of the converter, which is independent of the power batteries.

The NLC of the power batteries is zero.

The NLC in an Ortronic® converter is the same with the converter ON or OFF, and it is also the same when there is not any load connected at its output.

4.5 The converters efficiency.

The efficiency of a converter is obtained dividing its output power by its input power.

Efficiency $Ef = \frac{Wout}{Win}$ and the ideal efficiency $IEf = \frac{Wout}{Win} = 1$

The electrical motors, when they start, multiply their power by a number called ‘starting factor’. The starting factor values are shown in the following table.

Starting factors table

Receiver	Starting Factor
Air conditioning, Inverter model	4
Air conditioning with compressor	24
Refrigerators	22
Induction motors	7.5

In the majority of the installations, as houses, offices, commerce, restaurants, hotels, etc., the amount of receivers connected is very different during the 24 hours time, consequently, the demanded power and the energy utilized is also very different during that time.

In order to make realistic calculations in an installation, we have to consider the converter efficiency in terms of the different amount of receivers connected during the 24 hours time.

In order to allow any motor to start without the necessity of turning off other receiver, it is absolutely necessary that the converter has the necessary minimum power.

The starting powers are added to the effective power of the other receivers that are working at the moment of the starting.

4.6 The efficiency of the PWM converters.

As it is well known, the efficiency of the PWM converters varies in terms of the power connected at its output. Check that clicking on the following link, **Ortronic® Converter Efficiency Vs. PWM Converter Efficiency**.

4.7 The efficiency of the Ortronic® converters.

The efficiency of all Ortronic® converter models, is always over 97%, independently of the power connected at its output.

5 Necessity of a net analyzer:

In order to be realistic with the data used for the installation calculation and to avoid mistakes, it is essential to use a high precision net analyzer, which could measure peak power, from starting and transients, in time of nanoseconds.

Ortronic® recommends the 435 FLUKE net analyzer. You will find information in our website, please click on the following link, **Information Fluke 435**.

The net analyzer must be connected at the installation for a minimum time of three days, during this time it will take all the necessary data in order to guarantee the correct calculations.

5.1 Among other data, the net analyzer will save: the effective, starting and transients power. Once the three different powers are known, we can choose the converter model, with enough power to withstand them.

5.2 With the power measurements taken from the net analyzer, during the days it has been connected, we will do the following steps:

5.2.1 Take note of the total number of hours with power consumption lower than 100W, and call them: No-Load Consumption Hours, NLCH.

5.2.2 Take note of the total number of hours with power consumption higher than 100W and lower than 500W, and call them: Minimum Efficiency Hours, MEH.

5.2.3 Take note of the total number of hours with power consumption higher than 500W, and call them: Optimum Efficiency Hours, OEH.

5.2.4 The unit of energy is the Watt-hour and always must be referred to a time, expressed in hours. For all the energy calculations in the installations, we will use the '**Watts-hour-day**' (WHD) which is the energy consumed in a time of 24 hours.

5.2.5 The average power during MEH is calculated dividing the total consumption during the MEH by the number of hours. With that obtained average power, we calculate the energy losses due to the converter efficiency (ELCE), as indicated in paragraph 6.1.

5.2.6 The average power during OEH is calculated dividing the total consumption during the OEH by the number of hours. With that obtained average power, we calculate the energy losses due to the converter efficiency (ELCE), as indicated in paragraph 6.2.

6 Example of the calculation of an installation.

As a calculation example, we show in these following points, the measurements made by Ortronic® in a 24 kW RMS PWM converter.

6.1 The first measurement of losses percentage during MEH was made with a resistive load of 300 W RMS connected at the output of the converter, and the result was calculated in the following way:

$$ELCE = 1 - \frac{Wout}{Win} = 1 - \frac{300}{1396} = 1 - 0.2149 = 0.785 = 78.5\%$$

1 means an efficiency of 100% and $\frac{Wout}{Win}$ is the real efficiency.

The energy losses, with 300 W connected at the converter output, were 78.5%.

6.2 The second measurement of losses percentage during OEH was made with a resistive load of 1500 W RMS connected at the output of the converter, and the result was calculated in the following way:

$$ELCE = 1 - \frac{Wout}{Win} = 1 - \frac{1500}{3175} = 1 - 0.4724 = 0.5276 = 52.76\%$$

The energy losses, with 1500 W connected at the converter output, were 52.76%.

6.3 The starting powers and the transients were not taken under consideration in these energy measurements, because the maximum time for starting and transients is 200 milliseconds and, transformed into hours, that is the time unit for the energy measurements, means an insignificant value.

6.4 ELCE is essential for calculating the energy losses in the converter, and these losses plus the installation consumption define the size of the storage batteries bank.

6.5 Other essential data for the storage batteries bank calculation is the NLC, No-Load Consumption, normally during night.

We calculate the energy losses multiplying NLC, paragraph 4.3, by the NLCH, paragraph 5.2.1.

7 THE STORAGE BATTERIES BANK

Before continuing, read carefully what is explained in our website in point 3 at **Ortronic® Anti-Blackout Systems**.

7.1 The storage batteries bank is composed by 22 batteries of 12V each connected in series, plus one 12V battery, to energize the digital heart of the system.

7.2 The storage batteries bank size depends on the following variables:

7.2.1 **Autonomy of the installation:** Autonomy should be understood as the time in which the installation works only with the storage batteries bank.

In Emergency Systems, the autonomy must be calculated for corresponding to the blackout period time.

In Off-grid Systems, the autonomy is calculated to charge the batteries only once every 24 hours.

7.2.2 **Necessary energy during the autonomy:** The necessary energy is the addition of the energy used by the receivers, plus the losses in the converter, paragraphs 4.3, 6.1, 6.2 and 6.5, plus the losses in the batteries.

If the installations are working, with a generator set, with the electrical grid or both of them, the best way for knowing the exact data is connecting a net analyzer for a minimum of three days. We recommend a week if the installation is very big.

The net analyzer saves all the required data for the correct calculation of the installation, plus the technical characteristics of the energy supplied by the generator set or the electrical grid.

To extend the batteries useful life, Ortronic® recommends to discharge the batteries until the stored energy reaches a minimum of 40%. This data must be taken in consideration when calculating the size of the storage batteries bank. To enlarge the information about the losses in batteries please click on the following link, **Losses in Batteries**.

7.2.3 **The Ortronic® energy gains due to the recovery of the reactive energy:** The reactive energy calculations, when there are resistive and inductive receivers and the time of working of each one of the receivers is ignored, is very long and tedious.

With Ortronic® we can avoid those calculations due to the following facts:

In the worst case, the energy recovered is between 30% and 40%, which is the losses percentage of the batteries charging and discharging, plus the 3% of losses in the Ortronic® converter, consequently, the total losses always are compensated by the recovered energy.

8 THE BATTERY CHARGER

In all Ortronic® Systems, the battery charger has two different outputs, one to charge the power batteries and the other to charge the battery which energizes the electronic of the system.

The battery charger for the power batteries is always a three phase one, and it can be used with one, two or three phases. Its power must be the minimum needed to withstand the batteries charging current, plus the consumption at the installation during the charging time, when it is an ONLINE installation.

The battery charger for the battery which energizes the electronic of the system is always single phase and it allows a maximum charging current of 12 Amps.

9 THE ELECTRIC GENERATOR SET

It always must be three phase and its power must be the minimum needed to withstand the batteries charging current, plus the power used at the installation during the charging time.

The battery charger controls the current taken from the generator and it does not allow exceeding a limit pre-adjusted in factory.

When the Ortronic® installation is ONLINE, the total current goes through the battery charger, a part charges the batteries and the other feeds the receivers during the batteries charging time.

When the Ortronic® installation is OFFLINE the current that goes through the battery charger is all used for charging the batteries. The current used by the receivers, during the batteries charging time, it is taken directly from the generator set.

In OFFLINE Ortronic® installations, the functioning of the system, during the batteries charging time, is described as follows:

9.1 The Ortronic® converter turns off when the generator set starts.

9.2 The receivers are transferred from the Ortronic® converter to the generator set.

9.3 When the batteries charging process finishes, the generator set stops, the receivers are transferred from the generator set to the Ortronic® converter and the Ortronic® converter turns on. All this process is fully automatic.

The OFFLINE Ortronic® Systems are especially adequate for communications shelters, mobile phone repeaters and others. The reasons for that are the following:

9.4 The power batteries need a lower time to be charged.

9.4a The efficiency of the system increases and, consequently, the total energy saving increases.

9.4b The power batteries are charged in a better way, increasing their useful life.

9.5 **The power of the generator set:** The majority of the generator sets of the market only show their power in KVA, assuming that they always will be used with loads with a determined power factor, normally 0.8.

Theoretically, when the power factor is equal to one, the KVA should be transformed in kilowatts, however this does not happen in the majority of the generator sets, existing special cases in which a generator set with 16 KVA only withstand 11 kW.

These anomalies between KVA and kW, must be taken especially under consideration for the generator sets that works with Ortronic® because the calculations are done only in kilowatts and the power demanded is also in kilowatts.

The generator set manufacturer must guarantee its power in kilowatts, in other way the installation may have power failures.

10 PRACTICE EXAMPLE OF CALCULATION

Open a calculation sheet in Microsoft Excel, as done in the example below explained, and proceed as follows.

10.1 In the first column you have to write down all the receivers of the installation.

10.2 In the top cell of each column you have to write the legends showed in the example.

10.3 In the Wrms column you have to write the RMS power of each receiver, resistive and inductive.

10.4 In the Fsta column you have to write the starting factor of each receiver.

10.5 In the Wsta column you have to write the starting power of each receiver multiplying the RMS power by the starting factor. In receivers with a resistive load and an inductive load (as washing machines, dish washers,…) you have to consider them as if it was two different receivers, one resistive and one inductive.

10.6 In the Wtrans column you have to write the values of the RMS power for all the receivers with starting factor equal to one. For receivers with starting factor higher to one, you have to write the transients measurements obtained by the net analyzer Fluke 435.

If you have measurements previously done in receivers of the same brand, model and power, you will not need to repeat the transients measurements for that receiver, you will directly write down the previously obtained measurements.

When Ortronic® installations must be offered for those places where the receivers haven't been installed yet, you must use the daily consumption tables, in WHD (click on the following link, **Calculation Tables**), and follow the same process as done before for paragraphs 10.1 to 10.6 but writing down the power of the receivers that the customer wants to install.

11 HOW TO CHOOSE THE CONVERTER

11.1 You must have the converters power table, for the different models, with the values of the RMS power, the starting power and the transient power (click on the following link, **Calculation Tables**).

11.2 The converter that must be chosen is the one that withstand the three different powers above mentioned.

Receivers	Wrms	Fsta	Wsta	Wtrans	DUH	WHD
Air conditioning, Inverter model	2500	4	10000	15000	8	20000
Air conditioning, compressor model	2500	22	55000	82500	8	20000
Lighting	300	1	300	300	3	900
Vacuum cleaner	500	7.5	3750	5625	1	500
Mixer	200	7.5	1500	2250	0.5	100
Refrigerator	250	22	5500	8250	8	2000
Washing machine, motor	1000	7.5	7500	11250	2	2000
Washing machine, resistors	2000	1	2000	2000	0.5	1000
Dish washer, motor	1000	7.5	7500	11250	1.5	1500
Dish washer, resistors	2000	1	2000	2000	0.5	1000
Microwave oven	2500	1	2500	2500	0.75	1875
Computer	250	1	250	250	2	500
Iron	750	1	750	750	1	750
Hair dryer	400	1	400	400	0.75	300
TV	200	1	200	200	4	800
Video	200	1	200	200	2	400
TOTAL	**16550**	**N/A**	**99350**	**144725**	**N/A**	**53625**

Wrms = Effective Power (RMS power).
Fsta = Starting factor.
Wsta = Starting Power.
Wtrans = Transients Power.
DUH = Daily Use in Hours.
WHD = Watts-Hour-Day.

12 CALCULATIONS EXPLANATION.

12.1 The cells for inductive loads in the Wtrans column have been filled multiplying the starting power of each receiver by 1.5. These calculations are not correct and could be very different to the real ones.

The only purpose of these calculations is to have specific numbers for a better understanding of this practical example.

In the practice, the Wtrans column must be filled according to what has been explained in paragraph 10.6.

12.2 It has no sense to add the values of the Fsta and DUH columns because those numbers do not represent any useful value.

12.3 The energy used by the installation for a day, in WHD, will be the addition of all the values of the WHD column, in this case it is 53625.00 Watts-Hour-Day.

12.4 The energy that must be stored depends on the converter technology that will be used.

12.5 If an Ortronic® converter is used, the energy needed to be stored will be the expected energy for the daily use of the installation, plus the 40% that will always remain in the power batteries for extending their useful life, the data would be as follows:

A	Energy used in the installation	53625 WHD
B	Plus 40% for extending batteries useful life	21450 WHD
	Total energy to store	75075 WHD

12.6 If a PWM converter is used, the energy needed to be stored is the calculated energy of 53625 WHD, plus the no-load consumption in the converter, NLC, paragraph 4.3, plus the energy losses in the converter at the different powers connected, ELEC, paragraphs 6.1 and 6.2, plus the losses in the batteries.

The energy losses are calculated from the data obtained by the net analyzer, but in this practical example we do not have any data from the net analyzer so, we will proceed in the following way:

12.6.1 For calculating the NLC we consider that the hours with no consumption or consumption lower to 100 W from the receivers, would be during night and we estimate them in 8 hours.

The NLC during the 8 hours would be: 1163 x 8 = 9304 WHD.

12.6.2 The ELCE losses, in MEH, calculated in paragraph 6.1, for a load of 300W RMS are 78.5%.

12.6.3 The ELCE losses, in OEH, calculated in paragraph 6.2, for a load of 1500W RMS are 52.76%.

Considering that ELCE losses in MEH and OEH were 8 hours for each one, and taking under consideration that the estimated time for NLC is 8 hours, we could do the following calculations:

Average energy losses in MEH and OEH = 65.63%

Energy losses during NLC	= 1163 x 8	=	9304 WHD
Energy losses in MEH and OEH	= 65.63% of 53625	=	35194 WHD
Total ELCE losses		=	44498 WHD
Energy to be used in the installation		=	53625 WHD
Energy at the PWM converter input		=	98123 WHD

13 ENERGY LOSSES IN THE BATTERIES.

In the best case, the total energy losses in the batteries, due to the charging and discharging processes, plus the auto-discharging, would be 30% of the energy used in the installation plus the energy losses in the converter, so:

13.1 Energy to be used in the installation	=	53625 WHD
13.2 Energy losses in the converter	=	44498 WHD
Total	=	98123 WHD
13.3 30% of energy losses in the batteries	=	29437 WHD
Total energy needed	=	127560 WHD

The total energy needed by a PWM converter is 138% higher than the total energy needed by an Ortronic® converter for achieving the same amount of work realized.

13.4 Total energy needed to be stored in a PWM converter.

If working with a PWM converter, the total energy needed to be stored is the energy calculated in paragraph 13.3, 127560 WHD, plus the 40% that will always remain in the power batteries for extending their useful life then:

Using a PWM converter, the energy to store is 127560 x 1.4 = 178584 WHD

Using an Ortronic® converter, the energy to store is 75075 WHD

The difference in the energy needed to be stored implies that the batteries bank capacity must be a 138% higher in case of using a PWM converter in comparison to an Ortronic® converter.

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