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***AISM***Association Internationale de Signalisation Maritime ***IALA***

International Association of Marine Aids to Navigation and Lighthouse Authorities

Document Revisions

**IALA Guideline No. 1067-1**

**On**

**Total Electrical Loads of Aids to Navigation**

**Edition 2**

**April 2016**

Revisions to the IALA Document are to be noted in the table prior to the issue of a revised document.

|  |  |  |
| --- | --- | --- |
| **Date** | **Page / Section Revised** | **Requirement for Revision** |
| April 2016 | ??? | Review and update following the realignment of the documentation to the standards |
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**Total Electrical Loads of Aids to Navigation**

# Introduction

When planning to power an existing or a new Aids to Navigation (AtoN), it is highly advisable to choose the lowest consumption equipment to meet the operational requirements . Factors to consider includes power consumption and efficiency of the:

* light source and optic equipment;
* electronic AtoNs;
* sound signals;
* control and monitoring system, to name but a few

# How to use this guideline

This document is part of a set of guidelines and needs to be read in conjunction with the following documents:

IALA Guideline 1067-0 Selection of Power Systems for Aids to Navigation and Associated Equipment

IALA Guideline 1067-2 Power Sources

IALA Guideline 1067-3 Electrical Energy Storage for Aids to Navigation

# AtoN Load Overview

When determining the total electrical loads for a system, the following questions needs to be answered:

## What needs power?

Identification of equipment and on which system

## How much power?

Identification of the power need for each item in each mode of operation.

## How long it needs?

Any character, duty cycle, during the periods of operations

## When it needs it?

Daily, seasonal, weather dependant, traffic dependant, on demand,

The first task in establishing the total electrical load is to estimate the length of time that each load will be operating. Estimating the length of time that a load is operating should be as accurate as possible, noting that, if the AtoN is operating only at night, the length of operating time will vary with the seasons.

A small error in estimating load operating time will be cumulative day after day, magnifying the error over the year. This could be critical for installations at high latitudes. If detailed information is not available, the "worst case" situation can be considered and the system designed for the longest winter night.

The design should ensure that switching devices turn the light on and off at the correct light levels to match the light-on periods used in the calculating programme. At higher latitudes there will be a marked seasonal effect on light-on periods.

It is advisable to consider the effect of a failure in one of the AtoN subsystems with regards to the power consumption of a complex AtoN system. Manufacturers should be encouraged to disclose the most probable failure modes and corresponding power consumption scenario for supplied equipment.

## Quiescent load

The quiescent load is the power requirement of a piece of equipment which is idle, listening or monitoring. Transceivers generally have different load profiles when transmitting and when listening. Charge controllers typically consume more power during the day when the charging relays (which can consume significant power) are energised, than at night or when the battery is fully charged.

## Day/Night loads

Daytime or night time loads can vary significantly from season to season. As an example, a light operating at night at 58 degrees North latitude will be illuminated approximately 18 hours in December and less than 6 hours in June. These differences can have a significant impact on the size of the power source and the electrical energy storage system. Energy efficiency becomes very important in the higher latitudes. For example 5-mA idle current for a lantern during daytime does not seem much, but for autonomy period of 60 days about 7-Ah extra capacity is needed in the battery to allow for the idle current.

## Power demand variation

Temperature extremes and voltage fluctuations can also cause variation in the power requirements of loads. A resistive load will draw more energy as the voltage increases. Many components exhibit this characteristic.

Loads that operate during the daytime at photovoltaic powered aids to navigation will typically be exposed to higher system voltages as the array tries to recharge the battery. Components used should be able to handle these variations. The power consumption of the loads must be determined at the typical operating voltages.

In areas where there is often heavy cloud cover or fog the correct threshold setting of light switch-on and switch-off is important. If threshold for turn off is too high, it is possible that on a cloudy day the turn off of the light is delayed many hours from the intended time, which causes battery depletion.

Loads that operate both day and night may see different system voltages and thus average power consumption may need to be calculated to accurately predict system performance. Likewise, the power consumption of some loads varies as the temperature varies from ambient conditions.

The loads demands at different latitudes will need to be adjusted to take into account the different night time periods; a major consideration at some latitudes must be the seasonal variation of load.

An accurate load profile from the vendor and an idea of the operating conditions are very helpful in estimating the actual power requirements; actual measurements at the AtoN location (or calculated) are vital to confirming the adequacy of the power system design.

# Daily Loads including Seasonal Variations

NOTE: This section is to be read in conjunction with IALA 1038: Guideline On Ambient Light Which Aids To Navigation Lights Should Switch On And Off

## Computation of a Daily Load

The most important aspect of a primary or secondary battery powered system design is the calculation of the energy daily load (EDL). This is usually expressed as watt-hours per day (Wh/day). For a continuous load of 1 watt, for example, this calculation is expressed as:

EDL (Wh) = Load (W) x Duration of Operation per Day (h/day)

EDL = 1 W x 24 h/day = 24 Wh/day

This means that the energy source need to provide 24 watt-hours every day it operates.

### Duty cycle

The above energy daily load calculation can be modified by the following formula, if the load can be cycled.

Therefore, a cyclic daily load of 1 watt that operates 24 hours per day having a character of 3 seconds ON and 3 seconds OFF, is expressed as a daily load of:



By cycling the load, the daily load in this case is half of a load operating at 100 percent duty cycle. This is an important aspect in selecting equipment when using either primary or renewable energy systems. It can be beneficial to cycle off the load to conserve power, as long as this type of signal can still meet the operational requirement.

## Seasonal Variation of Daily Loads

Loads that are daylight controlled, that operate only during the day or only at night take more work to predict. Because the number of hours of daylight changes daily, the load will change daily. Most simple power system designs are based on the highest daily power consumption. In the Northern Hemisphere, this occurs around December 21 for night-time loads and June 21 for daytime loads. The dates are reversed for the Southern Hemisphere. A more precise method is to create a computer program, or use a computer spreadsheet, to calculate the load for each day of the year, and then assess energy balance during the most demanding period of operation.

Assuming that the loads switch on or off at sunrise or sunset, the first step in determining the daily loads is to calculate the number of hours of daylight or, conversely, the number of hours of darkness. The number of hours of daylight in a day, Hdaylight , is defined to be the number of hours between sunrise and sunset. The number of hours of darkness, Hdarkness ,is defined to be the number of hours between sunset and sunrise. Either of the following two equations can be used to calculate the number on hours of daylight.

If all calculations are done in degrees then:



or, if all calculations are done in radians (remember to express L and D in radians), then:

Where :

H daylight = the number of hours between sunrise and sunset.

L = the latitude of site, positive values for northern latitudes, negative values for southern latitudes.

D = the sun's declination, positive values for northern declinations, negative values for southern declinations.

Note:

The number -0.0151 is a number that has been derived to express the number hours of daylight that incorporates both the semi diameter and the refraction affects.

The sun's declination ranges between 23.45° S (-23.45°) and 23.45° N (+23.45°). The day with the largest number of hours of darkness occurs on the date of the winter solstice. The declination on the date of the northern hemisphere's winter solstice is 23.45° S (-23.45°). The declination on the date of the southern hemisphere's winter solstice is 23.45° N (+23.45°).

The sun's declination (D) in degrees can be approximated as:

D = 23.45 sin(1.008(n-80*))* for n = 1 - 80

D = 23.45 sin(0.965(n-80*))* for n = 81 - 266

D = -23.45 sin(0.975(n-266*))* for n = 267 - 365

Where n is the Julian date and all calculations are done in degrees.

For latitudes greater than 65.6° the term:



in the Hdaylight equations will be less than -1 for a portion of the year and greater than +1 for a different portion of the year. During these portions of the year Hdaylight  becomes as follows::



The number of hours between sunset and sunrise, Hdarkness, can be readily calculated

using Hdaylight:

Example: To find the maximum daily load for a cyclic load of 1 watt that operates at night, having a character of 3 seconds ON and 3 seconds OFF at 42 degrees N latitude, proceed as follows:

Since the load operates at night, the greatest daily load occurs at the time of the winter solstice when the sun's declination is -23.45°: D=-23.45°

Electing to perform all calculations in degrees:



Therefore, the maximum daily load (EDL) is:

To find the daily load for the same cyclic load on February 14 proceed as follows:

 D = -13.54°

Again electing to perform all calculations in degrees:



Therefore, the daily load is:

### Modifiers to Hdarkness

This is a theoretical figure of when the Aids to Navigation switched on and off, however in practice this is achieved with a photocell. Therefore, the real figure could exceed this value, subject to climatic conditions, local conditions, shading and photocell adjustment. To account for these variations, particularly at high latitudes, a safety factor may be applied to the equation. Such modifiers are:

The addition of an hour to extend the calculated duration of the night

Note: Further details on Hdaylight equation are given in the ANNEX 1.

## On Demand Loads

Illumination of towers via AIS or VHF

On demand lanterns via SMS or VHF

# Actual Loads

## Incandescent Light Sources

NOTE: Under Light Sources, only Lamps are discussed, LED’s are discussed in section ‎5.2. The inclusion of other sources will need to be examined and if required calculation should be amended.

The most common load to all aids to navigation is the light. Lamps are classified by voltage and lamp current or power. Lamps that receive regulated output voltage from a flasher or voltage regulator consume the rated or calculated current. For example, a 12 volt, 100 watt incandescent lamp will consume 8.33 amperes at rated voltage. This rating applies only to incandescent lamps operating fixed-on. Flashed lamps, while saving power during eclipse, draw more than the rated current during flash because of the cold current surge of the filament as shown in Figure 1.

1. Typical power of a flashed lamp

The area under the curve represents energy (E). The energy consumed during one flash (E1) can be divided into 2 parts:

Where:

E1 is energy consumed during one flash.

Esurge is the portion of the consumed energy associated with the surge. This is represented by the upper area of the curve in Figure 1.

Ess is the energy associated with *steady state* power. This is represented by the rectangular area in Figure 1.

Consider Esurge :for any given lamp Esurge can be considered a constant. A plot of the surge factor for common aids to navigation incandescent lamps in shown in Figure 2.



1. Surge Factor Esurge

Esurge can be approximated by the following equation:

Esurge = 0.1019 x2 + 1.24x - 0.3341

Where:

x is the lamp current in amps

Esurge is in watts-seconds

Now consider Ess :

Where:

Pss is the lamp's steady state power requirements (watts)

Tflash is the flash length (s)

Ess is in watts-seconds

To find the energy consumed in a day (daily load) you merely multiply by the number of flashes in one day:

Where:

E1 is in watt-sec

H is in hours per day light operates (hours)

Tperiod is the light's period (sec)

Note that EDL, the daily load, conveniently comes out in Wh/day

Putting it all together:

Example: What is the daily load of a 1.15 amp (13.8 watt) lamp that is flashing one second ON, one second OFF, on a day with 13.9 hours of darkness?

The calculations listed above for lamp energy are approximations based on empirical data and may be used in lieu of actual measurements. Suppliers of lamps should be able to provide average lamp current values for all popular flasher rhythms. This data permits a simpler calculation for daily load.

As an example, a 12 volt, 0.55 amp lamp (6.6 watt) flashing one second ON, one second OFF, on a day with 13.9 hours of darkness will have a daily load of:

Note:

From the manufacturer, a 12 volt, 0.55 amp lamp has an average current of 0.578 amps with a one second ON time.

Note: These surge effects decrease with the number of flashes in multiple flash characters.

## LED Light Sources

Application of a light emitting diode (LED) or an array of LED’s as a light source is becoming increasingly common. Due to different principles of generating visual light and different levels of complexity of the circuitry used to drive the LED’s, powering LED based light sources may introduce issues requiring attention in the course of proper system integration at AtoN outstations.

### LED Light Sources with Passive Power Supply Circuitry

The simplest LED light sources are utilizing passive drive electronics in the form of resistive components connected in series with LED’s to limit the current consumption. Overvoltage protection circuitry may exist, but is not expected to draw any significant power when properly designed. Level of electromagnetic noise generated by such products and risk of compatibility (EMC) issues is very low.

Power consumption of such LED products depends on the power supply voltage level (power consumption increases when input voltage increases) and on the temperature of the operational environment (power consumption increases when the temperature increases). Operation at power supply voltage and ambient temperature extremes may become fatal to such products, while poorly designed products may not light up at all at significant sub-zero (Celsius) temperatures.

Typically, such simplest LED light sources can be easily controlled by external flasher unit, including pulse width modulated (PWM) control, unless their power circuit contains a large filtering capacitor.

Power consumption of LED light sources with passive power supply can be calculated in similar manner to incandescent light sources (tungsten halogen lamps) outlined in section ‎5.1, based on the information supplied by the supplier for expected power supply voltage and ambient temperature scenario. LED’s themselves do not have the high starting current that is common for many other light sources, therefore, no significant inrush currents are expected; instead the current draw may increase slowly until the internal temperature of LED components stabilizes. Attention must be paid to the specification since output light intensity of such products may depend heavily on both the power supply voltage and ambient temperatures.

### LED Light Sources with Active Linear Power Supply Circuitry

LED light sources with active linear power supply circuitry typically utilize constant current drive electronics to stabilize the light output within a range of input voltages and, possibly, ambient temperatures, offering better protection and higher reliability. Most of the considerations introduced in ‎5.2.1 apply, even the power consumption dependence on power supply voltage is similar. Application of PWM control may be limited due to inertia of the circuitry.

### LED Light Sources with Switching Power Supply Circuitry

LED light sources with active switching power supply circuitry utilize some sort of internal oscillation, modulation and/or voltage level conversion to increase the power efficiency within a defined range of power supply voltages, operating at constant power consumption. Such medium and high power LED products may require a significant inrush current (surge) to start up, exceeding the nominal current by 100% or more. Manufacturer’s data must be consulted to find out the magnitude and duration of the inrush current surge to prevent situations where inrush current trips the system fuse.

Main difference of powering the LED light sources with switching power supply compared to simpler ones is in the way of controlling the light source: when the manufacturer has provided a control (modulation) input for such product, it is advisable to use this input for flashing and PWM control, and to avoid controlling the product by switching the power directly at least within the active phase of operation (night time). In case of using complicated flashing patterns or PWM control, it is advisable to get the confirmation on suitability of intended flashing mode for the product (bandwidth of the control signal may be limited).

Power consumption of LED light sources with switching power supply controlled by power input can be calculated in similar manner to incandescent light sources, based on information supplied by the manufacturer. In case of controlling such product using the control (modulation) input, guidelines provided in ‎5.2.4 should be used to account for the quiescent current during eclipse.

Presenting a potential source of electromagnetic noise originating from the switching power supplies in both radiated and conducted ways, integration of such products needs special attention. It is also recommended to confirm the capability of the product to power up at minimum power supply voltage at lowest ambient temperature expectedly encountered in product’s application scenario. Excessive length of the power supply wires may adversely affect the start-up of a switched power supply in cold specifically due to voltage drop caused by high inrush current, while the resulting voltage drop may render the rest of outstation equipment instable.

### Complex LED Light Sources

Many contemporary complex LED light sources consist of several subsystems, integrating LED’s, flashers, GPS receivers, measurement and monitoring modules within one product feeding from a single power input and utilizing one of the power supply solutions described above. In such case, the power consumption budget of a product should be calculated based on manufacturer’s information on all possible power modes expected to occur in the application scenario. In addition, manufacturers may have introduced functions in smart LED power supplies improving power efficiency at low ambient temperatures based on the fact that efficacy of LED’s improves at low temperatures: in cold, power supply current may be reduced to maintain nominal light intensity. From the other hand, LED component aging compensation functions may increase the power consumption with time.

Another consideration is power consumption of a redundant LED light source in a failure mode: manufacturers are advised to declare and describe expected failure modes for their products with indication of power consumption in such failure modes.

Most often the LED’s are integrated in a lantern that houses an integrated LED power supply and a flasher. The power consumption of such product can be divided into power consumption during flash, power consumption between flashes, and daytime quiescent power consumption.

Pfl is the power consumption during flash

Pbfl is the power consumption between flashes

Pidle is the daytime power consumption

To find the energy consumed in a day (daily load) some additional figures are needed:

H is in hours per day light operates (hours)

Tperiod is the light's period (sec)

Tflash is the total duration of flash in a period (sec)

EDL is the daily load

Example: What is the daily load of a 2W LED lantern that is flashing ½ seconds ON, 2½ seconds OFF, on a day with 13.9 hours of darkness? The power consumption between flashes is 150mW and the quiescent power consumption is 10mW

Pfl = 2W

Pbfl = 0.15W

Pidle = 0.01W

H = 13.9h

Tperiod = 3s

Tflash = 0.5s



This example demonstrates that the power consumption between flashes can become a significant part of the total daily load in low power LED lanterns.

## Metal Halide

## Flasher / Control

The device used to flash the lamp also requires power. Manufacturers of flashers should be able to provide the power requirements of their units; an average value may be sufficient for high efficiency units. Otherwise, the demand during flash, eclipse and when idle (daytime) may be required to calculate the load profile. In general, the energy demand is calculated as a daily load, as follows:

EDL(calculated) = Pquiescent (W) x Hours of Daylight (h/day)+Peclipse (W) x (1-Duty Cycle) x Hours of Operation (h/day) + Pflash (W) x Duty Cycle x Hours of Operation (h/day)

An example showing the simpler calculation using average power data is shown below:



Adding to the example, above:

E DL(lamp+flasher) = 104 Wh/day + 5.8 Wh/day = 109.8 Wh/day for flashed lamp and changer

Discharge lamps and associated ballast consume more than their lamp rating; the ballast must be added when sizing a load. Again, manufacturers should be consulted to determine power requirements at the rated system voltage and temperature; and these values should be confirmed by measuring the devices in a realistic setting.

The energy consumption of flash tube varies with power rating, flash rate and input voltage. Because of the charge/discharge cycle associated with the capacitor, the power requirements are generally averaged and described as a continuous load. Manufacturers can provide energy demand figures of these devices.

The introduction of an array of light emitting diodes (LED) as a light source is becoming more and more common. The power consumption of an array of LEDs may be calculated similar to that of a tungsten halogen lamp. An array of LEDs however does not have the high starting current reflected in Figure 1 and for practical reasons Esurge becomes zero.



## Self-contained Lanterns

## Optic Rotation

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International Association of Marine Aids to Navigation and Lighthouse Authorities

***AISM***Association of Internationale de Signalisation Maritime ***IALA***

**IALABATT WG-1**

**2008-10-02**

**IALA Guideline No. - 1**

**On**

**Total Electrical Loads of**

**Aids to Navigation**

**Edition 1**

**October 2008**































































Rotating optics have a load associated with the mechanism used to rotate the turntable assembly. Lighthouse services generally leave the turntable rotating continuously, both for operation at night, and during the day to prevent the sun from focusing through the lens panels and damaging the lamps or lampchanger. Therefore, the power requirements for the rotation mechanism should be entered as a continuous load. This load may vary significantly with temperature, so be sure to identify the operating environment when requesting power demand information from the manufacturer. As an example, a rotating beacon with a 2.03 ampere lamp with a fixed rhythm flasher operating at night at 42 degrees N latitude with a 1.2 mW continuous motor will have an energy demand of:



\**Assuming that the day and night power requirements are the same.*

Rotating beacons may use Fixed-ON flashers to regulate voltage and operate the lampchanger; then the energy demand is:



From above:

Hdarkness = 13.9 h/day

Eflasher = 5.8 Wh/day

EDL = [13.9 h/day x 24.4 W] + 5.8 Wh/day + 28.8 Wh/day = 373.8 Wh/day

### Optic Rotation Control

## Sound Signal

Sound signals operate over a wide voltage and temperature range. Request from the manufacturer of the signal the energy demand at the expected operating voltages (24 hour operation may have a high daytime and lower night time voltage when operating on an unregulated solar power system) and the expected operating temperatures.

For example, a sound signal with a power consumption of 21.6 watts during blast, and 0.24 watts when silent with a rhythm of one 3 second blast every 30 seconds will have an energy demand of:

Sound signals under fog detector control will require historic fog hour data to predict their operating time.

### Sound Signal Control

## Visibility Detector

Visibility detectors can be used to minimise noise pollution from Sound signals. These devices may use heaters in the projector and receiver windows to prevent condensation in cool weather. The temperature when these heaters turn on varies from model to model. You must determine the turn-on temperature of these heaters and have access to temperature data of the area. From this, an idea of how long the heaters will be activated (duty cycle) can be formulated. A data logging recorder is a useful tool to determine the duty cycle of the heaters, however failure to account for an unusually harsh cold spell may cause premature power system failure as the load will be substantially higher. The data logging recorder can also provide useful data as to how many hours the sound signal will be operating.

As an example, a visibility detector has a power demand of 6 watts with a heater load of 24 watts. The heaters turn on when the ambient temperature is below 10 degrees C. Temperature data for the area indicates that the average minimum temperature is below 10 degrees C between November and March and it is estimated that they will be activated 50% of the time during this period. The energy demands are:









## Control and Monitoring Systems

### Control Equipment

Equipment used to control main and emergency signals typically consume power. In general, the power consumption rating selected is for when the system is operating normally; i.e., main signals are operational and using the main power system. The loads associated with these devices are calculated as continuous loads.

For example:

A universal switching device for controlling the main and standby signals draws 300 mW. A typical battery/load-transfer circuitry and alarm circuit draws 240 mW when the main battery is on-line.

Therefore:

Since the aid has both main and emergency lights and sound signals (2 switching devices), the daily energy demand of the signal control equipment is:



### Monitor Systems

Monitor systems vary widely in complexity, means of transmission and power demand. Low energy models are available for solar powered applications. Transmission methods will greatly affect the power requirements. Phone lines, radios and satellite links each have different power requirements. They may use considerable power during interrogation. A strict regime should be established to control the time when the link is in operation. The power demand of the transmission device can usually be ignored if contact is made briefly once or twice a day. In this case, the quiescent demand is calculated as a continuous load and can be used to calculate the daily load. Many monitoring systems allow interrogation from the monitoring centre, and excessive operator-instigated requests for data from a single out-station can cause the energy drain to exceed the design parameters. Consult with the manufacturer of the unit to determine the actual power consumption for the application selected, but it is suggested to measure the current at the site to confirm the design data.

Large stations with several non-uniform loads may benefit from the measurement of both the power generated and energy demand of the loads at the site over a period of one year. Data recorders are available to measure and store daily average data over one year.

Monitoring units may offer additional functionality like GPS signal reception and flashing synchronisation, measurement, etc. It is advisable to establish the mission specific power consumption profile of the product with consideration of all relevant factors like ambient temperatures, power supply voltages, distance from shore stations, etc.

## Charge Controller

Charge controllers are used to provide overcharge protection, load disconnect in the event of low battery voltage. They also offer reverse current protection in photovoltaic systems. Charge controllers have both operating and quiescent power requirements. These values must be considered as loads. You must also determine when the loads are active; daytime, night time or both. Check with the manufacturer of the controller to determine what loads must be considered in the load equation.

For example;

One popular solar charge controller has a quiescent load of 360 mW with a maximum power consumption of 2 W when the array is charging. Assuming the controller is installed at 42 degrees North latitude, the maximum power consumption is:

Since the majority of the load occurs in the daytime (when charging\*), the maximum energy demand occurs on June 21.



\* Some controllers have normally closed relays that are energized (opened) only when the battery is fully charged. In this case, the quiescent load applies 24 hours a day.

## AIS

### General

AIS has the potential to replace or augment existing remote control and monitoring systems, as well as to provide AtoN service in its own right. IALA Recommendation A-126 on the use of AIS for AtoN refers.

The power consumption of an AIS AtoN station depends on which type (1, 2 or 3) of AtoN station is used, and on the setting of a number of parameters which may be configured in the unit. These parameters shown below are optimised to minimise power consumption.

* VDL access method – FATDMA will give substantially lower power drain than RATDMA;
* FATDMA slot selection –Channel A and Channel B slots should be close together in time, to minimise the period for which the processes in the AIS AtoN unit are active. (Assuming the recommended Mode B is used);
* Reporting interval – an extended reporting interval will, of course, reduce power drain, but the interval should satisfy the guidance given in IALA Recommendation A-126 \*;
* The AIS AtoN unit should be designed or configured to enter into a “sleep” mode when not active;
* Number and types of messages transmitted;
* Transmitter power.

\* -Repeating of the AIS AtoN messages by a local AIS base station, during the reporting interval of the AIS AtoN station, may allow the reporting interval of the AIS AtoN unit to be extended. For example, the AIS AtoN may have a 10 minute reporting interval, but the local AIS base station repeats the AIS AtoN message every frame, i.e. every minute.

### Calculation of the power requirements

The power requirement of an AIS AtoN unit transmitting Type 21 AtoN and Type 6 monitoring messages can be estimated by using the formula below:-

RATDMA Operation









Ps = Power taken by unit when asleep (Watt)

Pt = Power taken by unit when transmitting (Watt)

Pw = Power taken by unit when awake, but not transmitting (Watt).

Tm = Reporting interval for monitoring message Type 6 (secs)

Ts = Time taken for unit to acquire slot map after waking up (secs)

Tr = Reporting interval (secs)

EDL = Total Daily Power Consumption

ERX = Power Consumption when asleep or waiting to transmit

ET21 = Power Consumption for Type 21 message transmission

ET6 = Power Consumption for Type 6 message transmission

### FATDMA Operation

Use the same formulae as above, but the parameter Ts will be the time taken for the GPS receiver to obtain a position fix after waking up. (If a DGPS receiver is fitted Ts will be the time taken to obtain a DGPS corrected position fix after waking up.)

Note that Pw will be substantially lower when using FATDMA mode, as there is no requirement for VHF receivers to be powered up.

## RACON

The power consumption of RACONs is difficult to predict, as the load will be determined by on the number of times the RACON is interrogated. Most RACONs have an upper limit on the number of responses broadcast if the unit is continuously interrogated due to a moored ship with the radar left on or an unusually busy channel. Consult with the manufacturer for high, medium and low power demand values for these devices and local pilots in the area to determine what level of traffic exists in the waterway. A separate power system for a RACON is recommended, as this reduces the possibility of both the light and the RACON becoming inoperative at the same time. Alternately energy demand measurements can be made with an integrating ampere-hour or watt-hour meter over a 2 month period during maximum traffic to obtain a meaningful load profile.

The calculation below is a typical example based on a single manufacture, due consideration must be given to the equipment manufacturers data in calculating the load.

For example, a RACON has a quiescent current of 84 mW when idle and 11 W when transmitting. The duty cycle is limited to 50%. Therefore, as a worst case scenario, if the RACON is continuously interrogated:



## DGPS

# Other Loads

## Complementary Loads

### Illumination of Structures

## Non-essential Loads

Non-essential loads such as domestic lighting should ideally be under some form of automatic control to ensure that they cannot be left on and drain the power system. Add a sentence about non-essential loads being on a different battery system to that of the AtoN battery system

## Seasonal Aids

Seasonal aids are operated for a portion of the year and either removed or secured during the period of non-operation.

For example:

To calculate the energy demand, a seasonal buoy operating at 42 degrees N with a 1.15 amp lamp with a FL6(0.6) rhythm operating at night and deployed between 1 April and 31 October will have the following energy demand:

Determine which period has the highest daily load:



Therefore, the night time load will be the greatest on October 31.

The average energy demand is:

The maximum daily load is:



It is advisable to ascertain that the equipment powered off for a significant period of time does not contain internal energy storage used to maintain power to memory devices backing up critical information that might become depleted during the intended period of non-operation, and that when powered up by remote control, such equipment does not create excessive power consumption once power is applied.

### Battery Heating

# Typical Load Levels

The following table provide guidance on typical load levels.

1. Typical Load Levels

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Energy required in watt-hours for given | | | | load per day |
|  |  |  |  |  |
| Load | Duty cycle | 12 / 24 h | Energy required | Typical AtoN |
| Watt |  | operation | Wh/day |  |
| 3,000 | 100 | 24 | 72,000 | Lighthouse with major load |
| 3,000 | 50 | 24 | 36,000 | Lighthouse with major load |
| 3,000 | 10 | 24 | 7,200 | Lighthouse with major load |
| 3,000 | 100 | 12 | 36,000 | Lighthouse with major load |
| 3,000 | 50 | 12 | 18,000 | Lighthouse with major load |
| 3,000 | 10 | 12 | 3,600 | Lighthouse with major load |
| 1,000 | 100 | 24 | 24,000 | Lighthouse with medium load |
| 1,000 | 50 | 24 | 12,000 | Lighthouse with medium load |
| 1,000 | 10 | 24 | 2,400 | Lighthouse with medium load |
| 1,000 | 100 | 12 | 12,000 | Lighthouse with medium load |
| 1,000 | 50 | 12 | 6,000 | Lighthouse with medium load |
| 1,000 | 10 | 12 | 1,200 | Lighthouse with medium load |
| 300 | 100 | 24 | 7,200 | Lighthouse with low load |
| 300 | 50 | 24 | 3,600 | Lighthouse with low load |
| 300 | 10 | 24 | 720 | Lighthouse with low load |
| 300 | 100 | 12 | 3,600 | Lighthouse with low load |
| 300 | 50 | 12 | 1,800 | Lighthouse with low load |
| 300 | 10 | 12 | 360 | Lighthouse with low load |
| 100 | 100 | 24 | 2,400 | Range lights |
| 100 | 50 | 24 | 1,200 | Range lights |
| 100 | 10 | 24 | 240 | Range lights |
| 100 | 100 | 12 | 1,200 | Major floating aid |
| 100 | 50 | 12 | 600 | Major floating aid |
| 100 | 10 | 12 | 120 | Major floating aid |
| 30 | 100 | 24 | 720 | Range lights |
| 30 | 50 | 24 | 360 | Range lights |
| 30 | 10 | 24 | 72 | Range lights |
| 30 | 100 | 12 | 360 | Beacons |
| 30 | 50 | 12 | 180 | Beacons |
| 30 | 10 | 12 | 36 | Beacons |
| 10 | 100 | 24 | 240 | RACON buoy |
| 10 | 50 | 24 | 120 | RACON buoy |
| 10 | 10 | 24 | 24 | RACON buoy |
| 10 | 100 | 12 | 120 | Lighted buoy |
| 10 | 50 | 12 | 60 | Lighted buoy |
| 10 | 10 | 12 | 12 | Lighted buoy |
| Foot note 1 | By using modern light sources, i.e. metal halide, halogen and LEDs, the load can be reduced significantly thereby reducing the energy requirement per day resulting in significant cost savings. | | | |

# Conclusions

Once each load is fully characterized, then the sum of the loads for each day and each night must be calculated to determine the daily energy demand, and hence the system energy balance, battery daily minimum state of charge and seasonal minimum state of charge.

Using EDL, you can make a conservative system design with a couple of calculations. Calculation of EDL for every day of the year using a design program and comparing it to the battery capacity or energy produced from a renewable energy source will allow you to design a less conservative but cheaper system.

The most critical success factors in the estimation of the energy requirements are:

* The definition of the total load
* The definition of the load characteristics

# Reference documents

1. IALA 1038 : IALA Guideline on Ambient Light which Aids to Navigation Lights should switch on and off
2. IALA Guideline 1067-0 Selection of Power Systems for AtoN and Associated Equipment
3. IALA Guideline 1067-2 Power Generation
4. IALA Guideline 1067-3 Electrical Energy Storage for AtoN
5. IALA A-126: Recommendation on the Use of Automatic Identification Systems (AIS) in Marine Aids to Navigation

# ABBREVIATIONS

A Ampere

D Solar declination angle (in degrees)

D1 Apr Solar declination angle on 1 April

D31 Oct Solar declination angle on 31 October

EDL Daily load

EDL/max Maximum daily load

EDLapr-oct Maximum daily load between April and October

EDL/nov-mar Maximum daily load between November and March

Esurge Surge factor

FL Flash character < Esurge

h/day Hours per day

Hdarkness Hours of possible darkness

Hdarkness1Apr Hours of possible darkness on 1 April

Hdarkness31Oct Hours of possible darkness on 31 October

Hdaylight Hours of possible daylight

Iavg Average current

L Latitude (in degrees)

LED Light emitting diode

mA milli-Ampere

n Julian date

N North

S South

V Voltage

W Watt

Wh/day Watt hours per day

Ws Watt seconds

1. Further explanation of the Hdaylight equation

The derivation begins with the following basic astronomical equation which is stated without proof,

cos  h = cos L cos D cos  + sin L sin D (1)

Where;

 h = incidence angle of the solar rays upon a horizontal surface = zenith distance = angle between solar rays and vertical line

L = latitude of site

D = solar declination

 = hour angle

(Note: all angles in degrees)

From (1):

 = arc cos [ ( cos  h - sin L sin D ) / ( cos L cos D )] (2)

Sunrise is defined as the time at which the upper limb of the sun becomes visible. At sunrise the center of the sun is 52 minutes of arc below the horizon as follows: the semi-diameter of the sun subtends an angle of 16 minutes of arc and the effect of atmospheric refraction accounts for an additional 36 minutes of arc. Therefore, sunrise will occur when, in equation (2),  h = 90° 52’. Setting  h = 90° 52’ in equation (2) allows for the calculation of sunrise:

sunrise = arc cos [ ( cos 90° 52’ - sin L sin D ) / ( cos L cos D )]

arc cos [ ( - 0.0151 - sin L sin D ) / ( cos L cos D )] (3)

The amount of time between sunrise and local apparent noon is obtained by converting  to time (15° of arc in longitude correspond to 1 hour):

Hsunrise-noon = sunrise / 15° (Hsunrise-noon in hours)

The time from sunrise to sunset is double the time from sunrise to local apparent noon:

Hsunrise-sunset = 2 sunrise / 15o (4)

Combining (3) and (4):