IALA

IALA GUIDELINE

G1067-2
POWER SOURCES

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DOCUMENT REVISION

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

Date	Details	Approval
May 2009	1st issue	Council 45
December 2017	Entire document reviewed and updated following the realignment of the documentation to the standards. Updated to reflect information from the workshop on sustainable light and power for the next generation 2017.	Council 65
July 2022	Edition 2.1 Editorial corrections.	

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1. INTRODUCTION

1.1. SCOPE AND PURPOSE

This Guideline replaces IALA Guideline *G1044 on Renewable Energy Sources for Aids to Navigation* (June 2005) and includes text from IALA Guideline *G1042 on Power Sources for Aids to Navigation* (December 2004), which it also replaces.

This Guideline provides guidance on the selection and design of power sources. While this document gives general recommendations, product manufacturers may provide specific instructions for the selection, operation and maintenance of equipment.

This Guideline is meant to assist users in properly selecting and maintaining power sources used in Marine Aids to Navigation (AtoN) systems.

1.2. PRACTICAL GUIDE FOR THE SELECTION OF ENERGY SYSTEMS

Table 1 of IALA *G1067-0 - Selection of Power Systems for AtoN and Associated Equipment* is intended to assist in the selection of power systems for required types and sizes of loads, however, these are only approximate indications.

2. 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 *G1067-0 Selection of Power Systems for AtoN and Associated Equipment*
- IALA Guideline *G1067-1 Total Electric Loads of AtoN*
- IALA Guideline *G1067-3 Electrical Energy Storage for AtoN*

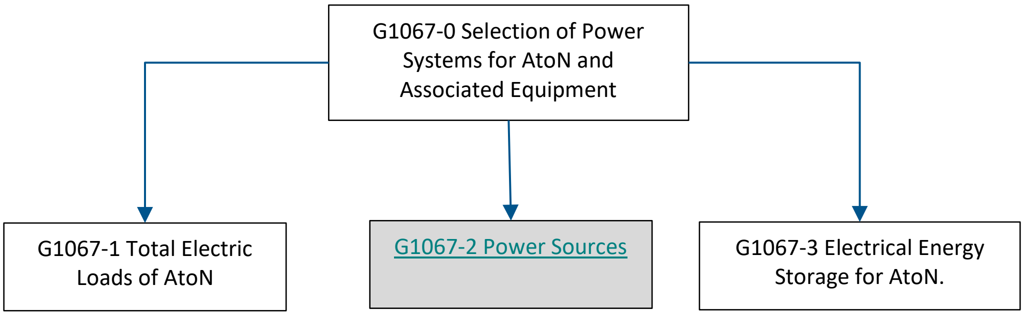

Figure 1 Overview of guideline structure

3. ALTERNATING CURRENT (AC) UTILITY POWER

3.1. GENERAL

The availability of AC utility power at or near the site should be the first consideration. Where a reliable AC power is available, it should be the preferred source of energy. Backup systems may be installed in order to prevent AtoN failure in the case of a power outage to avoid adversely affecting the availability.

3.2. ADVANTAGES

- Load on the system is not critical
- Low capital and running costs
- Low maintenance

3.3. DISADVANTAGES

- Reliance on external bodies
- Possible unreliability of the AC power supply
- Extended time to repair in remote locations
- May require a back-up system that will need periodic maintenance
- Lightning and overvoltage protection systems may be required
- Maintenance cost of owned power lines
- Periodic test and inspection required for safety
- Higher electrical risk to maintenance staff

4. PHOTOVOLTAIC POWER (PV)

4.1. GENERAL

If AC utility power is not available, reliable or too costly, solar power should be the preferred solution.

The approach taken in sizing the PV power systems may be different in different parts of the world. For a given load or site there is no one correct design solution. For example, for a given load, it is possible to increase the area of PV modules and decreasing battery capacity may be possible and vice versa.

An AtoN PV power system, in its simplest form, consists of a PV module, a charge regulator and a secondary battery. PV power systems are a well-proven technology and equipment is available from many suppliers. When properly designed with due consideration for protection from the marine environment, PV power systems are very reliable and are the most widely used renewable energy source for charging secondary batteries.

There has been a trend in some countries to reduce the range of long-range visual AtoN. This, combined with the use of modern high efficiency light sources, may mean that the AtoN can be converted to PV energy.

Figure 2 Grasøyane lighthouse solar array

4.2. ADVANTAGES

- Sustainable source of energy
- Low technical maintenance
- Long life
- Well proven and reliable technology
- Very low operational costs
- No energy purchase cost
- Improved electrical safety on extra low voltage systems

4.3. DISADVANTAGES

- Performance is subject to irradiance, and there is a need for large energy storage for period without sun.
- Deterioration of energy due to effects of the environment e.g., sand, dust, bird fouling, salt, shading, etc. These issues may also increase maintenance costs.
- Need to oversize for variability in solar cycle.
- Susceptible to vandalism and theft.
- Large installation footprint required on some sites to generate sufficient energy.
- Cost of the systems may not be effective in high latitudes due to low irradiance.
- Susceptible to wind and wave damage
- Heritage restriction may limit the use.
- Deterioration in performance at high temperatures.

5. WIND POWER

5.1. GENERAL

Wind energy is a renewable source of energy that can be considered in order to power AtoN. The wind generator can be used as a secondary source of power generation as part of a hybrid system. Wind generators are available in vertical and horizontal axis format.

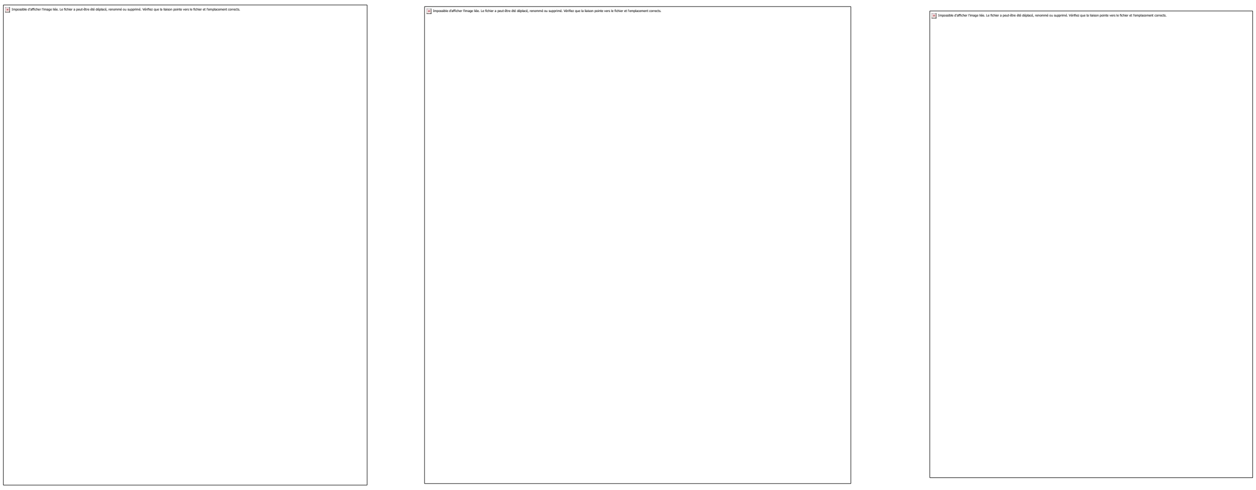

Figure 3 Various wind turbines used in Norway

5.2. ADVANTAGES

- Sustainable source of energy
- Alternate secondary source of power
- Power available day and night time
- High energy output from a small area
- No energy purchase cost

5.3. DISADVANTAGES

- High maintenance requirements
- Not suitable as a primary source of energy.
- Moving and rotating parts (safety)
- Subject to damage under local weather conditions, e.g., wind turbulence, freezing rain, typhoon.
- Might produce high noise pollution.
- Moving parts can be dangerous to birds.
- Variable power production output
- Might have to be stopped during storms.

- Minimum wind speed required to start power production.
- Can be destroyed by vibrations in the supporting structure.
- Permission may be required for siting of the wind turbine.
- For reliable performance laminar air flow is required.

6. WAVE ACTIVATED GENERATOR (WAG)

6.1. GENERAL

Wave activated generators are used on tail-tube buoys. They can be used on their own or may be used as part of a hybrid system typically with solar power.

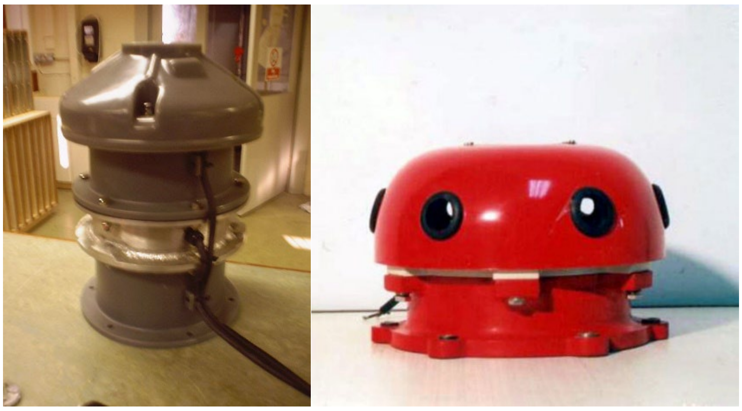

Figure 4 WAG

6.2. ADVANTAGES

- Relatively high energy density in floating AtoN with typically 60 - 100W output power
- Power is available night and day but is subject to wave state
- Renewable energy source with associated cost savings

6.3. DISADVANTAGES

- Normally used on tail-tube buoys, which may be inconvenient to handle
- High capital cost
- High maintenance cost - typically, installations need to be serviced at yearly intervals
- Limited availability – single source
- High level of noise pollution
- Marine growths will impact on the WAG performance

7. FUEL CELLS

7.1. GENERAL

Fuel cell technology is relatively new and is under continuous development. The fuel cell can be used as a primary energy source or in combination with PV or wind generator (Hybrid System) on AtoN in remote areas.

There are currently two types of fuel cells available on the market relevant to AtoN:

- Proton Exchange Membrane (PEM)
- The PEM uses gaseous hydrogen as direct fuel and can be used on medium and major fixed lights in remote areas.
- Direct Methanol Fuel Cell (DMFC)
- This technology uses a mixture of methanol and water as fuel. Currently, the technology can produce power from 100 Watts to 5kW.

7.2. ADVANTAGES

- No moving parts in the Proton Exchange Membrane (PEM) cell
- Low tech maintenance
- Low pollutant emissions
- Low operational costs
- Power is independent of most weather conditions

7.3. DISADVANTAGES

- Refuelling issues
- Fuel safety and transportation issues
- Stack lifetime is limited
- Low temperature performance for some types
- Capital cost.

8. DIESEL GENERATORS

8.1. GENERAL

Generally used for high power requirements on fixed AtoN at remote places or as backup for utility electricity.

Renewable energy systems should be used in place of diesel generators wherever possible. Diesel generation may provide the reserve part of a hybrid system, or may be provided as an emergency power source. Installation of a diesel generator system may be considered necessary where domestic power is required.

Figure 5 Examples of Diesel Generator installation in France

8.2. ADVANTAGES

- Good cost to power ratio
- Long established technology
- Power is independent of most weather conditions

8.3. DISADVANTAGES

- Complexity of installation
- Dedicated space required, i.e., engine room needed
- Regular maintenance required
- Produces noise and atmospheric pollution
- Regular refuelling required
- Cost of fuel transportation
- Unattended service interval is short, typically 4 – 6 months
- Fuel storage environmental risk has to be addressed at each site.

9. PETROL/GAS ENGINE GENERATORS

9.1. GENERAL

Generally, these power systems are used in a manner similar to the diesel generator systems described in the previous section. For the disadvantaged below, petrol engine generators are not recommended for fixed installations.

9.2. ADVANTAGES

- For the advantages, refer to section 8.2
- Good power to weight ratio

9.3. DISADVANTAGES

- Refer to section 8.3
- Fuel storage and transport safety implications
- Less durable than diesel engine generators
- Additional and more frequent service requirements due to the higher running speed

10. HYBRID POWER SYSTEMS

10.1. GENERAL

If one type of system (e.g., PV) is not sufficient to recharge the batteries, then the addition of another type of power source can be used to supplement the main source. This is referred to as a hybrid system.

The advantages of a hybrid systems lies in the mix of power sources chosen to reliably supply an AtoN systems. This can be achieved by combining different sources of power, such as PV modules, wind generators, or even diesel generators to provide sufficient capacity to power the AtoN or recharge the energy storage devices.

Figure 6 Smalls Lighthouse Hybrid Power System

10.2. ADVANTAGES

- Ability to reduce the capacity of the energy storage system
- More reliable at providing power than a single source

10.3. DISADVANTAGES

- More complex system
- Increase in maintenance
- Capital cost.

10.4. COMMENT

A cost comparison between over sizing a PV generator and adding a secondary energy source should be made, taking into account the fact that, generally, back up sources are less reliable than solar PV generators.

However, with large PV generators (> 1000 W) and at latitudes above 40 degree where summer and winter solar irradiation levels are quite different, a secondary source can be considered for the purpose of reducing the system battery capacity, at the same time saving weight, equipment volume and building space. Portable generators have been used to minimise life cycle costs by including the recharge during scheduled maintenance.

10.5. DESIGN CONSIDERATIONS

- Selection of Energy Storage solution
- Energy storage must be sized to accept the peak current output from multiple sources concurrently.
- Consideration to the mix of technologies. Ideally, select devices of different types, i.e., Passive and mechanical.
- Selection of a regulation system
- Due consideration should be given to the mixing of regulators and the parallel connection of the outputs, i.e., Diode protection.

Table 1 Power sources combination possibilities

Primary / Secondary	Fuel cell	Generator	Solar	Wind	Wave	Utility power
Fuel Cell		0	++	++	+	++
Generator	0		++	++	0	++
Solar	++	++		++	++	+
Wind	++	++	++		0	+
Wave	+	0	++	0		0
Utility power	++	++	+	+	0	

Key to the table:

++ - Preferred

+ - Recommended

0 - Not Recommended

11. LIGHTNING/SURGE PROTECTION

To protect a power system against destructive electrical surges such as lightning strikes, lightning protection should be considered. IALA Guideline G1012 on Protection of Lighthouses and AtoN against Damage from Lightning, refers.

12. INSTALLATION

12.1. GENERAL

Cables with a high cross section area (CSA)(mm^2) should be used to have a reduced resistance and a sufficient mechanical strength. Cables should be suitable for UV and the marine environment. The conductors would be better protected by plating, e.g., tinned copper wire.

In PV systems, some manufacturers supply their modules with waterproof junction boxes attached to the back. For modules with flying leads, care should be taken to properly secure the flying lead, and to ensure that no excessive mechanical load is placed on the lead at the point where it enters the module.

12.2. UTILITY POWER

This is usually arranged with the supply authority. Should the nearest available source be some distance away, then the supply authority may charge for routing a cable to a new location. This can be quite significant and should be compared against the cost of providing the power by some other source.

In all cases, inspection of the installation will be checked by the supply authority before final connections are made.

12.3. PHOTOVOLTAIC POWER

12.3.1. GENERAL

When designing a solar power system, Guideline *G1039 Designing Solar Power Systems for Aids to Navigation* [1] will help with the use of the IALA solar model and will give some general information.

The design of any solar mounting arrangement will be specific to the location and type of modules used. Any mounting arrangement should consider suitable galvanic corrosion protection between dissimilar metals (frame/structure) using insulators or stand-offs, given the environment it is to operate in.

Care needs to be taken to ensure that the water integrity of the solar module junction box is suitable for the life of the module. This often required the junction box to be potted with for life.

12.3.2. PROTECTION FROM BIRD FOULING

In some areas birds cause real problems by fouling modules. A great number of devices have been designed but none are totally effective, and bird spikes (plastic or metal) are preferred. Devices working at some places don’t work at others. Vertical modules reduce the problem, but in some cases, imply over sizing. The hazards presented to servicing personnel by metal bird spikes should be considered.

12.3.3. MECHANICAL PROTECTION

Protection to reduce the effect of wave impact, storms, vandalism, theft, and buoy-handling, is generally required. Vertical mounting of the modules on a floating AtoN reduces the vulnerability of the modules but affects the performance of the solar panel.

For PV systems, care should be taken at installation to ensure that the mounting hardware does not stress the module. Also, care should be taken with total or partial shadowing of the modules during the day or any season. Attention should be paid to growing trees, grass and other structures. Note that shadowing of one cell in a module will cause the power output from all the cells in that series string to be partially or totally lost.

Solar modules are desirable items and as such, suitable devices (special screws or nuts, welded pieces, etc.) may need to be employed to dissuade thieves from removing equipment. Notice board indicating the importance of the installation for maritime safety may help in deterring loss.

Metal backing behind the modules, and a clear front cover over the modules might reduce the effect of vandalism, but generally a front cover affects the efficiency because of lower transmission. This effect will increase if the cover is not self-cleaning. Metal backing may protect modules that have resin on the back, from bird pecking.

12.3.4. TILT ANGLE OF THE MODULE

For fixed installations, the solar array should face the equator, where practicable. The modules are generally mounted so that the angle between the module and the horizontal plane varies depending on where you are on the earth. For high latitudes the array mounting angle should be latitude plus 20 degrees to maximise power generation during the winter months. For low latitudes the angle needs to be the latitude angle, but to minimize the effects of bird fouling (even with bird protection) and dirt deposits, it is better not to have horizontal modules and tilting should never be less than 20 degrees.

On floating AtoN, where the orientation of the modules is random, modules are usually distributed around the vertical axis of the buoy. Modules mounted at a steep angle, or even vertically, make automatic washing of salt or bird fouling by rain or sea spray more efficient. This can also make integration in the superstructure easier and protection from damage more effective. The loss of energy at such mounting angles is partially compensated by reflection from the water surface. Some authorities have a policy of mounting single modules horizontally above the lantern on buoys. The horizontal mounting of modules is not recommended for high latitudes in both the northern and southern hemispheres.

12.4. WIND POWER

12.4.1. LOCATION.

All wind turbines perform best where the airflow is constant and laminar. This is often not available in the offshore and costal location of AtoN, either due to nearby structures or landscape. As such, any location is often a compromise.

12.4.2. STRUCTURES

When installing a wind turbine, the mounting structure may require significant ground excavation, which can be a significant cost. If mounting on an existing structure, the fabrication needs to be suitably sized to ensure survivability in all weather conditions and yet allow easy access for serviceability. Often guy wires are employed to rigidify structure, but this required the suitable ground space.

Vibration is often an issue with wind turbine and care in the design and fitting of the mounting should take this into account, with particular care in avoiding natural frequencies of the mounting.

12.4.3. HANDLING

When selecting larger output wind turbine (>1kW) a key consideration will be the site facilities available to handle the equipment into position.

12.5. WAVE ACTIVATED GENERATOR (WAG)

These small units are generally mounted on buoys which have tail tubes. A key factor to effective operation is ensuring that there is good airflow over the Wells turbine and that the air circuit that is pressurised by the wave action is effectively sealed.

Within the design and installation, consideration of how to baffle the unit from any wave action should be sufficient to ensure no damage to the turbine.

As part of the installation, a method of servicing and cleaning the air circuit is needed to ensure good effective operation and the elimination of marine growth that can quickly reduce the unit’s performance.

12.6. FUEL CELLS

12.6.1. FUEL MANAGEMENT

The fuel used on the different types of fuel cells vary from hydrogen, methanol and propane to name but a few. All of these require the fuels to be secured and managed, with both suitable bunding for the liquid fuels and ventilation for the gaseous fuels. All will need a secure mounting, but this will be subject to the operational location on the unit. Mechanism may need to be put in place for handling and refuelling, although on smaller methanol units, the fuel can be provided in small 25 litre containers.

12.6.2. VENTILATION

The location where the fuel cell is to be sited needs to have both suitable protection from the environment but also sufficient ventilation to ensure effective operation, as the process requires a ready supply of oxygen to create electricity.

The process also produces heat, which can either be lost to the environment via ventilation or can be used within the fuel cell or provide background heating for the room / building.

12.6.3. MANAGEMENT OF WATER

In the process of producing the electrical power, pure water is produced as by-product. This either needs to be lost to the environment or needs to be captured for later disposal. Suitable measures need to be put in place to ensure this water does not freeze such that it impedes the operation of the unit.

12.6.4. OPERATIONAL CONSTRAINTS

Depending on the type of fuel cell used, consideration of the start-up time may be an important factor. Some fuel cells need to be brought up to a high operating temperature (200°C to 1000°C) before any electrical energy is available as an output. The source of energy for this “warm up” phase is either met from the fuel or can sometime be sourced from an external electrical power.

12.7. DIESEL GENERATORS

12.7.1. FUEL MANAGEMENT

As part of a generator installation, the size of the fuel store needs to be sufficient to support the anticipated operational demands. Typically, the stored volume can range from 25 litre for a portable generator to 25000 litre for a large permanent installation. Such large installations also require means to remotely monitor the available volume.

Careful consideration of the transportation of the fuel from the fuel store to the engine, needs to ensure that likelihood of a leaks is minimised to avoid environmental pollution. In the process of designing and installing a fuel system, there may be many local, national and international regulations that need to be followed and stakeholder to be consulted.

All systems will require the need for refuelling and a suitable solution should be implemented. For small system this may be very simple, but at larger or offshore location, a more comprehensive solution, taking into account the delivery point will need to be used.

Where a generator is fitted within a room, then facilities need to be provided to capture and hold any fuels spills from escaping to the environment. Such systems need to follow local, national and international regulations.

For simple fuel systems, the delivery of the fuel from the storage tank is driven by gravity. In this configuration, suitable difference in height between the storage and the top of the engine is required. Failure to ensure this is sufficient will result in the engine stopping when the fuel tank is only partially empty.

12.7.2. VENTILATION

Ventilation needs to be provided for all engines installed within building. All portable generators are design to operate externally and will have sufficient ventilation for the operating conditions. Any ventilation needs to provide sufficient air changes per hour to give a stable environment for the generator to operate in under all loads and environmental conditions.

The ventilation can be either passive, just a ventilator, or active, in the form of a vent fan. In addition, the ventilator will have a shutter fitted, both to keep the environment out when the engine is not operational, but also to shut off the airflow in the event of a fire. The opening of the shutter may be delayed to allow the engine temperature to rise to its normal operating level.

Ventilators are always fitted in pairs, an in (low down) and an out (high up), and ideally on different faces of the room. These locations will not only allow good cross flow of air in the room but will allow the ventilation to operate even under high wind speeds on one ventilator.

12.7.3. EXHAUST MANAGEMENT

When installing an exhaust system there are a number of things that need to be integrated and considered. These are:

- Flexible joint. This is an essential component to isolate the vibration of the engine from the fixed installation of the exhaust.
- Lagging and silencing. Needed to both reduce the internal and external noise and protect personnel from the high temperatures of the surface of the exhaust.
- Exhaust cowling. Needs to be installed to protect the exhaust outlet from the environment getting into the engine. In addition, where the outlet is horizontal and subject to green water, a slight downward direction will allow any water that gets into the exhaust to be self-draining.
- Materials. Where the exhaust is subjected to the external environmental condition, along with the heating and cooling cycles, it is recommended that a corrosion resistant material is used, such as stainless steel 316 A4.

12.7.4. FIRE SUPPRESSANT.

When installing a generator, consideration should be given to the protection of life and property as a result of a fire. As such, following a risk assessment or unless required by legislation, an automatic fire system may need to be fitted.

12.7.5. HANDLING

All installed generators are of a significant mass and suitable handling facilities need to be provided to allow installation, maintenance and removal.

12.7.6. NOISE AND VIBRATION

Generators are an excellent reliability source of power, but they all produce significant amounts of noise and vibrations. To reduce this, anti-vibration matting or mountings on a level concrete base can be used along with noise absorbing materials.

13. MAINTENANCE

Maintenance of a power system at an AtoN should, of course, be planned as part of a total maintenance programme for all components of the AtoN site. Assessment of the maintenance required will be reflective of the initial investment and is part of life cycle costs.

For the power system, maintenance will probably include some or all of the following:

- Inspect all power sources components for corrosion (especially at the inter-cell connections and at the output terminals).
- Confirm load demand is within specified limits.
- Check connections and condition of cables.

13.1. UTILITY POWER

As a general rule, the level of maintenance required on a utility powered system is minimal. It is good practice to do general visual inspections of cabling and connections, but also to check the operation of any protection devices and cable insulation. In some countries such tests are mandated by law.

13.2. PHOTOVOLTAIC POWER

When undertaking maintenance on large solar arrays, care needs to be taken due to the potentially high voltages and currents. The best method for safe maintenance is to cover the array with a suitable sheet, also allow time for the panel to cool before handling.

For PV systems, inspect for cracks or discolouration of the encapsulant, de-lamination in the borders, e.g., by ice effects.

A visual check should be made of the frame and fixing to ensure no corrosion or erosion.

A check should be made for changes in environmental conditions, which may result in shadowing of the PV modules, i.e., trees, new buildings, etc.;

The performance of each PV panel may be checked at longer intervals by using a reference solar cell (to test at minimum the short circuit current and the open circuit voltage for each module).

13.3. WIND POWER

The maintenance on a wind turbine will be significantly affected by the location where it is operational. In highly demanding locations where the airflow is not laminar or where they are subject to wave action, the level of maintenance may well be higher to ensure continued and continuous operation. Typical checks are as follows:

- Inspect the blades and tail for cracking and damage.
- Check the yaw (rotation about the vertical axis) operation is smooth and resistance free.
- Visually inspect for corrosion on both the mount and turbine.
- Check all securing fixings on the mount.

13.4. WAVE ACTIVATED GENERATOR (WAG)

In order to effectively service a WAG a vessel that is able to lift a buoy with a tail tube is required.

The key part of maintaining a WAG is ensuring that the tail tube is clear of marine growth. This can take some time to clear and can be difficult to achieve, given the restricted access.

Should the WAG not be heard operating as the ship approaches, then checks on the condition of the Wells turbine will need to be done.

13.5. FUEL CELLS

The periodic maintenance on a fuel cell is minimal, other than re-fuelling and disposal of any collected water. However, if the fuel cell has a high operational demand, then there may well be a requirement to change a unit to allow the fuel cell stack to be replaced by the manufacturer. The typical life of a stack is a guaranteed 4000 hours, but operationally 7000 hours is often achieved.

13.6. DIESEL GENERATORS

Because they are made of many moving parts, a generator has a relatively high maintenance requirement. On an annual basis a number of checks need to be done and these are detailed below, although this is not an exhaustive list:

- The oil and filter need to be changed regardless of low operational hours.
- Air filter change
- Check exhaust is clear of soot and that the pipe has no leaks.
- Check the full operation of the generator, on both full and light load.
- Visual inspection of the generator for evidence of leaks and loose connections, including the starter batteries for electrolyte and post corrosion.
- Check coolant levels if require.
- Check and tighten the electrical terminations of the generator output.
- Measure the winding Insulation resistance and record the values.

13.7. FREQUENCY OF MAINTENANCE VISITS

The frequency of visit to an AtoN are often dictated by the equipment fitted and will require either planned, conditioned or corrective maintenance. For more details on the three approached see Guideline 1077 – Maintenance of Aids to Navigation.

In many locations, one maintenance visit per year should be adequate for a correctly designed system. There might be some sites where industrial fall-out, wind-carried sand, or a high bird population requires a more frequent schedule. In some hotter climates it may be better to visit twice per year for the timely topping up of the battery where applicable.

14. DEFINITIONS

The definitions of terms used in this Guideline can be found in the *International Dictionary of Marine Aids to Navigation* (IALA Dictionary) and were checked as correct at the time of going to print. Where conflict arises, the IALA Dictionary should be considered as the authoritative source of definitions used in IALA documents.

15. ABBREVIATIONS

AC	Alternating Current
Amp	Ampere
AtoN	Marine Aid(s) to Navigation
CSA	Cross section area
DC	Direct Current
DMFC	Direct Methanol Fuel Cell
kW	kilowatt(s)
mm	millimetre
PEM	Proton Exchange Membrane
PV	Photovoltaic
UV	Ultra Violet (light) (10 – 380 nm)
V	Volt(s)

W	Watt
WAG	Wave activated generator(s)
°C	degree centigrade

16. REFERENCES

[1] IALA Guideline G1039 Designing Solar Power Systems for Aids to Navigation.