Navguide: Chapter 7 - Power supplies

7.1 Types

A wide range of power systems and energy sources have been used or contemplated for operating lighthouses and floating aids.

Everything from clockwork to radio-active isotopes have been used.

Some of the more common types are listed in Table 23.

Electric Energy Sources	Non-Electric Energy Sources
Commercial power supply	Acetylene
Photovoltaic solar modules	Propane
Diesel and petrol engine driven generatores	Butane
Primary cells	Kerosene
Wind generators	
Wave activated generators	
Fuel cells using alcohol or hydrogen	

Table 23 - Power Sources for Operating Lighted Aids to Navigation.

There is a general trend away from gas, using mains utility electricity where available and photovoltaic solar power where mains is not available.

IALA has created a series of documents to assist in the selection of electrical power systems for aids to navigation.

Refer to IALA publications:

- Guideline 1067-0 on Selection of Power Systems for Aids to Navigation and Associated Equipment;
- Guideline 1067-1 on the Total Electrical Loads of Aids to Navigation;
- Guideline 1067-2 on Power Sources;
- Guideline 1067-3 on Electrical Energy Storage for Aids to Navigation.

Refer to:

- Applicable national standards for the safe handling of gases.

7.2 Electric - Renewable Energy Sources

7.2.1 Solar Power (Photovoltaic cell)

Solar power is an ideal power source for many aids to navigation applications. It offers:

- a power source with no moving parts;
- no maintenance requirements other than being cleaned;
- slight deterioration in power output over its life;
- low life-cycle costs.

When used to power a light, the battery recharging process is separated from the operation of the light source so that the recharge voltage can be optimized without detriment to the light's operation.

Potential difficulties associated with solar power are:

- finding ways to minimise bird fouling;
- mounting solar modules vertically is probably the best long-term solution for buoys;
- sizing arrays to operate at high latitudes;
- protecting solar modules from;
  - wave damage on buoys;
  - vandalism and theft
  - lightning.

Photo Courtesy of the Australian Maritime Safety Authority Table 24 - Silicon Solar Cell Technology

Aids to navigation exposed to icing conditions are perhaps the only applications unsuited to the use of solar modules.

Types

The three common technologies employed in the manufacture of silicon based, solar modules are listed in Table 24.

Technology	Comments
Monocrystaline Cells	Made from a thin slice cut from a single large crystal of silicon, usually produced as a circular section rod. Generally have the highest efficiency of the three technologies. If circular wafers of silicon are used the module fill factor is significantly less than with polycrystalline cells. It is now usual for the cells to be trimmed to approximate a square.
Polycrystaline Cells	Made from a thin slice cut from a large cast billet of silicon comprising many crystals. Are slightly less efficient than the mono crystalline cell but they can be shaped to completely fill the module.
Thin Film Technology	Made by depositing thin films of silicon directly onto a glass or stainless steel substrate a thin slice cut from a single large crystal of silicon. The cell has a lower efficiency than either of other technologies but can be multi-layered for enhanced performance. Problems have been found with lifetime of these cells.

Table 24 - Silicon Solar Cell Technology

In addition to the silicon cell technologies, there are two optional module configurations based on the numbers of series connected cells. The standard module normally has 36 cells in series to give an open circuit voltage of around 20 volts. For all battery charging applications, a voltage (charge) regulator is considered essential.

Modern developments in electronics have allowed new voltage (charge) regulators to be developed that use maximum power point tracking (MPPT). This ensures that they operate the solar module at a level to obtain the maximum power, for any given level of irradiance. This operating level is independent to the battery charge voltage level. This technology can lead to up to 30% more output than would be achieved with conventional voltage regulators.

Module or Array Orientation

In the northern hemisphere, solar modules are normally installed facing south and inclined at an angle to the horizontal that is related to the latitude of the site, and vice versa for the southern hemisphere. The inclination angle for solar modules is often optimised for the particular site as part of the sizing calculations.

One of the main problems experienced with solar powered aids to navigation has been bird fouling. Numerous, innovative solutions have been trialed, generally with mixed results. Generally solar modules mounted at an angle or vertically benefit from self washing from rain.

The cost of additional solar modules needed for a vertical installation may be largely off-set by the savings that result from simplifying the mounting arrangements or framework.

7.2.2 Wind Energy

Aids to Navigation Applications Wind generators (or wind turbines) have been used by a number of IALA Members to power aids to navigation.

The most popular type were horizontal axis machines with a two bladed (propeller type) turbine.

The maintenance requirements arising from the number of moving parts of a wind generator and susceptibility to storm damage, has limited the use of wind generators.

Installations Wind generator installations at aids to navigation sites pose a number of problems:

- wind generators tend to require a lot of maintenance if operated in turbulent air flows;
- if the wind generator is installed on a separate mast some distance from the aid to navigation, consideration has to be given to cable voltage drop;
- operation of wind generators to power aids to navigation needs to take into account the impact it may have on any environmental factors associated with the location, such as; flora, fauna, birds, etc.

Wind Generator Types A comparison of the typical performance of different types of wind generators is shown in Figure 35.

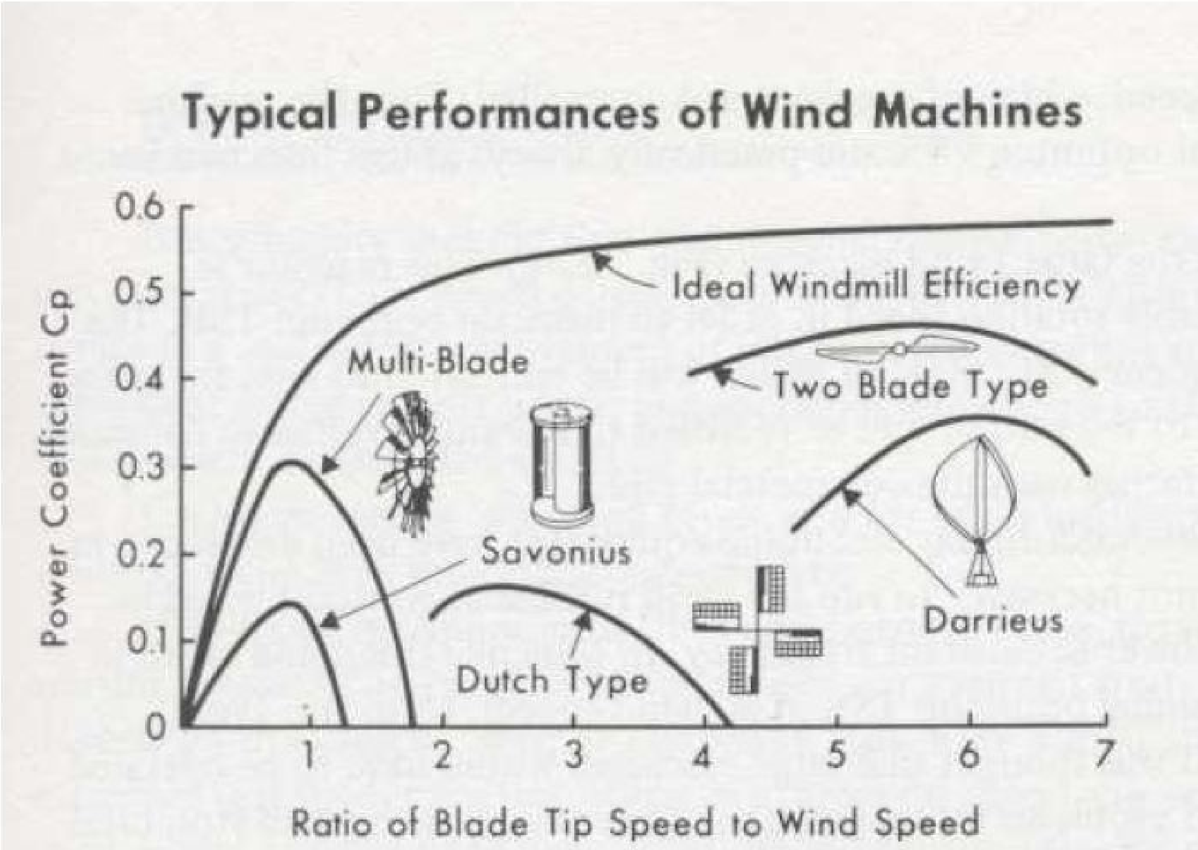

Figure 35 - Comparison of Performance of Wind Generator Types

7.2.3 Wave Energy

The wave activated generator (WAG) was developed in Japan and has been successfully used to power lighted buoys. The interaction between the buoy and wave motions acts as a simple air pump that is used to drive an air turbine and generator. The WAG is mounted on an extension of a hollow tail tube that passes through the buoy hull. With wave heights of 0.5 metres, the power output is almost 100 watts. WAG's have limited life and current systems suffer from excessive wear.

Site conditions will determine the rate at which the tail tube of the buoy accumulates weed and other forms of fouling, and these aspects need to be taken into consideration when developing the maintenance regime for the WAG. WAG's can also be very susceptible to storm damage.

7.3 Rechargeable Batteries

7.3.1 Principal Types

There are two main types of storage battery technologies applied to aids to navigation – lead acid and nickel cadmium. The lead acid type is generally preferred because of its lower cost and higher energy exchange efficiency (95% vs.80%) than the nickel cadmium battery. However, the nickel cadmium battery can operate in lower temperatures and for a greater number of deep discharge cycles.

Recently, new secondary battery technologies have appeared, including lithium batteries, nickelmetal- hydride (Ni-MH) batteries and lithium-iron phosphate ($LiFePO_4$) batteries. These batteries offer lower weight and longer life span from more charge-discharge cycles, for a given capacity.

Lead Acid

The basic form of this battery uses a lead dioxide positive plate and a pure lead negative plate immersed in an electrolyte of dilute sulphuric acid. These were originally wet or flooded cells. However in recent years various forms of "sealed" cell batteries have become available and are quite common in aids to navigation applications.

Lead acid batteries are available in two main designs, flooded lead acid and valve regulated (VRLA). The VRLA comes in two types, absorbed glass-mat (that use a micro glass separator system to absorb the electrolyte), and gel batteries, that use a jellified electrolyte and polymeric separators to prevent short circuits between the positive and negative plates.

Nickel Alkaline Battery

These batteries use compounds of nickel and, generally, cadmium with a solution of potassium hydroxide as the electrolyte.

Nickel-cadmium cells use perforated steel plates that hold the active material, mainly a nickel hydroxide in the positive plate and a cadmium compound in the negative plate. The construction is generally referred to as a "pocket plate" cell.

A range of valve regulated nickel-cadmium batteries that use a recombination process now complements the traditional flooded cell design. Under normal float charging conditions any gas produced is recombined within the battery and water loss is negligible. However if the battery is overcharged it will vent but water can be added if necessary.

Battery Disposal

A number of countries now have standards and regulations relating to the safe and environmentally acceptable methods of disposing or recycling of batteries.

7.3.2 Primary Cells

Primary cells provide electrical energy by a non-reversible chemical process. They were used in large numbers up until the 1980s to operate buoys and automatic beacon lights. The usage of primary cells has declined sharply since commercial solar power (photovoltaic) modules have become available. A related issue that hastened the decline of primary cells was the tightening environmental standards in a number of countries that required cells to be recovered from site for disposal in an approved manner. Disposal compliance costs, and occupational health and safety aspects of the frequent change-out of primary cells have worked in favour of converting to renewable energy sources (e.g. solar, wind and wave generators).

Zinc-Air Cell

The zinc-air primary cell was a common energy source for operating buoy and beacon applications. The cell uses a porous carbon block to supply oxygen from the air through an alkaline electrolyte to oxidize a zinc anode. Individual primary cells have an open circuit voltage of about 1.2 volts and can supply 1000 to 2000 Ah at a maximum rate of about 1 ampere.

Lithium-Thionyl Chloride Cell

Another type of primary cell in use in buoy applications is the lithium-thionyl chloride cell. This has a higher energy density and a longer shelf life than the zinc-air cell.

Sealed Alkaline Battery

Is commonly used in some countries, and has the benefits of good low temperature performance.

Sea-Water Cells

The sea-water cell[1] developed for buoy applications in Norway is a primary cell that uses a magnesium anode and a largely inert copper cathode. The sea water acts both as an electrolyte and the provider of dissolved oxygen for the cathode.

A single cell is installed as part of the buoy tail tube. The motion of the buoy has a beneficial effect in agitating the water to provide an oxygen-rich flow through the cell and carry away the reaction products.

Copper was selected for the cathode material because of its inherent antifouling properties. A magnesium anode was considered environmentally acceptable because it is a naturally occurring element of sea water. The cell produces a voltage of 0.8 to 1 volt under load.

AC-DC converter is used to raise the voltage to the level required by the load as it is impractical to use more than one cell due to the current leakage that would occur.

7.3.3 Internal Combustion Engine/Generators

Diesel Generators Diesel engine driven generators are often used as the primary source of electrical power where the location of an aid to navigation is too remote to be supplied from a mains electricity grid. Diesel generators are also used to provide emergency or backup power.

The generator capacity to support the operational and domestic loads of a standard lighthouse is in the region of 10kW. Smaller generators in the range of 2 to 5kW, combined with batteries and inverter-charger systems are now available to meet this variable load.

The requirement for diesel generators in lighthouses is decreasing as a result of:

- reduction in electrical load;
- improved efficiency of renewable energy sources.

Petrol Engine Generators

Petrol engine generators are a useful source of power for maintenance work, but are less common in permanent installations due to:

- fuel storage and transportation safety issues;
- maintenance requirements on the spark-ignition system;
- the petrol engine generally being regarded as less durable than a diesel.

Fuel Cell

This is a solid-state device that uses a catalytic process to oxidise fuel to generate an electrical current. A common fuel is hydrogen, or hydrogen rich fuels such as Methanol. It can be thought of as a continuously fed battery ideally preferring a constant load.

The fuel cell is now commercially available although the technology is still being further developed. Fuel cells offer a reliable and environmentally friendly energy source for supplementing AtoN power supplies.

Fuel cells do present an environmentally suitable solution, as Methanol can be manufactured from sustainable sources and the by-products of the generation of electrical energy is heat and water. There is some interest in the use of fuel cells in hybrid power systems with wind energy or solar energy.

7.4 Electrical Loads and Lightning Protection

7.4.1 Electrical Loads

IALA has prepared a standard methodology for calculating and defining the load profile of electric aids.

Some of the loads that this methodology covers are:

- lights;
- RACONs;
- AIS AtoN;
- electric sound signals;
- visibility detectors;
- monitoring and telemetry systems;
- charge controllers.

Refer to IALA publication:

- Guideline 1067-1 Total Electrical Loads of Aids to Navigation.

7.4.2 Lightning Protection

To assist those engaged in the design of aids to navigation, IALA has produced Guidelines to describe practical methods for the design, installation, inspection and testing of lightning protection systems. The information covers lightning protection for aids to navigation structures, equipment and systems.

Refer to IALA publication:

- Guideline 1012 on the Protection of Lighthouses and Aids to Navigation Against Damage from Lightning.

7.5 Non-Electric Energy Sources

Historically, non-electric energy sources were frequently used in aids to navigation, however, the use of electric energy sources is currently the norm, and is the recommended practice for new installations. There are various non-electric power supplies, the main types used in aids to navigation are acetylene and propane.

Acetylene

Acetylene (C_2H_2) has been used to operate lights on buoys and unattended aids to navigation for many years. Acetylene can explode if compressed directly, but can be safely contained under low pressure in special cylinders when dissolved in acetone. The manufacture of acetylene, standards for the cylinders and the filling process are usually controlled by government regulations.

Acetylene has been a convenient and reliable energy source for aids to navigation. However appropriate attention should be given to:

- safe handling of cylinders;
- the broad range of explosive mixtures with air (between 3 and 82% acetylene);
- the purity of the gas;
- minimizing leaks in pipe work and fittings.

Propane

Propane gas (C_3H_8) has been used as an alternative fuel to acetylene, particularly in buoys. Although propane has to be consumed in an incandescent mantle burner to provide a white light, it has several advantages over acetylene:

- it is a by-product in oil refining processes;
- its abundance and low cost;

- propane liquefies at a pressure of 6 atmospheres at 17ºC, and can be transported in low weight and low cost gas bottles;
- propane will maintain a positive pressure down to -40ºC and will not freeze in conditions likely to be encountered at sea;
- placing the bottles in pockets in the buoy or by filling it directly into the body of an buoy, or pressure vessel;
- the comparable containers are the 20 kg propane bottle with gross weight of 48 kg and the 7,000 litre acetylene cylinder, weighing 105 kg;
- furthermore the cost of the propane bottle is only about one third of that of a acetylene cylinder;
- propane is a particularly safe gas, as only some 6% of all its possible mixtures with air are explosive against a figure of 80% for acetylene;
- burns cleanly without the risk of sooting that can occur with a poorly adjusted acetylene burner.

Refer to:

- Applicable national standards for the safe handling of gases.

Notes

[1] The chemistry of the sea-water cell and the prototypelight buoys using this cellhave been described in papers for the 1900 IALA Conference and IALABATT 2 and 3

Article Sources and Contributors

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