Learning resource

Demonstrate and apply knowledge of renewable energy electricity generation systems
(Level 4, Credits 4)

Trainee Name: ____

skills.

Contents

Introduction

Renewable electrical energy has become big business and is one of the fastest growing areas in the NZ electrical industry.

This learning resource focuses on the common types of renewable energy systems and we will look at small scale renewables typically used in domestic environments.

The key types of renewable systems used in New Zealand in order of usage are:

1. Photovoltaic
2. Wind
3. Micro-hydro

Micro-hydro is generally considered as being any system up-to about 10KW in size, as is also the case for wind and PV.

Often, these systems are connected to the electricity grid (grid connected) and feed excess power they produce back into the supply grid.

Key learning points

At the conclusion of this module, the trainee will be able to demonstrate knowledge of common renewable energy generation systems and some related technology which includes:

1) Photo-voltaic generation systems
2) Micro-hydro generation systems
3) Wind turbine generation systems
4) Battery storage systems
5) UPS systems

let’s discuss some of the key types of systems currently available.

Photo-voltaic (PV)

Photo-voltaic (solar) is an area of emerging and rapidly changing technology. To be able to harvest electricity from sunlight is quite fantastic and you will more than likely come across solar installations in your work in the electrical industry.

The equipment is getting more efficient, lasting longer and the cost of manufacture is decreasing.

Principles of solar cell operation

Photovoltaic literally, means ‘light electricity’, ‘photo’ is from the Greek word ‘phos’ (light), and ‘volt’ is an abbreviation of Alessandro Volta’s name.

Definition

Photovoltaic effect	The photovoltaic effect is the generation of a potential difference caused by visible or other radiation at the junction of two different materials.

A photovoltaic cell takes sunlight energy and converts it into another form of energy- which is flowing electrons (current).

Photovoltaic cells have a layer of two different materials sandwiched together inside them (similar to a diode) which forms a wide flat junction. This is sometimes referred to as the P-N junction.

In simple terms, the light knocks electrons loose from silicon atoms at the junction of the two materials and the freed electrons now have extra energy or voltage.


Photo by Graeme Jeffrey

The solar cells internal electrical field pushes the freed electron to the front surface of the cell, causing a potential difference across the depth of the cell. If connected into a circuit, the potential can cause current to flow to other cells, or to an associated load.

Individual solar cells typically produce about 0.5V and are not very useful on their own. Solar panels are generally made up of multiple solar cells.

To form solar panels, solar cells can be configured in series or parallel, or a combination of both, depending on the manufacturer and what the desired output of the panel is.

Once the cells are assembled and wired together, the completed panel is mounted in a frame and encapsulated for protection from the environment.

These panels can then be mounted into an array of panels forming a PV system. The number of panels and size of the array depends on the load requirements.

Crystalline solar cells

There are two types of crystal solar cells:

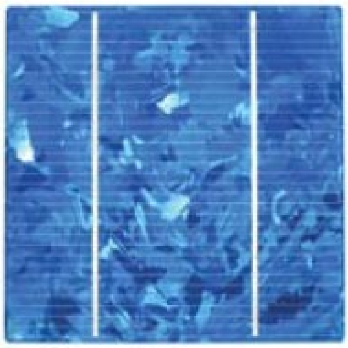
The mono crystalline silicon PV cell

- The oldest type of commercial cell.
- The surface is a single colour, often black to look at.

Mono-Crystalline Silicon PV Cell

The poly crystalline silicon PV cell

- Newer technology.
- The surface is a blue/purple colour to look at.
- Traditionally less efficient than mono crystalline cells but getting more efficient as manufacturing technology improves.



Poly-Crystalline Silicon PV Cell

Thin film solar cells.

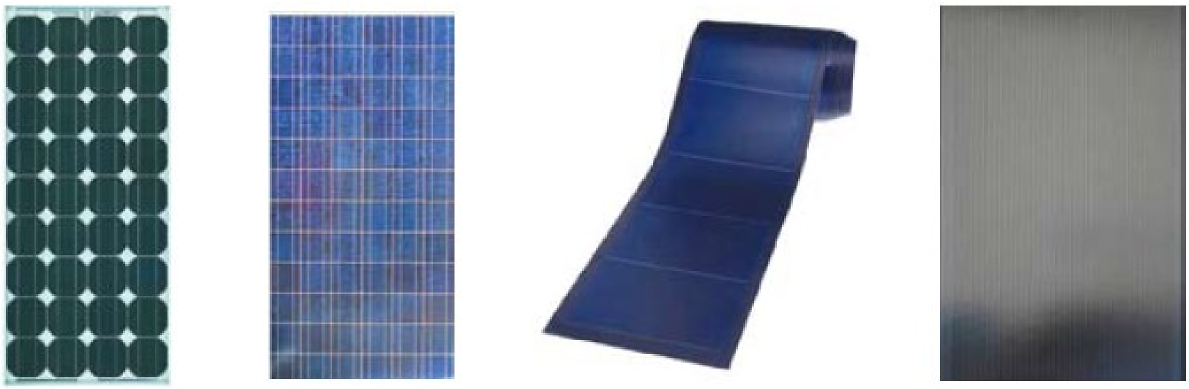
Some of the newer ‘thin film’ PV panels are not actually panels but strips of sheeting which can be glued onto a suitable surface.

This type of PV panel is sometimes called the second generation of PV, and whilst they have a similar output to the crystalline type mentioned above, they have an increased efficiency of around 20 - 30%.

These cells are made by depositing one or more thin layers (thin film) of photovoltaic material onto a substrate such as plastic, metal or glass. Thus, these thin film solar PV cells are more flexible and weigh significantly less.

Further research and development is ongoing and may lead to a third generation centred around the use of organic materials in conjunction with organometallic compounds, as well as in-organic substances. Some early prototypes of the third generation have approached laboratory efficiency in excess of 30% (and in one case 41% efficiency).

Figure 3: *Common PV Module Technologies*



Mono-crystalline silicon | **Poly-crystalline silicon** | **Flexible amorphous thin film** | **CIGS thin film**

PV panel performance

Ultraviolet radiation from the sun causes some damage to the cell over time, this means solar panel performance can decrease with age.

Typically, a drop of 10% in a panels output may be experienced within the first 12-18 months, and a further 10% drop over the life of the panel, which is generally twenty years or more.

It is therefore possible for a PV panel to be only capable of producing 80% of its nameplate rating towards the end of its life.

Another performance issue is to do with cleaning. For these panels to perform at their optimum they must be kept clean, especially from bird deposits.

This will necessitate cleaning with a soft brush or cloth so that the hardened deposit is removed without scratching or marking the glass surface.

PV system types

Photovoltaic systems can be stand alone or grid tied.

Standalone systems usually have storage batteries, but batteries are optional for grid tied systems, depending on the customers budget and installation requirements.

Standalone PV systems

Standalone systems are called standalone because they are not tied to the electricity supply grid and often need to be able to supply all the electrical needs of an installation.

Definition

Standalone PV system	A standalone PV system uses solar panels to charge batteries that are used as an electrical storage system. It does not rely on the supply grid as a supply source, the PV system provides all of the installations electricity supply.

An example might be a house in a remote area that has no national supply grid connection and relies solely on a solar generation system for electricity.

Sometimes a combination of alternative supply sources are used to provide for the electrical needs of an installation, i.e. solar and wind together.

Stand-alone power systems must meet the requirements of AS/NZS 4509, and battery installations must meet AS 4086 as well as NZS 4219.

Advantages and disadvantages of standalone systems

The advantages of the standalone system are that they can:

- Be remote to the grid.
- Don’t incur energy suppliers’ cost for energy and services.

However, there are disadvantages.

- Requires a storage system
- No backup if the source of PV energy is below that required of the electrical load.
- Only a single source of energy to charge batteries.
- Installation can be more expensive because of the cost of batteries.

Grid tied PV systems

A PV system installed to provide supplementary power to an installation that is also connected to the electrical supply grid is called grid tied.

As a result, a grid tied PV system does not have to have batteries to store the generated electricity. This will reduce the cost of the installation.

The electricity produced must either be used as it is produced or, sent back to the grid for a credit.

> Note: The property owner will need to apply to the local lines company to allow the solar PV system to be connected to the grid.

If the PV system has batteries, the electricity generated is able to be stored and used whenever the load requires, including at night.

This is a far more efficient use of a PV system, but the installation cost is significantly higher because of the price of purchasing and installing the batteries.

The value of supplying surplus generation back to the grid

In the case of grid-connected systems, in order to receive money for the surplus generation, an agreement needs to be reached with the electricity retailer, currently in NZ, the price paid for generated electricity is 0.08c/KWHr.

Typically, a grid tied PV system for an average house (in 2019) is around $25K for an 8-10KW system.

At 8 cents per unit, the payback period is around 15 to 20 years for the system and an average New Zealander stays in a home 7-10 years.

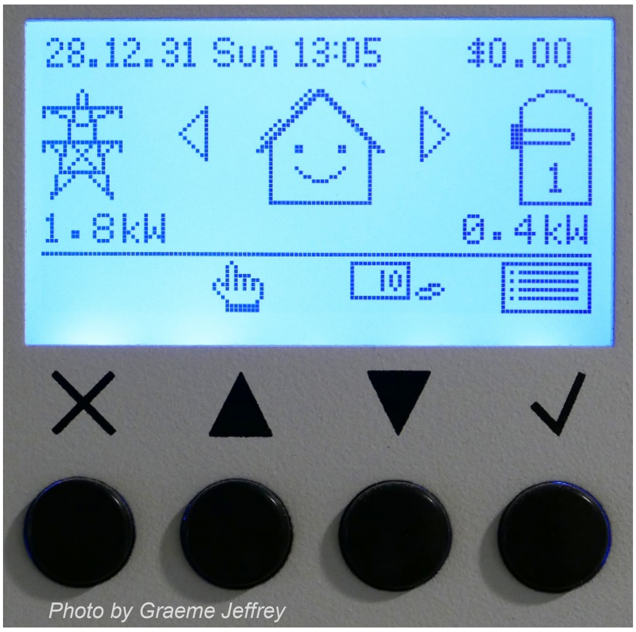


Photo by Graeme Jeffrey

Grid tied inverters

For PV installations that are connected to the electricity supply grid (hereafter called the grid), a key component is a grid tied inverter (GTI).

Photo by Graeme Jeffrey

A grid tied inverter converts the solar array DC output into AC and performs the function of synchronising the AC produced with that of the grid.

The GTI will perform the following functions:

1. Sense the incoming grid frequency.
2. Sense the incoming grid voltage.
3. Sense the polarity (if three phase) of the grid.
4. Look at the generated frequency and voltage and polarity (3 phase).
5. Synchronise the generated AC voltage and frequency to the grid frequency to ensure the inverter outputs are synchronised before closing a contactor connecting the GTI to the grid. Technically, we call this process mains synchronisation.
6. Most controllers also sense the presence of the grid, and if this impedance value changes for one reason or another, then the controller will shut down assuming there is a supply fault. This impedance sensing forms part of the monitoring and control function of the inverter.

A block diagram of how a PV array is linked using a grid tied inverter (no batteries) to the consumer's metering and electricity retailers' grid. is shown in figure 6.

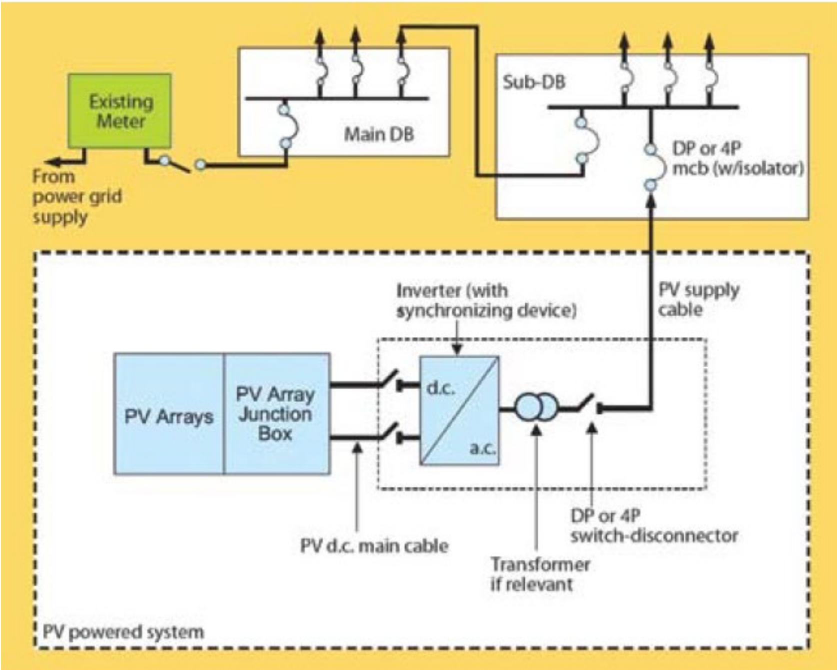


Figure 6: *Connection of array is linked using a GTI to the consumer's metering and electricity retailers' grid.*

The output from the solar array is fed into the main distribution board and any excess power generated made available via an import/export meter to the grid.

Anti-islanding

A very important point is that when there is no grid supply available, a GTI must isolate itself from the grid.

This is so that it will not back feed into the grid and potentially electrocute a linesman working on a fault somewhere on the network. This is referred to as anti-islanding in inverter terminology.

It is important to note, the average homeowner expects that when the grid goes off, they will still be able to carry on as normal using the output of their solar system.

Unfortunately, the GTI will turn off the PV system if there is no grid power and a PV system will not continue to supply any of the installation when the grid supply goes off.

A grid tied PV system will not continue to supply the installation when the grid supply goes off.

Grid tied PV system with battery storage

Many PV systems feature a storage battery and battery charging system which integrates with the grid tie inverter (GTI).

What this means is that the GTI and solar charger communicate with each other and use some smart control features such as cell balancing and efficient integration between the two systems.

The following equipment will be needed to control the isolation and protection of a grid connected PV system that has energy storage batteries:

- Suitably rated DC circuit breakers and isolators
- Residual leakage detection
- Lightening protection
- LV and GTI isolation and circuit breakers

Energy supplier requirements for exporting power to the grid

For any renewable energy system exporting to the grid, the local lines company must have appropriate documentation of the system, its performance, and its protection systems.

An ICP connection number will then be issued and an export meter installed with separate revenue meters for import and export of energy from the renewable source.

Standards for renewable energy systems

Connection of any form of generation to the grid system is governed by legislation, both at a governmental level and at a local lines company level

Standards & Regulations

At a governmental level there are several key pieces of legislation such as:

1) AS/NZS 3000,
2) AS/NZS 3820,
3) AS/NZS 3008.1.2,
4) AS/NZS 4509.2,
5) AS/NZS 4777.1,
6) AS/NZS 4777.2,
7) AS/NZS 5033.

AS/NZS 4509.2

This standard relates to the design of standalone systems, which could be either, photovoltaic, wind, hydro, all with energy storage at extra low voltage or low voltage in domestic installations. It requires standards AS/NZS 3000 and AS/NZS 4509.1 also.

It helps in establishing the:

- design criteria
- system configuration
- component sizing and selection
- installation design
- costing and economic evaluation
- documentation

This standard must be consulted when implementing a standalone system.

AS/NZS 4777.1

AS/NZS 4777.1 covers GTI’s that are used with other energy sources like batteries, photovoltaic arrays, hydro and wind.

AS/NZS 4777.2

AS/NZS 4777.2 is the standard that determines the must do’s around connecting inverters to the grid. This is different to UPS’s which use AS 62040.

Grid tied PV systems must meet the requirements of AS/NZS 4777.2:2015.

This is also the standard an installer would refer to, to find information about safe isolation and testing procedures of a grid connected energy system

AS/NZS 5033

This standard is important for the installation and safety requirements for photovoltaic (PV) arrays.

It covers aspects of PV array configuration and mechanical design.

This standard is of interest to the installer because it covers a lot of key information about requirements for the installation. The installer and the electrical inspector need to check that all equipment supplied and installed meets the required standards.

Developing a PV design

While developing a design for and installing a PV system, there are some groups of people who you can consult with and get advice and help with information such as:

- Local council
- Structural engineer for wind loading and additional loading on roof
- Electrical Inspector
- Professional company providing PV systems

If the PV array mounts onto a roof, then building consent from the local council may be required, it does vary between local councils, always check the local rules.

Roof loading and wind loading on the house may need to be assessed by a competent engineer and in some areas, the local council's building consent department.

There will also be health and safety considerations, such as, working at heights during panel installation. Scaffolding may be required for all involved in the installation.

The array frame must be installed to ensure:

- It meets wind, weight loading and seismic building standards.
  - This may involve a structural engineer (CP Eng – Chartered Professional Engineer).
- Building penetrations are weather tight.
- It meets restrictions on shading of neighbouring properties.
- It is isolated to prevent electrochemical corrosion with different metals in the solar panels or the building fabric – New Zealand metal roof manufacturers specify a 100 mm gap so that panel installations allow for roof washing, and do not void roof warranties.
- It allows for adequate airflow behind the panels to provide cooling – approximately a 100 mm gap for crystalline silicon panels.

Checking and signing off the design

Depending on the area the installation is in, energy output and PV panel mounting arrangement on the roof, the following people may be required to test/check and sign off the PV installation.

- Council inspector
- Structural engineer
- Electrical inspector

According to Worksafe NZ, the following applies:

In a PV system that operates with a combination of extra low voltage (ELV) and low voltage (LV) the system must be installed to comply with the standards AS/NZS 3000 and AS/NZS 5033.

The work on the ELV-DC side of the system is not PEW unless considered high risk, therefore will not require certification or inspection.

However, the work on the LV-alternating current (AC) side of the system, including the inverter, is PEW and will require certification.

If this PV system is an independent supply and the inverter is not paralleled to a mains supply, it will not require an inspection.

Regardless of who installs it, a PV array with LV has to comply with AS/NZS 5033 and ESR 60. However, for small PV arrays, using ELV and power wattages under 250 watts the AS/NZS 5033 doesn't apply.

The PV final terminal voltage at the inverter of a domestic installation might be in excess of 200V DC under load, but the open circuit voltage could very likely be up to 600V DC, these can be considered high risk.

Determining the requirements for a domestic PV installation

There are two basic ways that people can go about determining the size and specifics of an off grid domestic solar system.

One method commonly done by some solar companies, is to add as many solar panels that can be mounted on the dwelling at the required elevation to the sun path. The rest of the requirements are then built around this available solar energy.

A more scientific approach is to monitor the size of the loads occurring each day and the period each load is on. This is to determine the total watt/hours of generation, and storage required per day. The storage required will depend on how long this load pattern needs to be maintained when the solar panels are not producing a useful output.

This exercise is somewhat subjective though. It depends a lot on personal preference and, what each dwelling deems essential and non-essential, the age of the occupants in the dwelling and whether there are any out of the ordinary needs like life threatening illnesses or health issues.

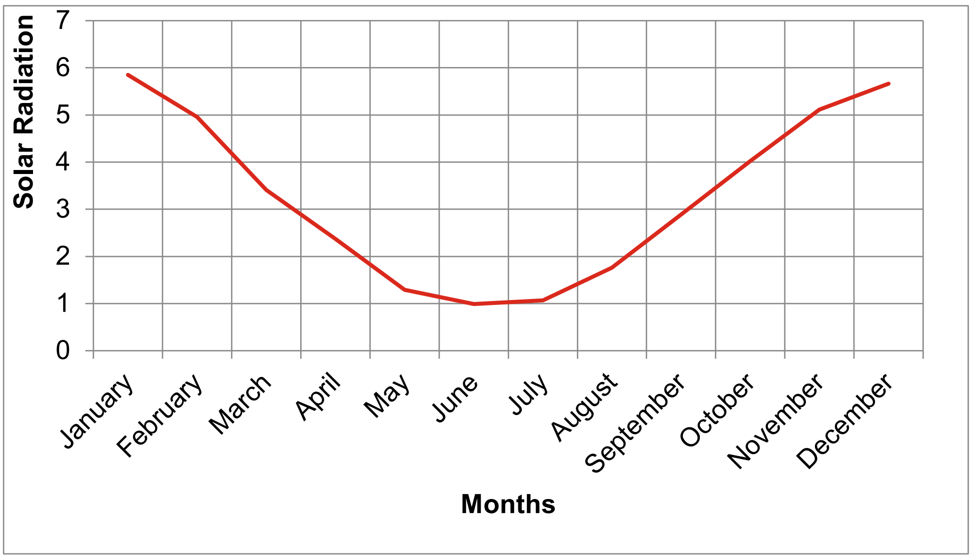
For an example, in an older persons dwelling, the requirement for heating and light becomes more critical than perhaps is the case with a younger family.

Sizing of solar panels

To size a solar array, start with the minimum daily required watt hours and adjust the figure up by a panel sizing (redundancy) factor. This allows for the fact that a fixed position panel will not be at peak output all day, there will be periods of time where the sunlight is not as intensely shining directly onto the panel. Typically, the panel redundancy factor is between 1.2 and 1.6, but depends on the panel design.

There is also the solar radiation figure for the region, the time of the year to consider and the peak watt (Wp) output of each panel.

The vertical axis in the graph below is Solar radiation and is measured in kWh/m^2/day.



The temperature of the panels can also have a derating factor on hot summer days, but it generally doesn't cause an issue because in the heat of the day the solar radiation is higher as well. Panel output temperature loss can be as high as 15% in NZ on a very hot day.

Any calculations must be done at the lowest level of solar radiation, that is during June in New Zealand.

$f(x)$

Formula

To work out the sizing of solar panels you can use this formula:

$$\text{Sizing of panel} = \frac{(\text{total Watthours per day} \times \text{panel factor})}{(solar\ radiation\ factor \times peak\ output\ of\ solar\ panel)}$$

Maximising sunlight absorption

The capacity of any given photovoltaic system is directly proportional to:

- The amount of sunlight absorbed.
- Solar irradiance – which depends on the location in the world.
  - Solar radiation in New Zealand has a maximum of 6kW/m^2 during the peak of the summer months.
  - Photovoltaic cells can still generate electricity in cloudy conditions, though at a lower output. In the deepest, darkest South Island winter the daily solar radiation (when the sun does shine through the clouds), can be as low as 0.75kW/m^2.
- Solar panel area – Approximately 1 kWp requires 5–17 m^2 of solar panel, depending on type.
- Solar panel orientation
  - In New Zealand, the sun follows an arc to the North. Solar panels should, in general, be oriented to the North. It may also be necessary to change the orientation because of shading, aesthetic reasons, lack of available space or poor building orientation. Facing the panels away from true North will result in a drop-off in performance. Panel angle to the sun should be 22° in New Zealand.


Photo by Graeme Jeffrey

Inverter sizing

An inverter must be able to handle the peak load which would include start-up loads of some appliances.

Generally, to ensure the long life of an inverter, a capacity factor of 25 to 30% above the maximum peak load is used for inverter selection.

This is to result in an inverter that has some extra capacity, to allow for some unexpected overloads and to reduce ‘stress’ on the inverter so that it will run in a more efficient state, rather than sizing it smaller and having it constantly working too hot and hard.

Also, the inverter must be able to cope with the peak load if all the required appliances in the installation were turned on at the same time.

$f(x)$

Formula

To work out the required size of an inverter you can use this formula:

$$\text{Sizing of inverter (kW)} = \text{peak load current} \times \text{output voltage} \times \text{capacity factor}$$

Photo by Graeme Jeffrey

Solar charge controller sizing

Solar charge controller sizing is done using the PV system current rating and maximum voltage rating.

The choice of the type of controller is very important to ensure as much available solar energy is used as effectively as possible to replace battery energy used by the load.

The most effective charge controllers use a system called Maximum Power Point Tracking, (MPPT).

What is Maximum Power Point Tracking (MPPT)

MPPT refers to maximum power point tracking, which means that the charge controller part of the inverter system optimises the DC voltage for the connected batteries. This is to ensure their correct charging levels are maintained.

Definition

MPPT	MPPT = Maximum Power Point Tracking, an advanced battery charging system that optimises how the storage batteries are charged.

The MPPT charge controller checks the output of the PV array, compares it to the battery voltage and their state of charge, and then decides what is the optimum power that the PV array can deliver.

When the batteries are fully charged, then the GTI can supply electricity to the home to offset the dwellings power usage or demand, and if this is minimal then the remaining power will be exported to the grid.

These types of controllers are more expensive than the previous pulse width modulated (PWM) controllers, but the features available and the increased efficiency out way the additional cost.

Size requirements for a renewable battery storage system

The size of the battery storage system needs to be able to provide the required Ahrs per day of electrical load and to do so for the length of time deemed necessary.

In a standalone system, there is no back up and the generation system and storage batteries need to be able to get the installation through reasonably expected periods of poor generation. Periods like in winter months or a week of bad weather where a PV system is not producing much electricity.

If the charging and storage capacity of the system is below the required output for any period, then the system will not be adequate in a stand-alone situation.

Determining battery size for a renewable energy system.

The first step in the process of determining the battery size requirement is to ascertain what the total Kwh reading is for one typical day.

You can measure the energy used over one day or several days for more accuracy and then divide total Kwh reading by the number of days. Use a recording meter to monitor the peak current that occurs over the period as well.

Most dwellings use around 2-4KW continuously during the day, peaking around dinner time at between 8-10KW depending a little on the season (summer/winter) and whether gas or electric cooking is installed.

Knowing the number and type of appliances that are considered ‘essential must haves’, their starting and running currents, and how long the homeowner ‘must have’ these devices operating is critical information for the designer to calculate the necessary capacity of the batteries.

The battery is required to hold enough energy to operate the electrical load at night and on cloudy days continuously.

There are some losses associated with batteries, these are, depth of discharge and battery self-loss. Generally, these figures are around 0.85 for a new battery and 0.6 for depth of discharge.

$f(x)$

Formula

To work out the required battery you can use this formula:

$$\text{Battery capacity (Ah)} = \frac{(\text{total Watthours per day} \times \text{days required})}{(Depth\ of\ discharge\ system\ \times battery\ self\ loss\ factor\ \times\ nominal\ battery\ voltage)}$$

Example PV system size calculation

Example

An average size dwelling consumes 1.66 kWh per day and the peak current observed is 25 amperes.

The dwelling uses gas for cooking, water and space heating.

Given that the depth of discharge factor is 0.85 and battery self-loss factor is 0.65, panel redundancy factor 1.3 and solar radiation factor is 0.99 and the required inverter capacity factor is 130%.

Determine:

1. The minimum size of the battery in ampere/hrs to run the household for three days if the battery voltage is 24 v nominal;
2. Number of panels required if each panel has an output of 250 watts peak;
3. Size of the inverter if the inverter output voltage is 230V.

1)

Battery capacity (Ah) $= \frac{(\text{total Watthours per day} \times \text{days required})}{(Depth\ of\ discharge\ system \times battery\ self\ loss\ factor \times nominal\ battery\ voltage)}$

Battery capacity (Ah) $= \frac{(1660 \times 3)}{(0.85 \times 0.65 \times 24)}$

Battery capacity (Ah) $= \frac{(4980)}{(13.26)}$

Battery capacity (Ah) $= 375.57\text{hr}$

2)

No. of panels $= \frac{(\text{total Watthours per day} \times \text{panel factor})}{(solar\ radiation\ factor \times peak\ output\ of\ solar\ panel)}$

No. of panels $= \frac{(1660 \times 1.3)}{(0.99 \times 250)}$

No. of panels $= \frac{(2158)}{(247.5)}$

No. of panels $= 8.72$

The number of panels required would be 9.

3)

Sizing of the inverter $= \text{peak load current} \times \text{output voltage} \times \text{capacity factor}$

Sizing of the inverter $= 25 \times 230 \times 1.3\ (\text{ie } 130\%)$

Sizing of the inverter $= 7.47\text{Kw}$

PV system installation

Warning - electrical hazard

While working on PV systems, you must remember that:

Solar panel outputs cannot be turned off when light is shining on them.

This presents a real electrical hazard for workers working on PV equipment and is particularly an issue if the array is connected with a combined output voltage of a few hundred volts. If you have to work on the system, you may have to work at night, prevent light from shining on the panels (difficult) or use live line techniques.

Solar panels

Typically, solar panels mount onto the roof of a dwelling, but they may also be pole mounted, mounted on a ground frame or mounted in a tracking system, etc.

Array frames allow the solar panels to be tilted to the optimum angle for receiving solar energy. They can be:

- Fixed (permanently oriented in one direction, frequently at the roof angle).
- Adjustable (so the orientation can be manually changed to suit the time of year).
- Tracking (which move to follow the sun to provide more electrical power output throughout every day of the year). Normally controlled by an electric motor or a refrigerant gas.


Fixed polycrystalline installations and a grid tied inverter system.

Solar panel connections can be made as a string of series or parallel connections or a combination of both. Remember that for 1kW of PV, this will require a roof area of roughly 5-6m^2.

This figure is based on a panel area of about 0.8m^2 putting out about 175W of power at 21V DC.

> In New Zealand, solar panels are usually installed at an angle of 22° to the sun for optimal sunlight collection.

Junction boxes

Most PV panels have a junction box associated with them on the rear as shown in figure 4.

These junction boxes are IP rated for use in all external weather environments and can be used to connect the panels together in several different combinations.

Figure 4: *Isolation of PV panels*

Circuit breakers and isolators

From the array to the junction box, the next step is to install a DC main circuit breaker and isolator.

This provides a means of isolation and protection from surges in DC voltage and current, as well as a means of protection for the homeowner, electrician, etc.

Some installations have series and parallel connected PV panels with a final terminal voltage in the hundreds of volts.

It is important that the circuit breaker and isolator have enough rating to cope with the applied voltage and be able to safely open the circuit while under load.

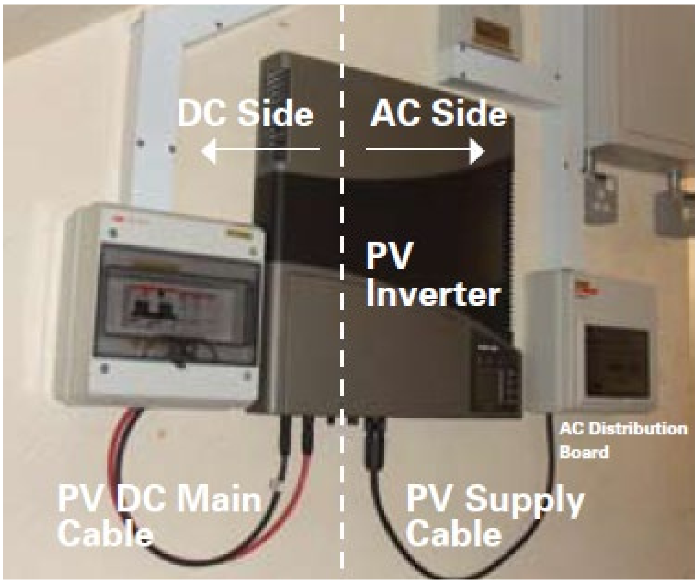


Figure 5: *Typical PV inverter connected to a building's installation*

Signage

PV systems require specific signage.

The signage should clearly indicate to electricians and emergency services personnel that there is a PV system on the premises.

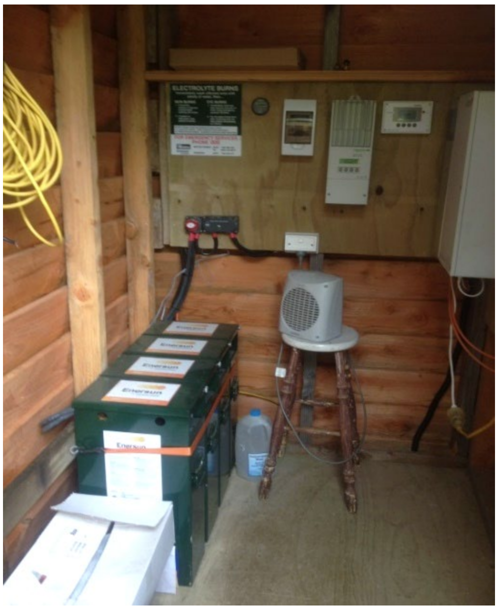
There must also be signs to say where the DC isolator and AC isolator are located and outline the appropriate isolation procedure for the system.

Batteries

Traditionally, the main types of battery used were the traditional lead acid, sealed lead acid, the deep cycle variety and nickel cadmium batteries (Ni-Cad).

Next the Nickel Metal Hydride battery and in more recent times, the lithium ion or lithium ion phosphate battery types.

Deep cycle batteries have, until recently, been the mainstay for PV systems. With the advent of newer technology lithium batteries, a higher charge density for the size and weight of battery can now be achieved.



On this basis, it is expected that the number of deep cycle installations will reduce.

Rapid recent technological development of batteries has been helped along by large scale investments in technology and manufacturing, e.g. Elon Musk and the Tesla car which has led to battery walls for energy storage – basically walls containing highly packed cells of around 1.1-1.2v DC each, and being only slightly larger than a standard AA battery.

It is beyond the scope of this section to go into batteries and their different technologies, suffice to say that each type of battery has its own set of requirements for ventilation, charging, charge balancing, discharge and charge level, maintenance, fusing, etc.

A battery storage system can easily be integrated with most grid tie inverters. In this case though, the PV solar cells feed into a charge controller which also has a voltage limiting or clamping feature along with an MPPT ability or feature.

Battery charging and maintenance

Care should be taken with any charging system to ensure that all batteries in the string receive and retain the same amount of charge – this is called cell balancing. Many newer charging systems have an inbuilt cell balancing feature.

Battery discharge and charge cycles are also important, as some battery types will suffer permanent damage if they are discharged too far, i.e. below 50% in some cases.

The charge controller needs to be set for the correct cycle for the batteries it is controlling.

Batteries, especially the lead acid variety, need to have their cells checked regularly and fluids topped up. This is not the case with the sealed lead acid variety.

The general life span of batteries is around 5 to 7 years if well maintained.

Charging stages

There are four main stages involved in charging storage batteries used in renewable energy systems:

1. **The Bulk phase (first stage)**

The bulk phase is primarily the initial stage of charging a battery when the sun shines, or when the generator is turned on.

The bulk phase will initiate when the battery reaches a low-charge state, and that is usually when the charge is below 80%.

In this stage, the charger delivers as much amperage as possible to the battery by having the terminal voltage higher than the battery absorption voltage, to ensure a high charging current is maintained.

To achieve this, the charging voltage rises over time as the batteries absorb the charge.

2. **Absorb Stage (second stage)**

The second stage of battery charging is known as the absorb stage. This stage starts when 12V lead acid storage batteries (for example), reach a charge of 14.4 to 14.8 volts, or when the charge level is between 80 to 90% full.

The absorb stage continues until the number of amps entering the batteries reaches a pre-set amount, or the programmed time elapses. To achieve this the controller must have a feature to be able to enter the battery capacity in A/hrs.

3. **The Float stage (third stage)**

The float stage comes immediately after the absorb stage. During this third stage, the charge controller lowers the voltage to a specific pre-set value. The float stage is complete when the batteries reach a charge level of 100%.

4. **The Equalization stage (fourth stage)**

The final stage or the equalization stage is a controlled overcharge stage, which is done periodically. This ensures that the battery is kept up to full charge when load is light.

Suitability, advantages and disadvantages of photovoltaic systems

Environmental impact:

- Quiet
- Non-polluting
- Contribute to reduction of greenhouse gas emissions

Sustainability:

- Dependent on sun availability
- Dependent on tilt angle
- Generally sustainable and renewable
- Can provide a sizeable amount of electricity
- May need other systems to be used such as battery backup, alternative heat source, and generator backup
- Low maintenance costs

Construction of system:

- Requires licensed professionals
- Ease of access
- Dangerous
- Tilt angle is critical
- Bracing may be required
- High initial cost

Disassembly of system:

- Sign access may be difficult
- Cannot turn off output when light is shining on panel
- Working at height
- Restoration of building roof and water tightness may be necessary

General disadvantages of photovoltaic systems:

- May require local council consent before installation
- Has limited output during parts of a 24hr period
- Can be damaged by lightning strikes
- Electricity production is dependent on availability of sun
- Have high initial capital costs
- Electricity production times may not match when household requires electricity

Wind generation

Sometimes you see the old-style multi-vaned windmills on farms. They rotate a central geared shaft, which in turn drives a mechanical load such as a water pump.

Over recent history, we have realised the same potential for generating electricity by using the wind to drive blades to drive an alternator directly or via a gearbox.

Here, we will have a look at small wind generators for a domestic or urban environment, up to around 10KW. Obviously, an optimum site will be chosen for its constant wind and suitability for the tower height, etc.

Wide open spaces represent the best possible sites for wind turbines, but also these sites represent the best sites for lightning and high wind gusts, which can be harmful to wind turbines. In other words, the installation site for a wind turbine will always be a compromise.

Basic wind turbine components

The basic components of a wind generator system are as follows:

- Blades to capture the wind energy attached to a hub or gearbox.
- An AC or DC generator.
- A nacelle (housing) for the drive gear.
- A tower to mount the nacelle onto and in some cases, a facility to be able to be lowered for maintenance purposes.
- A foundation designed to effectively hold the tower in place.
- An Inverter and control system, which interfaces with the AC power grid (where required) via isolators and contactors.
- When installed, an energy storage system, i.e. batteries.

A typical small three bladed wind turbine with direct drive alternator is shown here in figure 7.

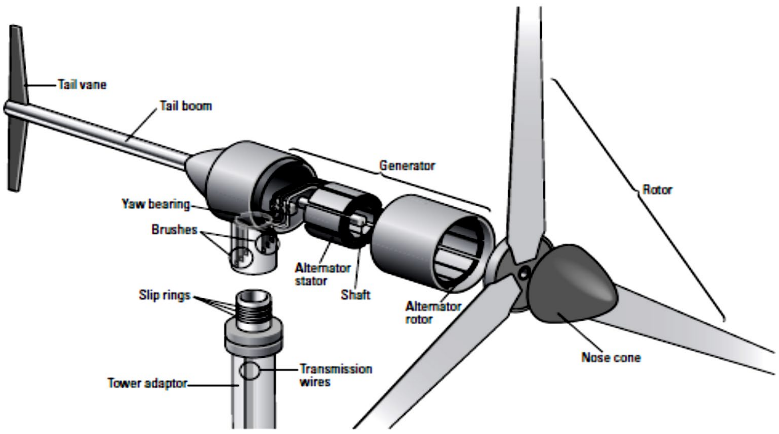


Figure 7

Wind turbines can be mounted horizontally (more common), or vertically, or be a combination of both.

The blades and their construction must be manufactured to survive the toughest of weather storms, lightning strikes, wind shear, gales and high intensity wind gusts of short durations, torrential rain, snow and ice. This is a tall order.

The alternator can be a wound rotor design or a typical squirrel cage design, or even a permanent magnet DC type. Each type has their own advantages and disadvantages, but normally comes as part of the system package from the supplier or manufacturer.

Wind shear

Most people live near buildings and trees. This means that most people live on sites that have ‘high wind shear’. Wind shear is a term used for sudden changes in wind speed or direction between two different places, like walking around a building and suddenly being hit by a gust of wind.

Wind shear is the rate of change in the winds speed/direction. Wind shear increases as you move upwards from the ground, it increases very quickly the higher you get over rough terrain. Wind shear increases more slowly over smooth terrain.

Definition

Wind shear	Wind shear is the rate of change in the winds speed/direction

There are various different influences on wind shear and the list below ranks terrains from low shear (smooth), to high shear (rough):

- Perfectly smooth water
- Flat grassland or low shrubs
- Trees or hills, with buildings in the area
- Close to trees or buildings
- Surrounded by tall trees or buildings

Factors affecting generation capacity

A system's generation capacity depends on its effectiveness at converting wind pressure into rotary inertia. This increases with:

- Larger turbine diameter – there is more turbine blade area for the wind to impact on.
- Appropriate blade profile for the local wind speed – this varies depending on average wind speed and on whether the wind is constant or comes in short periods of high velocity.
- Lower friction losses in the mechanics of the blades and turbine.

Generation capacity will decrease if the turbine is located:

- Lower to the ground – wind speed increases with height above the ground.
- Within the turbulent airspace downwind of an obstacle (for example, trees, hills, buildings, structures) – downwind turbulence will be twice as high as the obstacle and affect the air stream for a distance of around 20 times the obstacle height.

Calculating wind power

Wind, unlike solar is available 24 hours per day. Wind is peculiar though in that it is never constant, and it gusts.

What is of relevance to a wind generator is the average wind speed and the power that will produce. For safety and design, the maximum strength of a wind gust (sometimes also called peak) is also important information to know.

Calculating the power of wind follows the cube law:

Power = ½ x the density of the air (D) x swept area (A) of the wind generator x wind speed (V) cubed.

$f(x)$

Formula

To calculate the power of wind you can use this formula:

$$P = ½\, D\, A\, V^3$$

A doubling of the wind speed will give eight times (8x) the power, and halving the wind speed will reduce the power by an eighth (1/8).

The higher the tower or mast, the greater the wind speed, but also the more structural issues you will have to deal with, as the tower will be taller and need more stays and a larger foundation.

Another point to remember is that, at low wind speeds there is very little energy available:

e.g. 2 x 2 x 2 = 8 whereas 10 x 10 x10 = 1,000

Air density

The density (D) of the air will significantly affect the power available to the wind turbine. Basically, when the air temperature is warmer, the air expands (takes up more room) and is less dense. When the air is cool, the air is denser.

Dense air gives more power than is possible with hot and thinner air.

On this basis, in winter, the air has more power to spin the blades than in summer. Similarly, higher altitude means thinner air than at sea level and less driving power.

Swept area

Swept area (A), is defined as the circle that the spinning blades (rotor) creates and is effectively the energy collector of the wind source.

Therefore, the larger the swept area, the more wind energy is captured, but, and it is a large BUT, the larger the blade or rather the longer the blade means that the tip of the blade will spin faster.

The issue is that the tip speed must not break the sound barrier, otherwise it will set up a resonance in the blade which will cause the blade to shatter or fly to pieces. The area of a circle is of course related to

the well-known formula where r is the radius of the blade circle:

$f(x)$

Formula

To work out the area of a circle you can use this formula:

$$A = \pi r^2$$

If you can double the size of the collector area, the swept area is doubled and so the energy collected will also double.

Choosing a wind turbine

Most wind turbines come in preferred sizes (much like resistors), except that instead of being measured in ohms, the unit of measure is in knots or m/s or kmph or mph.

It is important to obtain the correct size wind turbine for the wind that is to be experienced in the location you are planning.

Wind speed distribution charts are available from many wind turbine manufacturers, and these should be matched with the wind profile for the site.

Some more terms that you should know in relationship to wind turbines are:

- Cut-in – this is the minimum wind velocity below which the turbine will not function, as there is no useful power to be obtained from the wind – e.g. typically 3-4m/s (10-14 kmph or 7-9mph).
- Rated or Nameplate speed – this is typically the lowest speed at which the turbine will develop its maximum power. This is typically 12.5-15 m/s.
- Cut-out speed – this is defined as the maximum SAFE working wind speed. At this speed the wind turbine is designed to shut down by feathering the blades and or applying brakes. This is to prevent damage to the turbine. A cut-out speed of 25m/s is typical especially for larger machines.
- Survival wind speed – this is the maximum speed that a given turbine is designed to withstand and will not survive any wind speed above this. In larger machines this is around 50m/s.

Building consents and electrical standards

The building codes are peculiar to each local council and so the installer must refer to their local council for their rules about wind turbines.

Local council consent and neighbours' consent (especially if the tower is higher than 5 metres) may be required in addition to any electrical sign offs from the local lines company, and those required by the relevant standards including AS/NZS3000 and AS/NZS 3820.

The consent will also consider the noise generated by the tips of the blades.

The installation must comply with all necessary electrical standards and codes of practice and be signed off by a registered electrical inspector.

Wind turbine safety considerations

With wind turbines, not only do you have the usual electrical hazards, but you now also introduce a rotating hazard in the form of blades, gear boxes or belt reduction, exposed shaft and rotor, plus working at heights.

Inverter and controllers

If the wind turbines energy is exported and not stored, then a GTI and controller or battery charging controller will be required because it is extremely difficult to synchronise a wind generator with the supply grid (because of wind gusts).

If, however, a battery storage system is involved, then a charge controller and dump load will be required. A dump load is used to load the output of the generator when the installation electrical load demand is low in strong winds.

Another feature of a controller can be to provide electrical braking for the turbine.

Suitability, advantages and disadvantages of wind generation systems

- Can be designed to provide increased electricity generation by installing the prime mover (turbine blades) higher off the ground
- Can be designed to provide electricity generation 24 hours per day
- Can have good generation capacity

Environmental impact:

- Non-polluting
- Produces noise
- Vibration affecting tower or roof mount
- Visual impact

Sustainability:

- Efficiency of between 10% and 40%
- Sustainable with winds in excess of 6-8 m/s
- High Maintenance costs
- Obstacles downwind or upwind will affect capacity
- Height will affect capacity

Construction of system:

- May require local council consent before installation
- Should be installed within 100 m of the electricity supply or storage system, to reduce line losses
- Must withstand the wind and seismic loads
- Usually has a concrete footing for the tower (and each guy wire)
- Must have vibrations in the tower dampened if it is connected to a building
- Must have protection from large animals at ground level – they like scratching themselves on the tower and guy wires

- Should have lightning arresters to protect electronic components from lightning strikes
- High initial cost
- Needs sufficient area to lower and raise the tower for maintenance and repairs.

Disassembly of system:

- Needs sufficient area to lower and raise the tower for disassembly
- May be in a difficult to get at position
- Requires lifting equipment/crane
- Possible rotating equipment

General disadvantages of wind generation systems:

- Relies on constant wind within a speed range
- Can provide noise and visual pollution
- May require local council consent before installation
- Operation must be limited in adverse weather conditions
- Are positioned high and open for lightning strikes.

Micro-hydro

Micro hydro generation systems are generally classified as being up to 10KW in size. Typically, micro hydro systems tend to be 0.5–1kW in size.

Definition

Hydro generation system	A hydro generation system is one that relies on the flow of water being diverted into a canal or pipe which is then directed through a turbine.

A typical micro-hydro scheme is river or stream-based setup. The run of the river type scheme in figure 8 includes a river side intake, a canal to a surge chamber and a penstock conveying the water to the turbine or runner.

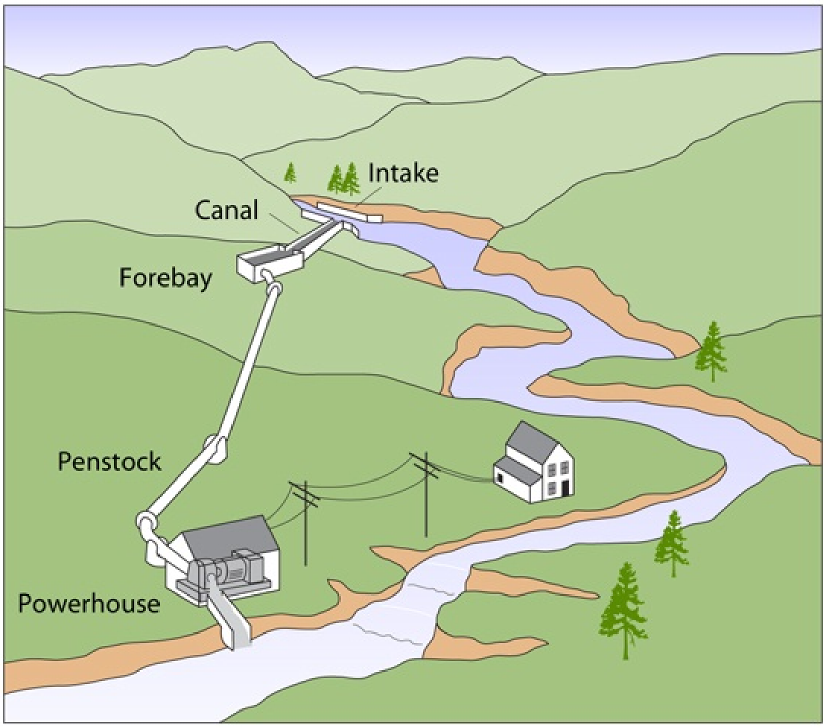


Figure 8

As the water spins the turbine, it generates power. The generator system output is fed into a controller which connects the generated supply with the home directly or a via a battery storage system.

More than one turbine can be installed depending on the water resource available.

Because micro hydro works 24 hours a day 7 days a week, it can potentially provide all the power a house needs. These systems can be a better option than wind or photovoltaic generation if the circumstances permit.

This form of generation tends to be more suitable for rural farms or lifestyle blocks and is a great choice for reliable energy production 24 hours a day.

Overall in New Zealand, installation numbers are small as not everyone has a stream or a river that they can utilise

Choosing an appropriate site for micro-hydro systems

An appropriate site would have a running stream or river with the necessary fall and flow to run a turbine efficiently. For a standalone system, the site will need to have an adequate continuous flow of water all year round to provide consistent generation performance.

Also, it is good to be able to have the generation plant as close as possible to the load to reduce voltage drop, but it may need to be a compromise as some types of turbines can be noisy when operating.

The site and design of the system should be such that there is dry access to the turbine for maintenance i.e. out of the water.

Choosing a turbine

The type of turbine chosen depends on the available flow of water through the penstock pipe or canal, and the water “head” of the scheme, (head is defined as the height difference between where the water, enters the penstock, and the turbine or runner).

.

Turbine output power

The net head of the system (H_n), is defined as being the gross head less the losses due to friction caused by the pipe.

A rule of thumb to estimate the electrical power delivered would be:

$f(x)$

Formula

To estimate the turbine output power delivered you can use this formula:

$$\mathrm{P(kW)} \approx 5\mathrm{Q}\ (m^3 \div \mathrm{s})\ \times H_n\ (\mathrm{m}) \quad \textit{or} \quad \mathrm{P(W)} \approx \frac{\mathrm{Q(gpm)} \times H_n\mathrm{(ft)}}{10}$$

Sometimes both the metric and the old imperial units are given for calculations. 1” is 25.4 mm and 1’ (ft) = 304.8 mm. Most buckets are the equivalent of 9 litres or 2 gallons.

Example:

If a stream has a measured flow rate of 112 litres per minute (125gpm) through a 75m long 64mm PVC penstock pipe, determine the power generated by the turbine mounted at the end of the penstock 30m lower than the intake.

From the imperial chart in figure 10, a 64mm (2.5") PVC pipe at 125gpm will have a friction loss of 7' per 100' of pipe. So, at 250' in length, the friction loss will be 2.5 x 7' loss = 17.5' loss. This converts back to a head loss of 5.3m. Given conversion factor between metres and feet is 3.28.

Therefore, the net head (Hn) will be 30-5.3 24.7m (24.7 x 3.28 = 81 feet)

Now substituting this into the formula:

$$P(W) \approx \frac{Q(\mathrm{gpm})\ x\ Hn(\mathrm{ft})}{10}$$

$$P(W) \approx \frac{125\ x\ 81}{10} \approx 1013\ W\ \text{or}\ 1\ kW$$

Looking at the graph in figure 10, simply changing the pipe internal diameter and possibly the type of material the pipe is made from, would result in a performance increase due to lower friction losses.

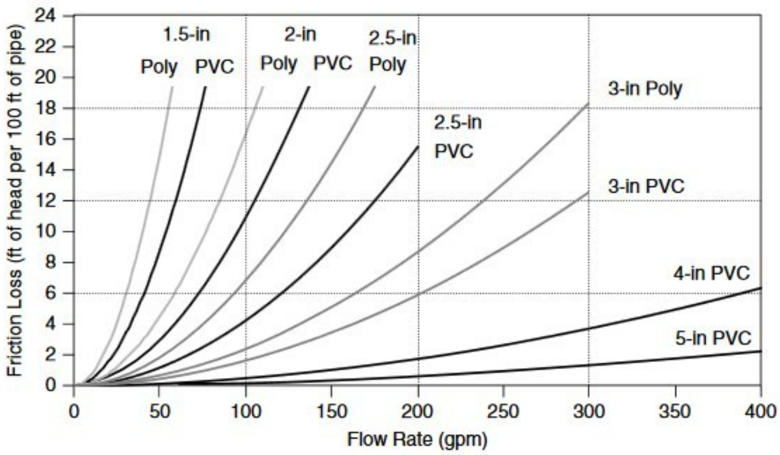


Figure 10

If the penstock was made from 3" PVC,
then the friction loss reduces to 2' per 100' of pipe;

or 250/100 x 2 = 5' of friction head loss.

On this basis, the net head would be 100'- 5' = 95'.

Substituting this into the formula:

P(W) = (125 x 95)/10 = 1187.5W or 1.1875 KW

$$P(W) \approx \frac{Q(\mathrm{gpm})\ x\ Hn(\mathrm{ft})}{10}$$

$$P(W) \approx \frac{125\ x\ 95}{10} \approx 1187.5\ W\ \text{or}\ 1.1875\ kW$$

This is a 156.5W or 15% improvement in power output.

Turbine types

Turbine styles are often named after the designer of the impeller as shown in figure 9.

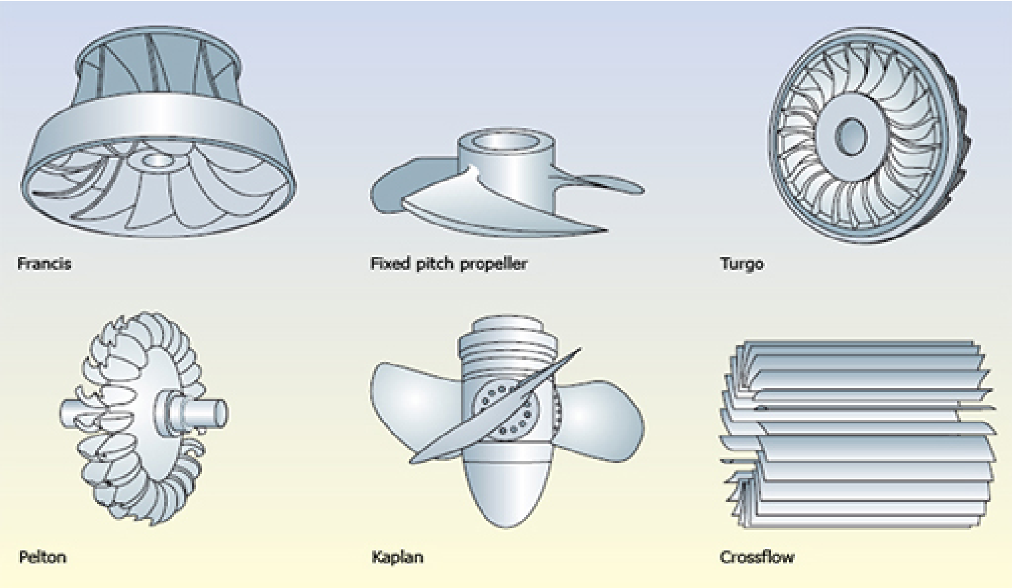


Figure 9: *six basic types of turbine commonly in use*

Turbines or runners can be mounted horizontally or vertically. The choice and type of mounting in many instances is determined by the location, access to pipe work, water head, flow rate and discharge water race characteristics.

A higher water head generally restricts the choice of turbine to being either a Turgo or Pelton (vertical orientation). Lower heads and higher flows suit the Francis or Kaplan types (horizontal orientation).

Turgo and Pelton turbines

Turgo and Pelton turbines have a series of cups mounted on a central hub.

High pressure jets of water are then directed at these cups.

The ‘Impulse’ of the cup is to ‘get out of the way’ from the force or high-pressure jet of water and so it spins - hence this type of turbine is called an impulse turbine.

Typically, the jets are located at 90° around the turbine, and it is possible to have up to four jets. More jets greatly increase the efficiency of the system.

Figure 11: *a typical one-jet Turgo turbine*

The Turgo and Pelton types are generally reserved for high pressure scenarios, where the source of water is located some distance away from the turbine, and the connection between the two is via a 3 or 4-inch (75 -100mm) polyethylene or PVC pipe.

***Figure 12**: typical Pelton turbines and their notched cups.*

Using the power spout reference table (see the ‘power spout’ or ‘eco-innovation’ websites where some of this material has been sourced from), a Pelton turbine will be more suitable for a head range of 3 – 130 m at a flow rate of 0.1 – 10 l/s.

A Turgo turbine is suitable for 2 – 30 m head at 8 – 15 l/s, and a propeller or Francis type is suitable for heads from 1 – 5 m at a flow rate of 14 – 55 l/s.

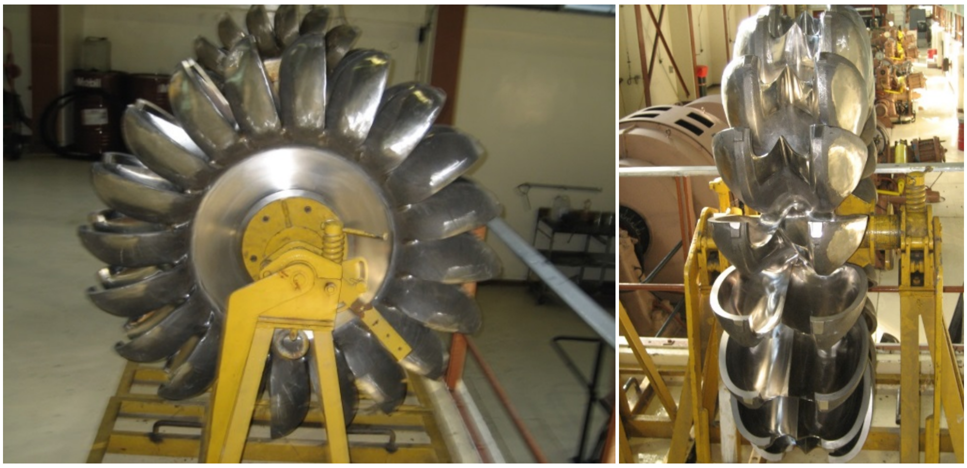


***Figure 13**: some typical Pelton turbines in common use*

Francis

The Francis turbine design features blades which are of a fixed curvature, with a top and bottom rim or lip. They have a hollow centre for the shaft, and the design allows the water to pass through the turbine and exit freely out the bottom.

Figure 14 shows the view from the draft tube of a Francis turbine.

***Figure 14**: typical Francis turbine.*

Crossflow

The crossflow turbine is suited for low head high flow rates. The key difference with this type of turbine is that a sheet of falling water is fed over the long blade or runner.

The falling water causes the turbine to rotate. A sectioned drawing of an Ossberger crossflow turbine is shown in figure 15.

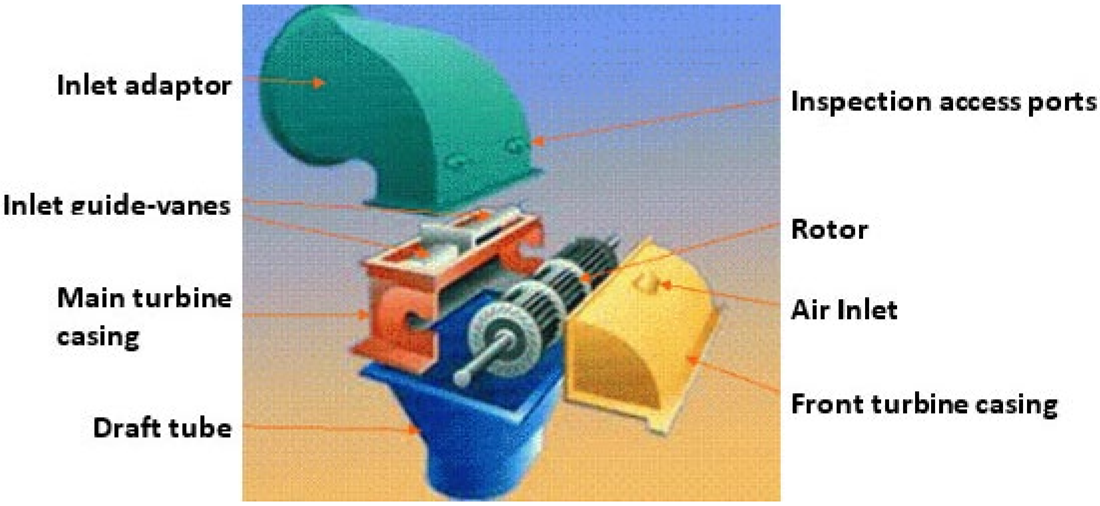


***Figure 15:** Crossflow turbine*

Electrical output

The electrical energy generated can be in the form of extra low voltage DC, typically 24V DC, or other voltage such as 230V AC, depending on the requirements for the scheme.

DC generators are a common choice for micro hydro schemes. The DC can be used directly, or to charge batteries for use later. For AC generation, the electricity generated is fed to a controller of some type, which regulates the output voltage and the frequency.

A grid tied inverter is an option if the customer wishes to tie the system to the grid, although most micro hydro systems tend not to be grid tied.

The alternator

For many of these smaller systems, the runner or turbine is connected to a central shaft which connects directly to the alternator.

In many cases, to keep the cost down, an induction motor is reconfigured to act as the alternator in conjunction with a suitable controller (which is often known as an AVR - Automatic Voltage Regulator).

Depending on the turbine speed, a gearbox may be required to produce optimum shaft speed for the alternator. This is to achieve the maximum power output and/or the correct frequency.

In addition, there can be a control on the water fed to the turbine. As the load varies, the water flow to the turbine is also varied to compensate, either up or down.

Diversion load control can also be used to keep a constant load on the alternator when water control is limited. It is a series of dummy loads which operate automatically at set load points, to regulate the system.

Open circuit voltage

The open circuit voltage of the alternator is important to know as this may be up to three times the on-load voltage. This could, if connected to the controller or inverter system, cause it to fail as the voltage rating of the generator/alternator exceeds that of the controller's acceptable input level.

During installation and commissioning, it is a simple matter to carefully, with reference to appropriate safety precautions, measure the open circuit voltage of the turbine at full flow rate.

Isolation

As with any plumbing and electrical system, there is a need for isolators for both the electricity and the water supply.

> The higher the resistivity a material has, the more it "resists" current flow and the better insulator it is.

If the generator output is DC, the electrical isolator and control gear needs to be DC rated.

Shutting off the water may be able to be achieved using an isolating valve or water gate. If the flow of water cannot be shut off, it may need to be able to be diverted using a water bypass system.

Suitability, advantages and disadvantages of Micro-hydro systems

- Can be designed to provide electricity generation 24 hours per day
- Is non-polluting
- Generates no carbon emissions
- Good efficiency
- Generally, requires little maintenance as it has few moving parts – the main issue is normally having to replace the alternator brushes and clearing the waterway.

Environmental impact:

- Other users downstream
- Plant life and wildlife in and beside the water
- Stability of the land through excavation

Sustainability:

- Sustainable when there is a reasonably continuous water supply
- Seasonal rainfall will vary water flow
- Snow and ice melt in the mountains will vary water flow
- Cycles of flooding or drought will impact on water flow
- Blockages higher up the water source will impact on water flow
- Medium to high initial cost

Construction of system:

- Requires licensed professionals
- Subject to planning and resource consent
- should be installed as close as possible to the electricity supply or storage system, to reduce line power losses
- May require construction of a reservoir to maintain water flow
- Must withstand the water loads
- Must have protection from impact, particularly for the less solid pipework
- Must incorporate a means of restricting the natural outward flow of water to build up reserve capacity
- must incorporate a bypass overflow in case of flooding of the reservoir

Disassembly of system:

- Need access to equipment in awkward places and near flowing water
- May have buried water pipes
- May need water diversion method to decommission system

General disadvantages of micro-hydro systems:

- Has specific site requirements that are not commonly available
- Can be noisy
- Subject to planning and resource consent
- May need regular cleaning of the filter, depending on the amount of debris in the water supply

UPS technology

Definition

Ohms law	The current flowing in a circuit is directly proportional to the applied voltage, and inversely proportional to the resistance of the circuit.

UPS stands for Uninterruptible/Uninterrupted Power Supply. A UPS system is used in installations where the loss of power would adversely affect the operation of things like plant, computers/servers or life support systems.

A UPS will operate to run a load during a complete loss of supply (blackout) and also in times of power problems such as too high a supply voltage, too low supply voltage (brownout) and poor-quality supply frequency situations.

A UPS has batteries and all the elements of a GTI integrated into it. They are designed to provide a source of power for critical plant for as long as the batteries last.

UPS Operation

Under normal mains-on operation, a UPS (depending on its type) will just sit between the mains and the critical load and filter out any 'nasty glitches or surges' in the mains supply, and trickle charge its batteries at the same time.

A UPS will sense a loss of the mains incoming power supply, start supplying the load via its battery and inverter circuit and 'beep' to warn of the power supply problem. If a PC is connected, some UPSs will also notify the PC or server via software as well.

This means that the PC operator has a period of time that the UPS will keep the computer or equipment going. This is so the user has time to save their work and shut down the computer safely before the UPS power supply runs out. This is preferable to just going 'black' when the power goes out.

A typical battery backup supply time for a UPS may be 10 minutes with a newer UPS, or 3-5 minutes on an older UPS where the batteries are not as good as they used to be.

Larger UPS systems can be designed to provide power to keep critical power supplies going for longer periods if required.

A good example of where large UPS systems are common is in hospitals to keep critical systems going in the event of a power failure - until backup generators start up.

Types of UPS

There are two main types of UPS system:

1) Off-line
2) On-line

The off-line UPS

An off-line system is shown in Figure 16. It is connected in parallel with the power supply. It is autonomous (self-sufficient), using the capacity of its battery upon loss of the AC power supply. Off-line units are normally of low rating (<3 kVA).

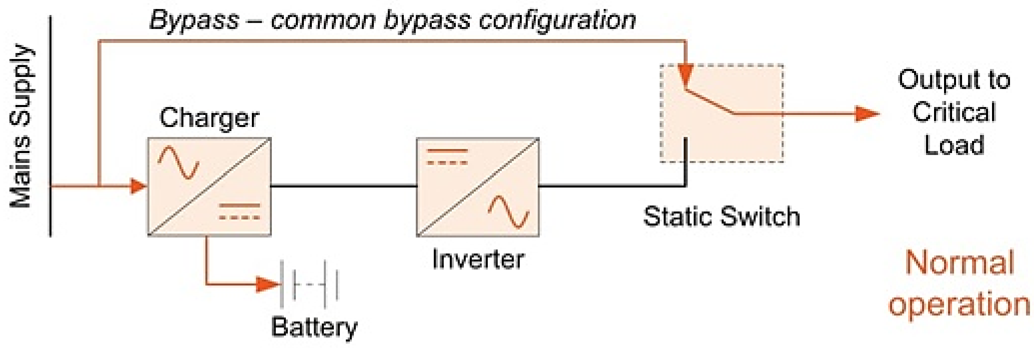


Figure 16 *Off-line UPS system*

During normal mains-on operation, a filter improves the quality of the power output supplied to the load and the voltage is also regulated to a constant and correct value by the filter unit.

If the electrical supply is completely lost (or the voltage rises/falls beyond its set tolerance limits), the UPS backup power circuit connects very quickly (in 10ms or less) and then the load is supplied from the batteries in the UPS.

With an off-line UPS:

The backup power is only connected to the load if the electricity supply is lost

When the normal power supply resumes, the contactor changes back to its original condition, the UPS is bypassed, and the battery then recharges back to its full capacity.

The most common use for such units is the supply to small PC's / servers / electronic equipment installations, e.g. cash registers.

The on-line UPS

On-line UPS systems (Figure 17) are connected directly between the power supply and the load and uses a double conversion method so that the inverter is always running. They also have autonomous capability, the length of time of which is determined by the battery capacity and size of the load.

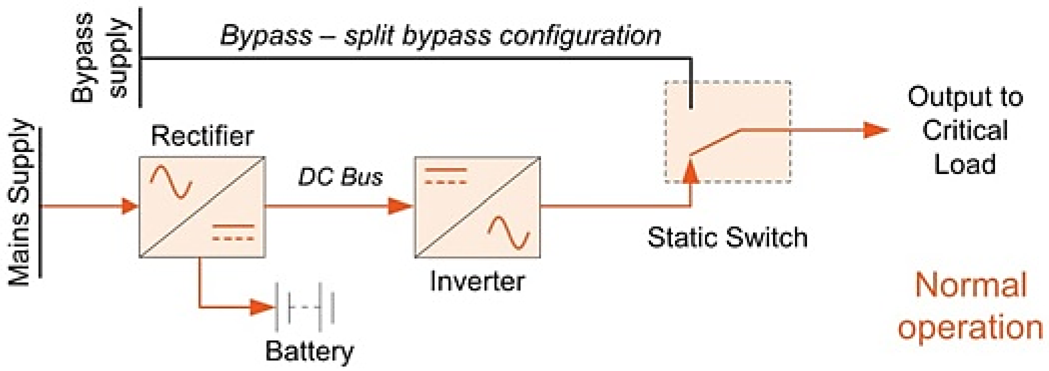


***Figure 17** On-line UPS system*

An on-line UPS uses a double conversion method so that the inverter is always running

The load current is supplied by the UPS all the time and the UPS output is clean, pure AC and stable regardless of the condition of the supply.

If the incoming power supply is lost, the UPS just carries on supplying the load without interruption. The battery continues to supply the UPS but is no longer being replenished by the lost incoming power supply.

This system is equally suitable for small loads (< 3 kVA) and up to several MVA.

Galvanic isolation

Some UPSs provide galvanic isolation between the load and the grid. This is the electrical and physical isolation of the input circuit from the output circuit.

The reason is to prevent possible unwanted current flow especially between parts of an electrical installation that may have different earth potentials.

In summary the principal functions of a UPS are:

1. To provide a filter for HF (high frequency) mains parasites, surges and brownouts, etc.
2. To maintain an uninterrupted source of power to a critical load in the event of a power supply failure.

The Skills Organisation
0508 SKILLS (0508 754 557)
skills.org.nz