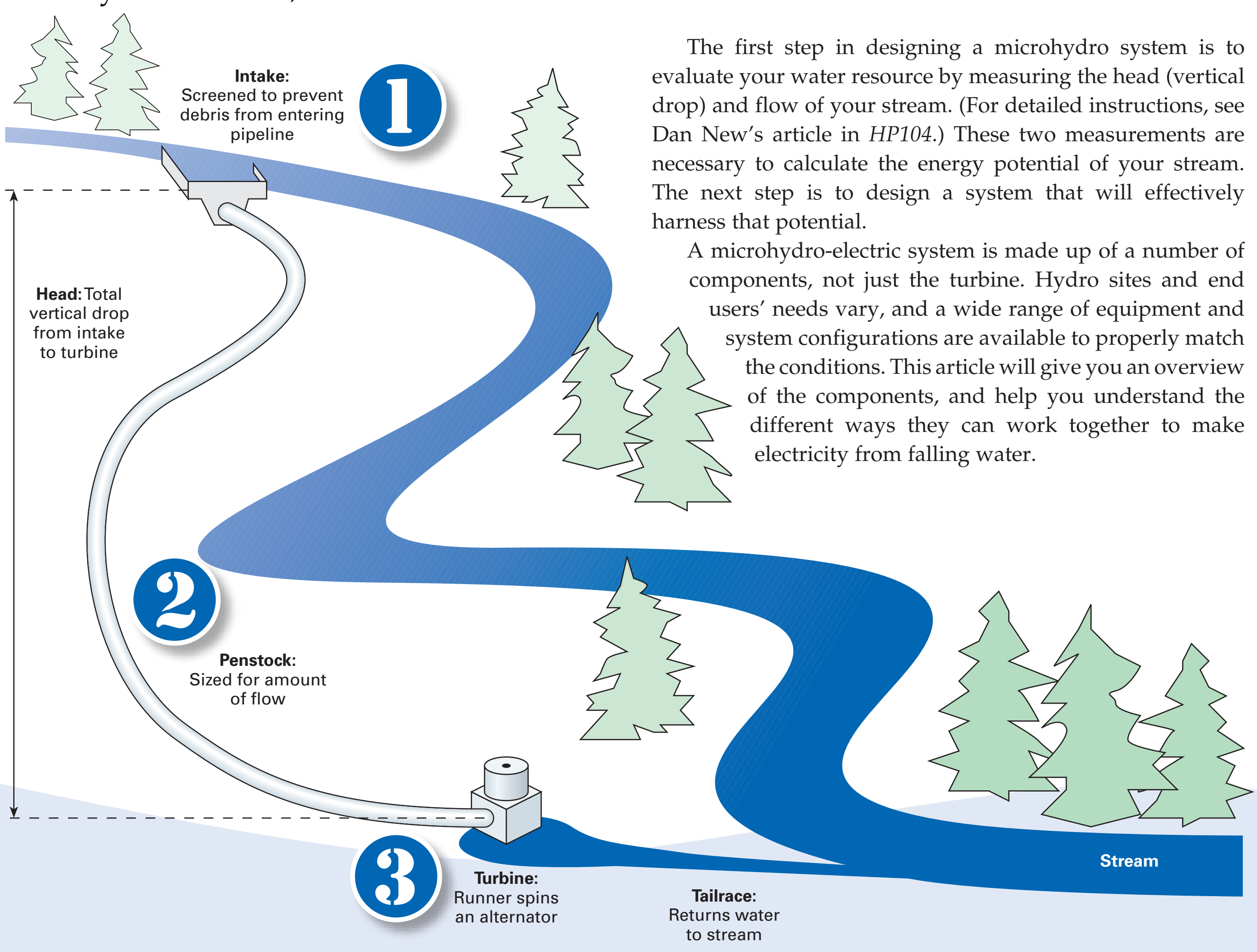
Microhydro-Electric Systems SIMPLIFIED

by Paul Cunningham & Ian Woofenden

If you have a suitable site, harnessing the energy in a stream or creek can be the most cost-effective way to make renewable electricity. Compared to the sun and wind's variability, a stream's flow is relatively consistent, making microhydro-electric system output the most predictable of all the renewable energy (RE) electrical systems. Hydro resources are also the most site specific, since your property must have a usable water source. If you are one of the lucky few with a stream running down your hillside, it's the resource to assess first.



The first step in designing a microhydro system is to evaluate your water resource by measuring the head (vertical drop) and flow of your stream. (For detailed instructions, see Dan New's article in *HP104*.) These two measurements are necessary to calculate the energy potential of your stream. The next step is to design a system that will effectively harness that potential.

A microhydro-electric system is made up of a number of components, not just the turbine. Hydro sites and end users' needs vary, and a wide range of equipment and system configurations are available to properly match the conditions. This article will give you an overview of the components, and help you understand the different ways they can work together to make electricity from falling water.

1 Intake *AKA: Screen, diversion, impoundment*

Intakes can be as simple as a screened box submerged in the watercourse, or they can involve a complete damming of the stream. The goal is to divert debris- and air-free water into a pipeline. Effectively getting the water into the system's pipeline is a critical issue that often does not get enough attention. Poorly designed intakes often become the focus of maintenance and repair efforts for hydro-electric systems.

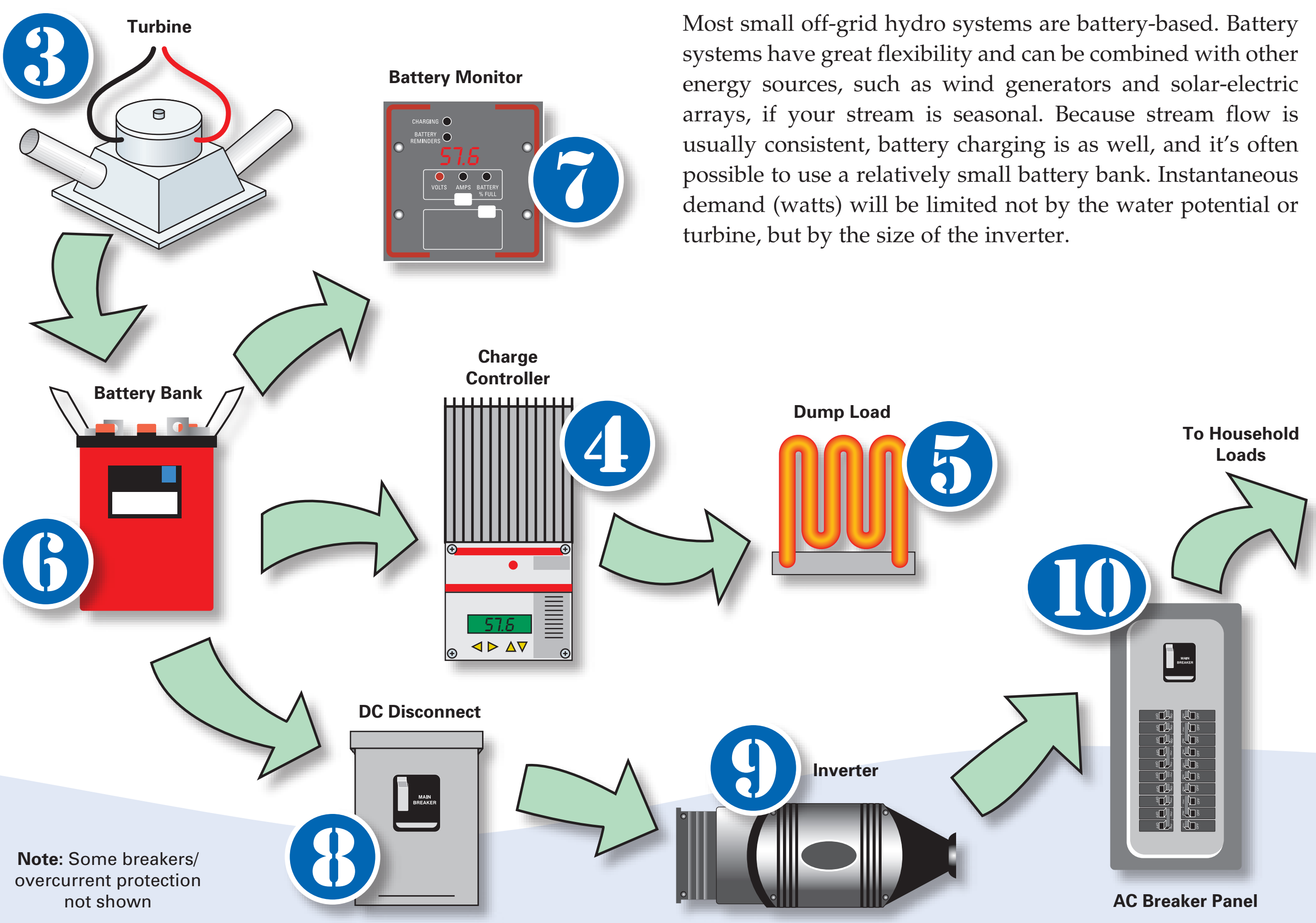
A large pool of water at the intake will not increase the output of the turbine, nor will it likely provide useful storage, but it will allow the water to calm so debris can sink or float. An intake that is above the bottom of the pool, but below the surface, will avoid the grit on the stream bottom and most of the floating debris on top. Another way to remove debris is to direct the water over a sloped screen. The turbine's water falls through, and debris passes with the overflow water.

2 Pipeline *AKA: Penstock*

Most hydro turbines require at least a short run of pipe to bring the water to the machine, and some turbines require piping to move water away from it. The length can vary widely depending on the distance between the source and the turbine. The pipeline's diameter may range from 1 inch to 1 foot or more, and must be large enough to handle the design flow. Losses due to friction need to be minimized to maximize the energy available for conversion into electricity. Plastic in the form of polyethylene or PVC is the usual choice for home-scale systems. Burying the pipeline is desirable to prevent freezing in extremely cold climates, to keep the pipe from shifting, and to protect it from damage (cows, bears, etc.) and ultraviolet (UV) light degradation.

OFF-GRID BATTERY-BASED HYDRO-ELECTRIC SYSTEM

Most small off-grid hydro systems are battery-based. Battery systems have great flexibility and can be combined with other energy sources, such as wind generators and solar-electric arrays, if your stream is seasonal. Because stream flow is usually consistent, battery charging is as well, and it's often possible to use a relatively small battery bank. Instantaneous demand (watts) will be limited not by the water potential or turbine, but by the size of the inverter.

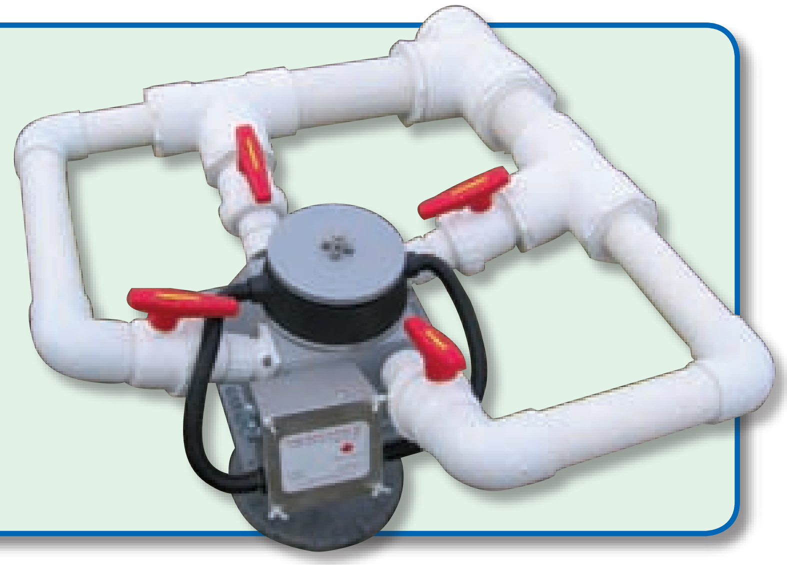


Note: Some breakers/ overcurrent protection not shown

3 Turbine *AKA: Waterwheel*

The turbine converts the energy in the water into electricity. Many types of turbines are available, so it is important to match the machine to the site's conditions of head and flow.

In *impulse* turbines, the water is routed through nozzles that direct the water at some type of runner or wheel (Pelton and Turgo are two common types). *Reaction* turbines are propeller machines and centrifugal pumps used as turbines, where the runner is submerged within a closed housing. With either turbine type, the energy of the falling water is converted into rotary motion in the runner's shaft. This shaft is coupled directly or belted to either a permanent magnet alternator, or a "synchronous" or induction AC generator.



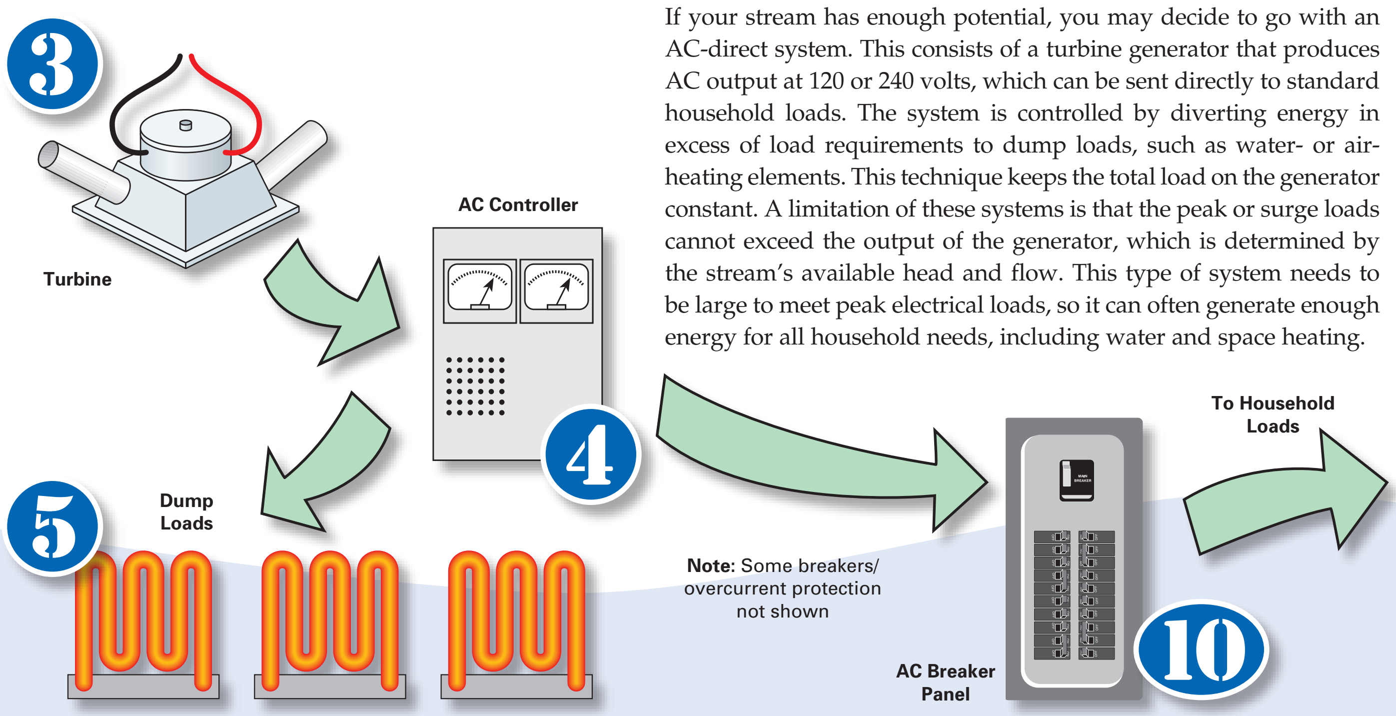
4 Controls *AKA: Charge controller, controller, regulator*

The function of a charge controller in a hydro system is equivalent to turning on a load to absorb excess energy. Battery-based microhydro systems require charge controllers to prevent overcharging the batteries. Controllers generally send excess energy to a secondary (dump) load, such as an air or water heater. Unlike a solar-electric controller, a microhydro system controller does not disconnect the turbine from the batteries. This could create voltages that are higher than some components can withstand, or cause the turbine to overspeed, which could result in dangerous and damaging overvoltages.

Off-grid, batteryless AC-direct microhydro systems need controls too. A load–control governor monitors the voltage or frequency of the system, and keeps the generator correctly loaded, turning dump-load capacity on and off as the load pattern changes, or mechanically deflects water away from the runner. Grid-tied batteryless AC and DC systems also need controls to protect the system if the utility grid fails.

OFF-GRID BATTERYLESS HYDRO-ELECTRIC SYSTEM

If your stream has enough potential, you may decide to go with an AC-direct system. This consists of a turbine generator that produces AC output at 120 or 240 volts, which can be sent directly to standard household loads. The system is controlled by diverting energy in excess of load requirements to dump loads, such as water- or air-heating elements. This technique keeps the total load on the generator constant. A limitation of these systems is that the peak or surge loads cannot exceed the output of the generator, which is determined by the stream's available head and flow. This type of system needs to be large to meet peak electrical loads, so it can often generate enough energy for all household needs, including water and space heating.



5 Dump Load

AKA: Diversion load, shunt load

A dump load is an electrical resistance heater that must be sized to handle the full generating capacity of the microhydro turbine. Dump loads can be air or water heaters, and are activated by the charge controller whenever the batteries or the grid cannot accept the energy being produced, to prevent damage to the system. Excess energy is "shunted" to the dump load when necessary.

6 Battery Bank

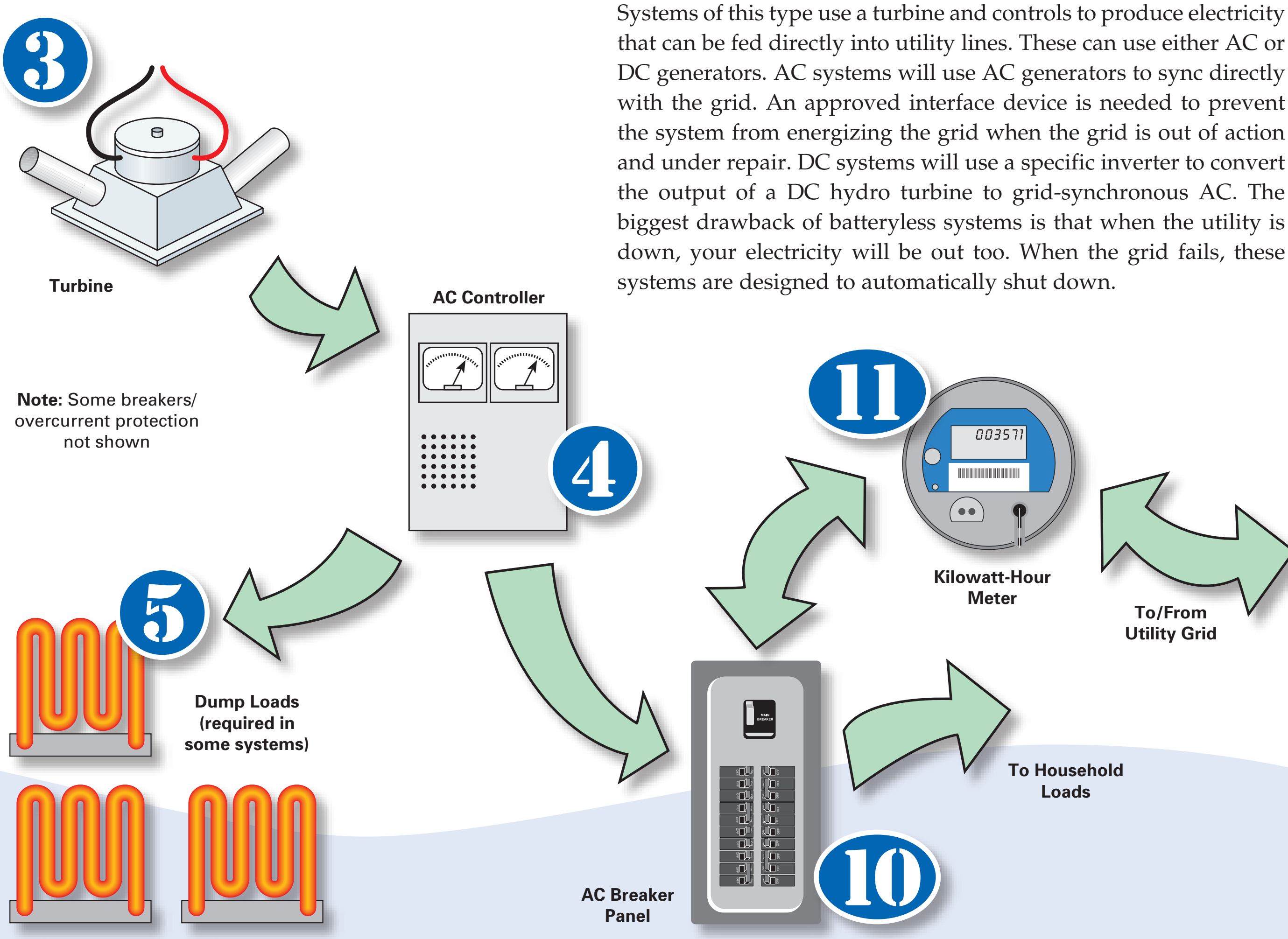
AKA: Storage battery

By using reversible chemical reactions, a battery bank provides a way to store surplus energy when more is being produced than consumed. When demand increases beyond what is generated, the batteries can be called on to release energy to keep your household loads operating.

A microhydro system is typically the most gentle of the RE systems on the batteries, since they do not often remain in a discharged state. The bank can also be smaller than for a wind or PV system. One or two days of storage is usually sufficient. Deep-cycle lead-acid batteries are typically used in these systems. They are cost effective and do not usually account for a large percentage of the system cost.

GRID-TIED BATTERYLESS HYDRO-ELECTRIC SYSTEM

Systems of this type use a turbine and controls to produce electricity that can be fed directly into utility lines. These can use either AC or DC generators. AC systems will use AC generators to sync directly with the grid. An approved interface device is needed to prevent the system from energizing the grid when the grid is out of action and under repair. DC systems will use a specific inverter to convert the output of a DC hydro turbine to grid-synchronous AC. The biggest drawback of batteryless systems is that when the utility is down, your electricity will be out too. When the grid fails, these systems are designed to automatically shut down.



7 Metering *AKA: Battery monitor, watt-hour meter, amp-hour meter*

System meters measure and display several different aspects of your microhydro-electric system's performance and status—tracking how full your battery bank is, how much electricity your turbine is producing or has produced, and how much electricity is being used. Operating your system without metering is like running your car without any gauges—although possible to do, it's always better to know how well the car is operating and how much fuel is in the tank.

8 Main DC Disconnect *AKA: Battery–inverter disconnect*

In battery-based systems, a disconnect between the batteries and inverter is required. This disconnect is typically a large, DC-rated breaker mounted in a sheet metal enclosure. It allows the inverter to be disconnected from the batteries for service, and protects the inverter-to-battery wiring against electrical faults.

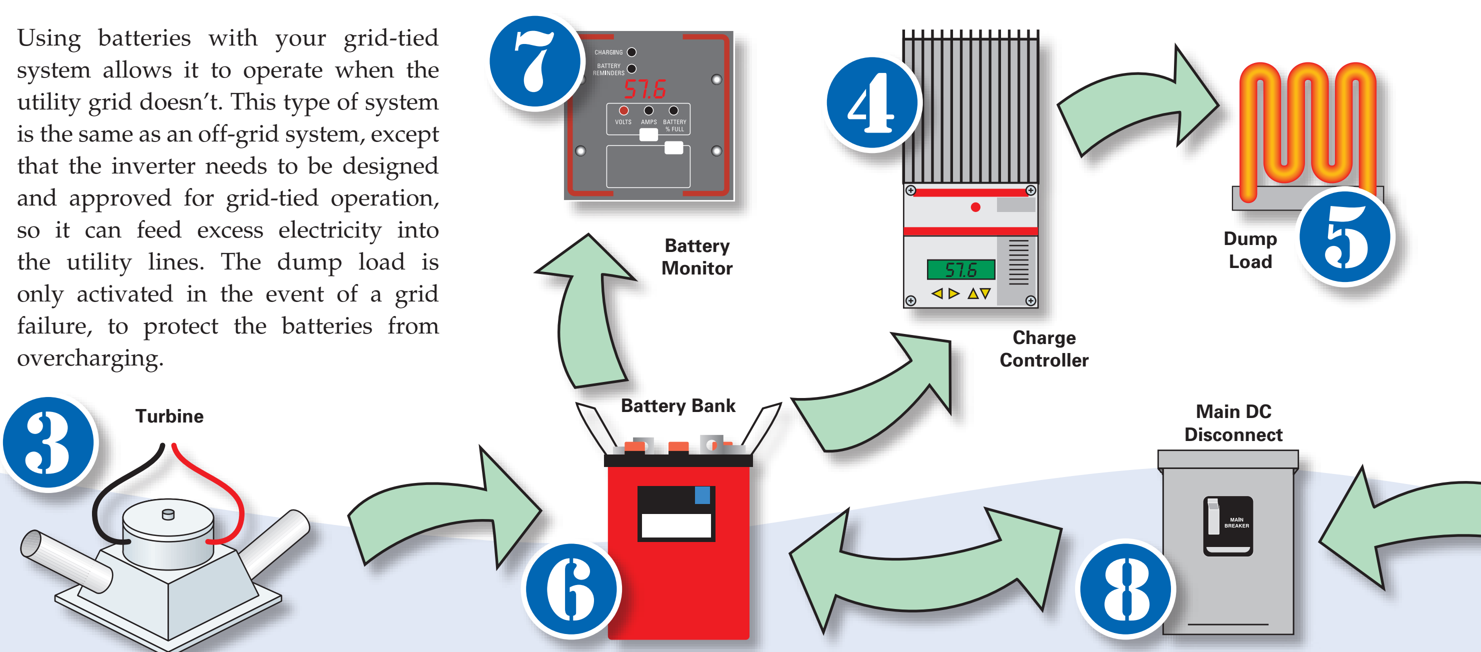
9 Inverter *AKA: DC-to-AC converter*

Inverters transform the DC electricity stored in your battery bank into AC electricity for powering household appliances. Grid-tied inverters synchronize the system's output with the utility's AC electricity, allowing the system to feed hydro-electricity to the utility grid. Battery-based inverters for off-grid or grid-tied systems often include a battery charger, which is capable of charging a battery bank from either the grid or a backup generator if your creek isn't flowing or your system is down for maintenance.

In rare cases, an inverter and battery bank are used with larger, off-grid AC-direct systems to increase power availability. The inverter uses the AC to charge the batteries, and synchronizes with the hydro-electric AC supply to supplement it when demand is greater than the output of the hydro generator.

GRID-TIED BATTERY-BASED HYDRO-ELECTRIC SYSTEM

Using batteries with your grid-tied system allows it to operate when the utility grid doesn't. This type of system is the same as an off-grid system, except that the inverter needs to be designed and approved for grid-tied operation, so it can feed excess electricity into the utility lines. The dump load is only activated in the event of a grid failure, to protect the batteries from overcharging.



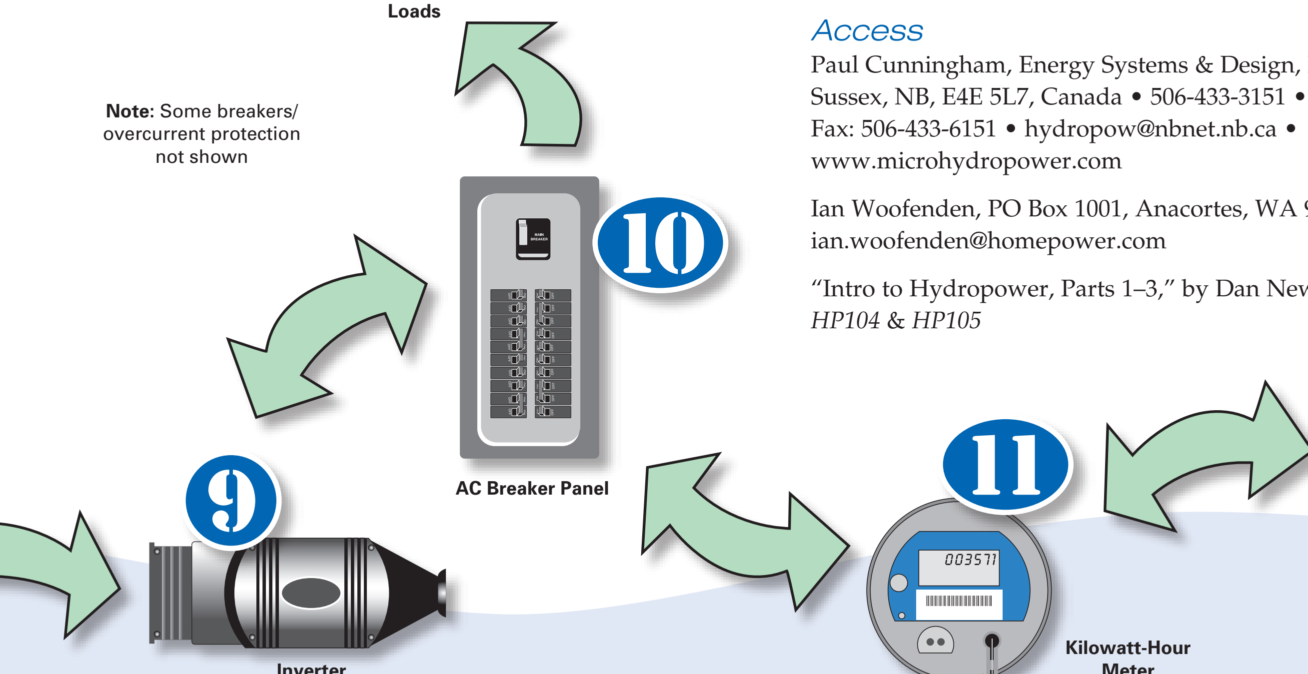
10 AC Breaker Panel *AKA: Mains panel, breaker box, service entrance*

The AC breaker panel, or mains panel, is the point at which all of a home's electrical wiring meets with the provider of the electricity, whether that's the grid or a microhydro-electric system. This wall-mounted panel or box is usually installed in a utility room, basement, garage, or on the exterior of a building. It contains a number of labeled circuit breakers that route electricity to the various rooms throughout a house. These breakers allow electricity to be disconnected for servicing, and also protect the building's wiring against electrical fires.

Just like the electrical circuits in your home or office, a grid-tied inverter's electrical output needs to be routed through an AC circuit breaker. This breaker is usually mounted inside the building's mains panel. It enables the inverter to be disconnected from either the grid or from electrical loads if servicing is necessary. The breaker also safeguards the circuit's electrical wiring.

11 Kilowatt-Hour Meter *AKA: KWH meter, utility meter*

Most homes with grid-tied microhydro-electric systems will have AC electricity both coming from and going to the utility grid. A multichannel KWH meter keeps track of how much grid electricity you're using and how much your RE system is producing. The utility company often provides intertie-capable meters at no cost.



Realize Your Potential

Hydro-electric systems have great potential, but several things can make using this technology difficult. Diverting the water in a stream or creek is likely subject to regulation by local authorities and may require seeking approval. You also may need to contend with droughts or floods. All hydro turbines have moving parts that require maintenance and periodic replacement. The most common maintenance chore is keeping debris out of the intake.

Despite the various challenges, most of the problems can be easily overcome. If installed correctly and properly maintained, a microhydro system can provide many years of service. The predictable and often ample output is the envy of those restricted to using only wind or solar electricity. As an owner of a microhydro system, you'll go to bed at night with the knowledge that while you are sleeping, your system is charging and will be ready for another day of energy use when you rise.

Access

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"Intro to Hydropower, Parts 1–3," by Dan New, *HP103*, *HP104* & *HP105*