Chapter 11

Energy management systems

"Automation does not need to be our enemy.
I think machines can make life
easier for men, if men do not let the
machines dominate them."

John F. Kennedy, US President 1961–1963.

Any off-grid system for pumping and cleaning water needs a control system to take care of the energy management. A solar PV unit or a wind turbine will produce electric energy independent of the required demand. An automatic control system will balance the power flow through the system. The energy production system includes not only the solar panel and the wind turbine; other components are inverters, batteries and charge controllers. The load consists of lighting, small household devices and low-power television sets as well as water pumps, disinfection lamps and desalination units. Their management must prioritise the demand side when the delivered power is not sufficiently high to provide any of the loads.

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11.1 THE ROLE OF THE ENERGY MANAGEMENT SYSTEM

The role of the energy management system (EMS) is discussed. Since there is more than one source of electric energy, the energy production must be controlled. Likewise, not all the energy requirements of the loads can always be satisfied. This requires some prioritising between the various loads that are to be controlled by the EMS. The EMS can be implemented in a simple PLC.

The solar PV and the wind turbine are the key producers of energy. If they deliver less than minimum power, then the battery storage will be discharged. If this energy is insufficient, then as a last resort a diesel generator can be started.

The inverters (see also Chapter 4.5) will convert the DC power from the solar panels into AC power, while the wind turbine inverter will convert the generator power into a frequency that is suitable for the loads. It should be noted that the inverter rating must be large enough to handle the total power of the load that will be running at any one time. It is usually recommended that the inverter size should be 25–30% bigger than the total power of the load. For motor and compressor loads the inverter size should be at least three times the capacity of those appliances to be able to handle current surge during start-ups.

The battery charger (Chapter 10) will ensure that the voltage and current to or from the battery storage are within permitted limits.

The various loads are defined in the next section. The management system will also direct the power flow both when the solar and wind production is higher than the load and when it is insufficient.

A detailed design has to account for the changes in the efficiencies of the components depending on the load and the solar radiation and wind availability. The efficiencies are different if the system is operating in a PV/wind-to-load mode, PV/wind-to-storage mode or storage-to-load mode.

11.2 THE LOADS

The loads will be organised according to their importance. If the produced electric power from the solar panels, the wind turbine and the batteries is not sufficient to satisfy all the load requirements then

some priority of the loads should be defined. The load with the highest priority (for example lighting) will be the last load to be shut down if energy production fails. The priority between the various loads will of course depend on the individual user. Naturally the water pump control is connected to the operation of the disinfection, desalination and the biological reactors.

The loads can be classified something like (see Figure 11.1):

- Lighting,
- Small appliances like radios, TV sets,
- Cooking facilities,
- Water pumps
- Disinfection lamps,
- Desalination unit,
- Biological water reclamation.

The energy management system will deliver available power to the loads according to the defined priority. Lighting, small appliances and cooking are probably the loads with highest priority.

Let us consider some operational modes and how to prioritise the loads:

(1) PV/wind power is greater than the required load.
   - Any excess power should be used wisely. If the batteries are not fully charged this ought to be the highest-priority load.
   - If the batteries are fully charged, then the excess power can be used to pump or treat water. Water serves as an energy storage, as described in 10.6.

(2) PV/wind power is not sufficient for the load requirements.
   - If there is sufficient storage capacity, then we are back to case 1.
   - If added storage power does not satisfy the load requirement, then we must define priorities for the loads. Only the most important loads should be connected.
   - If the batteries have been discharged, then the storage turns into a load, most likely the load with highest priority. Other loads must be disconnected according to their priorities.

(3) PV/wind power is not sufficient for the load requirements and batteries are discharged. This ought to be an unusual condition. Here the traditional diesel generator can be used as a backup, as pointed out in 10.7.

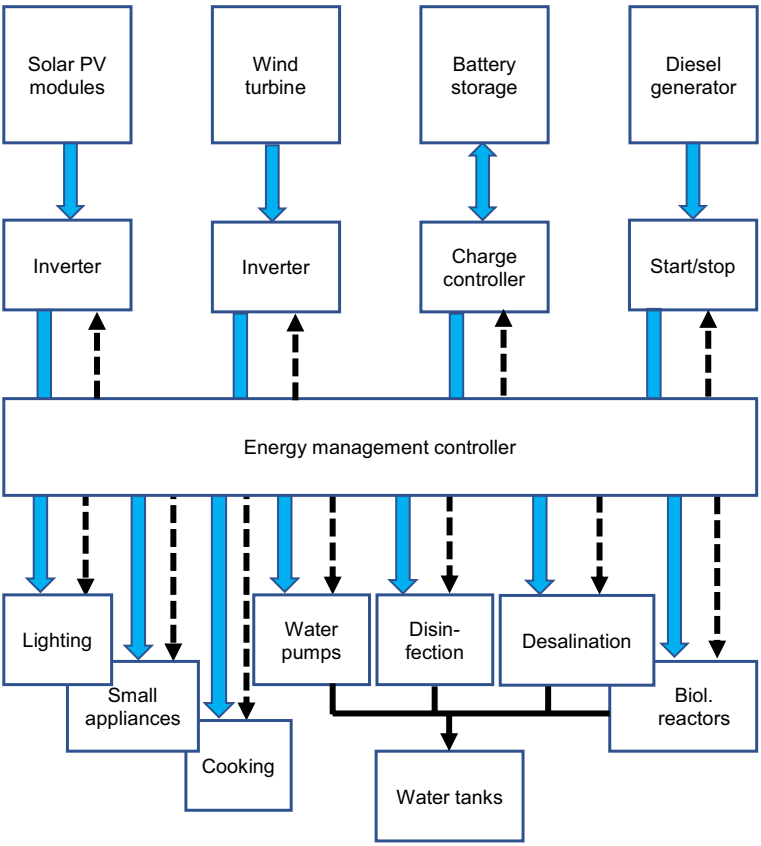

Figure 11.1 Block diagram of an energy management system for a combined solar PV and wind turbine system in a stand-alone operation. The production units are shown above the control system and the consuming devices are below the controller. The wide arrows indicate the energy flow through the system, while the broken arrows show the information and command flows.

It is apparent that energy management ought to take many operational modes into consideration. Naturally the user should not worry about the details. Still it is crucial to clearly explain to the user how the system prioritises its operations.

There are some issues to keep in mind with all installations of renewable energy:

- It is important not to confuse daylight hours with sun hours;
- Do not underestimate the power needed for the various loads. For example, a machine tool may require high power over short time intervals;
- When considering the load priorities, start with the small consumptions, but consider carefully the consequences of not being able to deliver power to a specific load;
- Water tanks can easily be supplied with a level detector so that the pump will be switched off when the tank is full;
- Solar panels are designed to run at certain temperatures. Remember that the capacity of the solar panel depends on temperature;
- Of course, a solar panel installation must be done properly, otherwise the calculated energy output may be quite wrong.

Some basic instrumentations for the water production system are:

- Pressure sensors;
- Level indicators for storage tanks;
- Temperature.

In more advanced installations the feed pump and high-pressure pump may be supplied with variable speed control, but fixed-speed pumps are more common.