Turbines

- Water under pressure contains energy.
- Turbines convert the energy in water into rotating mechanical energy.
- Impulse turbines convert the kinetic energy of a jet of water to mechanical energy.
- Reaction turbines convert potential energy in pressurized water to mechanical energy.

Selected References

- Microhydro by Scott Davis
- Microhydro Design Manual by Adam Harvey
- Waterturbine.com for picohydro units
- BC Hydro Handbook
- Idaho National Labs

Impulse Turbines

- Tolerate sand.
- Easy to fabricate.
- Efficient at wide a range of head and flow.
- A nozzle converts pressurised water into a high-speed jet of water.

Pelton Turbine – Canyon Industries

Impulse Turbi

- Pelton
  - Low Flow
  - Medium to High Head
- Turgo
  - Medium Flow
  - Medium to High Head
- Crossflow
  - High Flow
  - Low to Medium Head

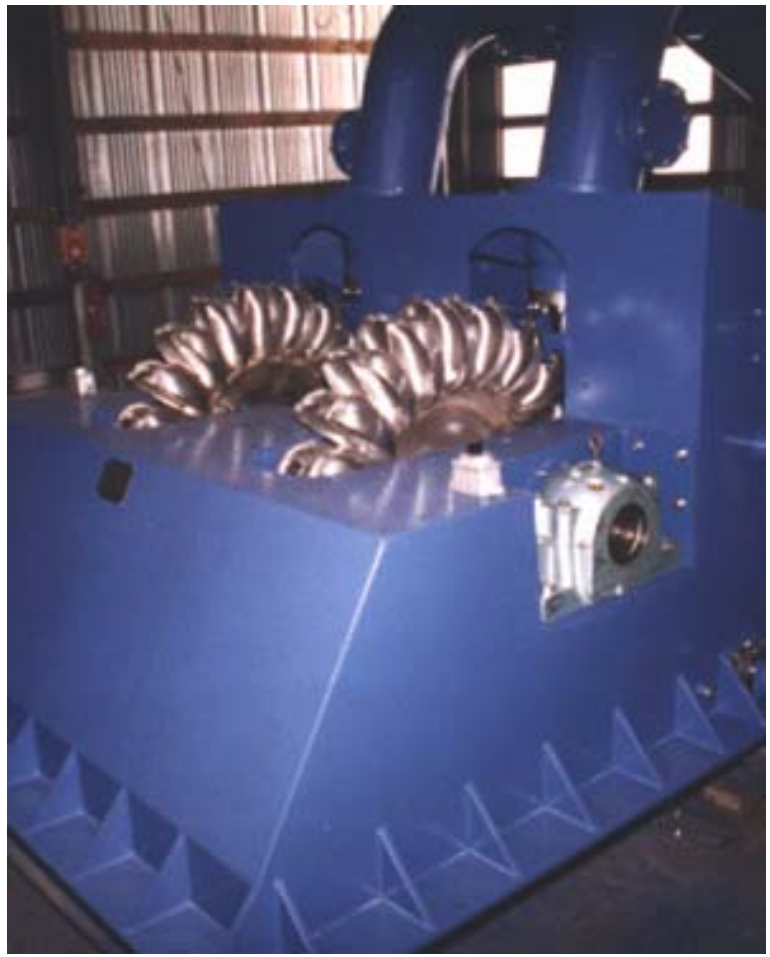
Pelton Turbines

- At least one jet of water strike the buckets at atmospheric pressure.
- Maximum jet diameter about 1/3 bucket width.
- More jets increase flow and are used at low head.

0.61m Pelton – Dependable Turbines Ltd.

Multiple Runners

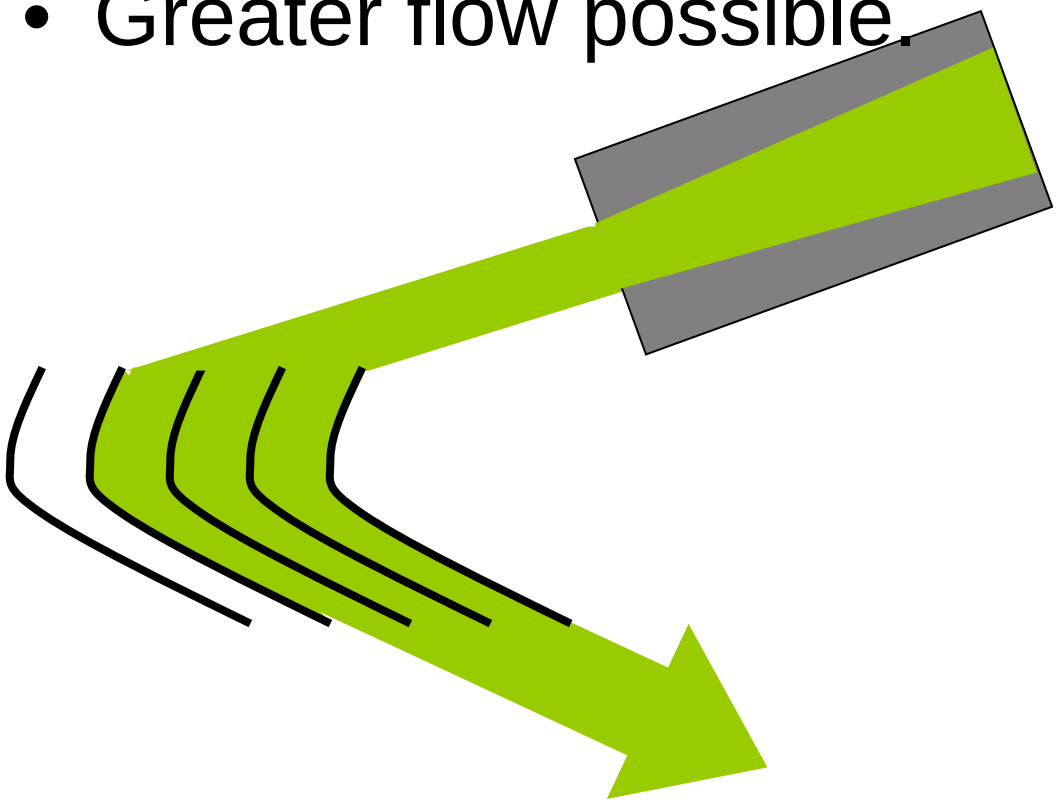
- Advantages
  - Greater Flow
  - Flow control
- May be placed in the same housing or separate housings.



1000 kW Twin Pelton – Canyon Industries

Turgo Turbines

- Similar to Pelton runner, but a more complex blade design.
- Greater flow possible.

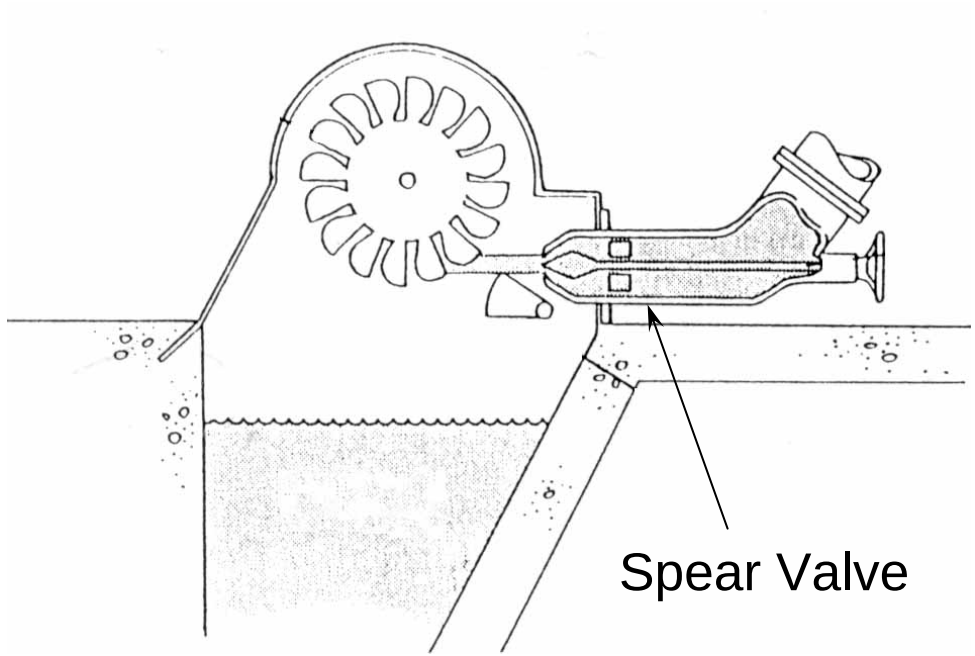


Multiple nozzles

- Four to six nozzles may be added before splash interference occurs.
- Power output is proportional to the number of nozzles.

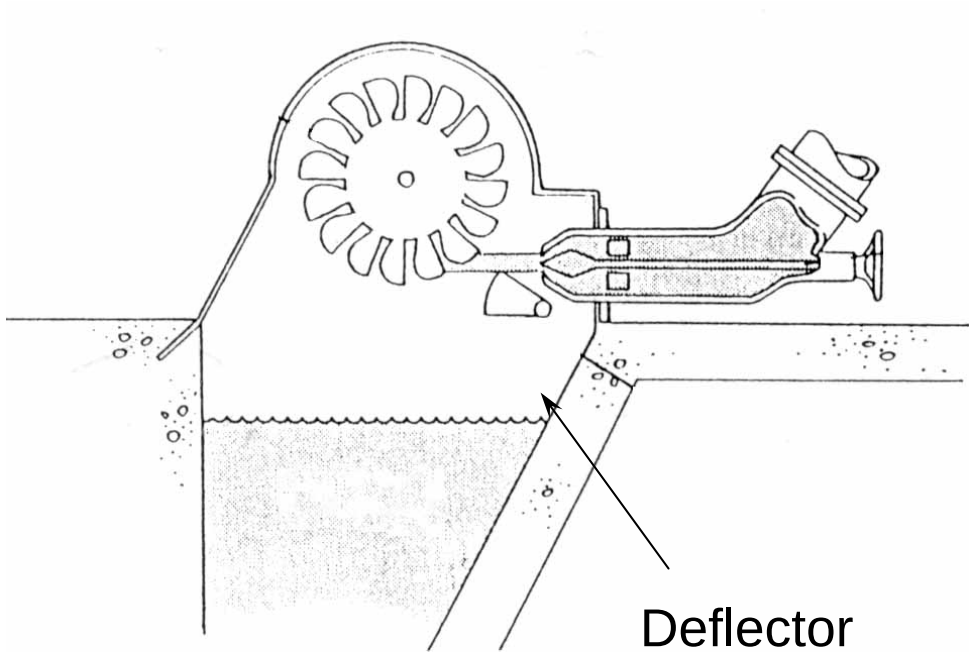
Spear Valves

- A spear valve changes the nozzle size without stopping the turbine.
- Expensive.



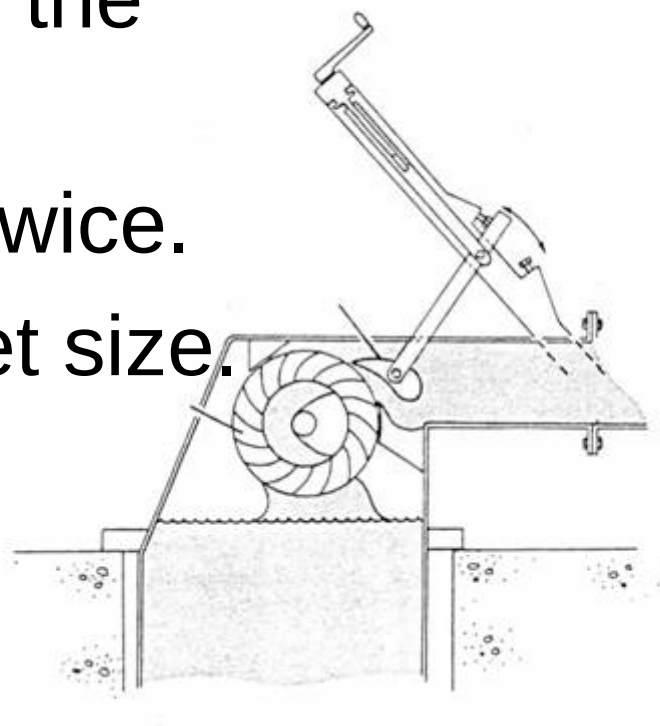
Deflectors

- **Deflectors can be used to vary flow.**
- **Usually used for emergency stop without causing water hammer.**



Crossflow Turbines

- Banki or Mitchell turbine.
- Shaft oriented horizontally.
- Rectangular nozzle forms the jet.
- Water strikes the blades twice.
- A control vane changes jet size.



Crossflow Turbines

- A draft tube increases head.
- Longer blades increase flow and power.
- Part flow is achieved with partition vanes.

40 kW Crossflow – Canyon Industries

Impulse Turbine Manufacturers

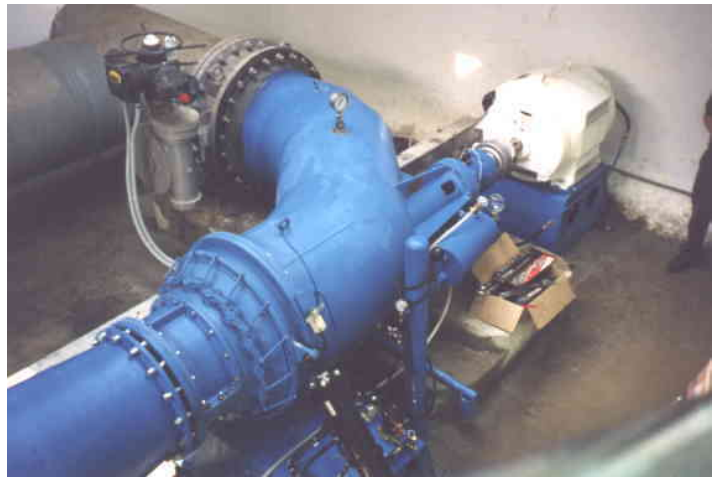
- Harris Hydro - Pelton
- ES&D - Turgo
- Platypus - Pelton
- Canyon – Pelton
- Dependable – Pelton, Turgo
- Tamar Designs Pty. Ltd. – Pelton, Turgo
- HTS - Crossflow

Reaction Turbines

- Expensive blade manufacture.
- High flow rates.
- More site specific than impulse.
- Uses pressure drop across turbine.
- Cavitation must be avoided.
- High turbine speed at low head.

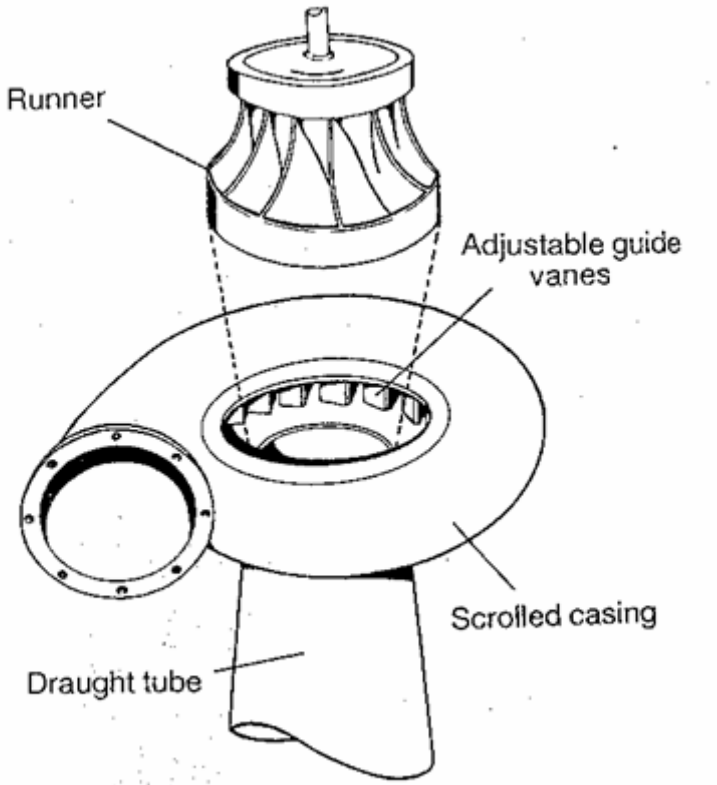
Reaction

- Francis
  - Medium Head
- Propeller and Kaplan
  - Low Head
- Pump as Turbine
  - Medium Head



Francis

- Guide vanes may be adjusted by governor.
- Efficiency decreases as flow decreases.
- Water flow is radial from exterior to interior.
- Flow changes gradually from radial to axial.



Propeller Turbine

- Similar to ships propeller.
- Has guide vanes similar to Francis Turbine.
- A Kaplan Turbine has variable pitch blades.
- Part flow efficiency is poor.

Propeller Turbine – Dependable Turbines Ltd.

Pump as Turbine

- Centrifugal pumps may be used as turbines.
- Low cost due to mass production.
- No direct correlation between pump characteristics and turbine characteristics.
- Flow is fixed for a given head.
- Some manufacturers have tested their pumps as turbines.
- Good for grid-tie with induction motors.

Turbine application

Turbine	Head (pressure)		
	High (30m +)	Medium	Low (<10 m)
Impulse	Pelton Turgo	Crossflow Pelton Turgo	Crossflow
Reaction	-	Francis Pump	Propeller Darius

Other Turbines

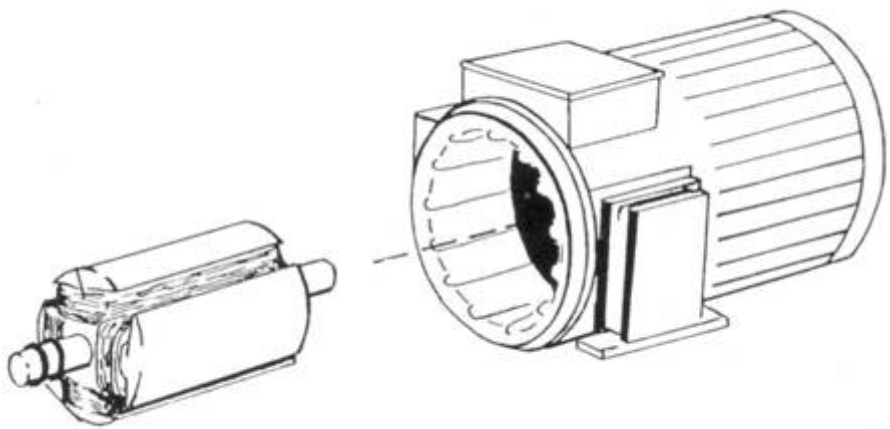
- Aquair
- Gorlov Helical Turbine
- Water Wheels
  - Overshot
  - Undershot

Generators

- Types of Generators
  - Synchronous
  - Induction
  - DC generators
- Characteristics of Generators
- Selecting a Generator
- Voltage Regulation
- Governing (speed and frequency)
  - Mechanical
  - Electronic

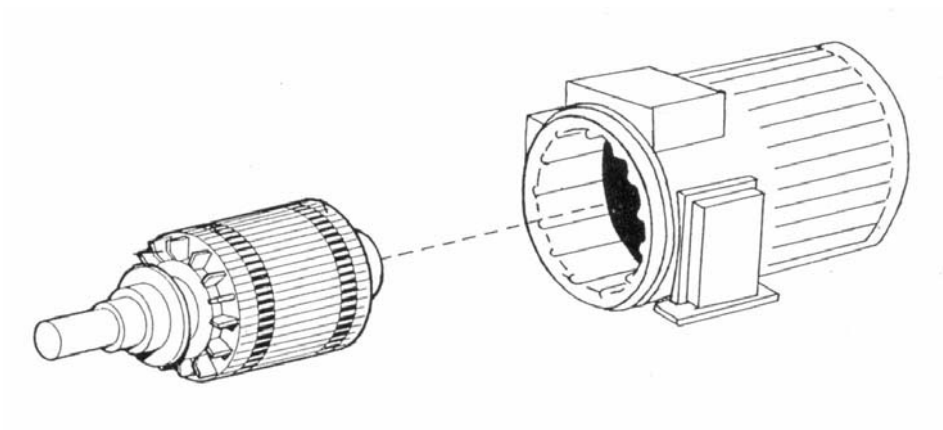
Synchronous Generator

- Used in almost all stand-alone applications.
- Single phase used up to 10 kW.
- Most three phase are smaller than equivalent single



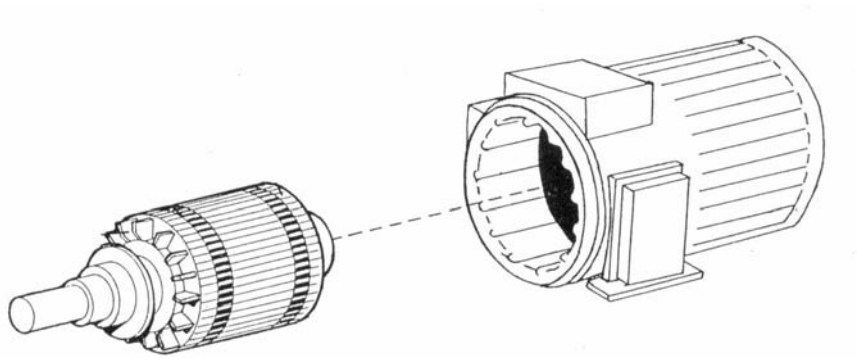
Induction Generator

- Just an induction motor with negative slip.
- Used most often with grid-tie systems.
- Used by some for battery based systems.



Induction Generator

- Simple and robust.
- Readily available and inexpensive.
- Requires external excitation from the grid or from capacitors.
- Control is more difficult, especially for inductive loads.
- It requires frequency controls if not tied to the grid



DC Alternator

- Produces rectified alternating current.
- Readily available.
- Easy to service.
- A rheostat controls excitation.

Selecting a Generator

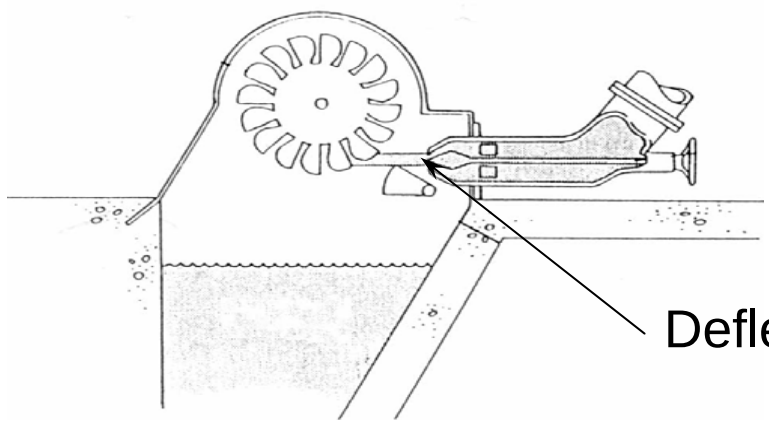
- Type (synchronous, induction)
  - Stand-alone or grid-tie
- Single or Three phase
  - Loads
  - Generator size
- Voltage
  - Loads
  - Transmission
- RPM
  - Size and availability
- Size

Selecting a Generator

- A larger generator:
  - makes up for transmission losses
  - is required for reactive loads.
- An oversized generator
  - is more efficient.
  - allows for future expansion.
  - runs cooler.
- Centripetal forces during over-speed can damage generators.

Mechanical Governing

- Mechanical flow control is not common.
  - More expensive
  - Slower reacting
  - Fine for very large systems
- Mechanical deflectors are used for emergency shut down.



Electronic Governing

- Frequency governing is used for synchronous generators.
- Voltage governing is used for induction generators
- Diversion Loads
  - A load must always be present.
  - Water heating or air heating.
- Diversion loads may be useful loads.

Diversion Controllers

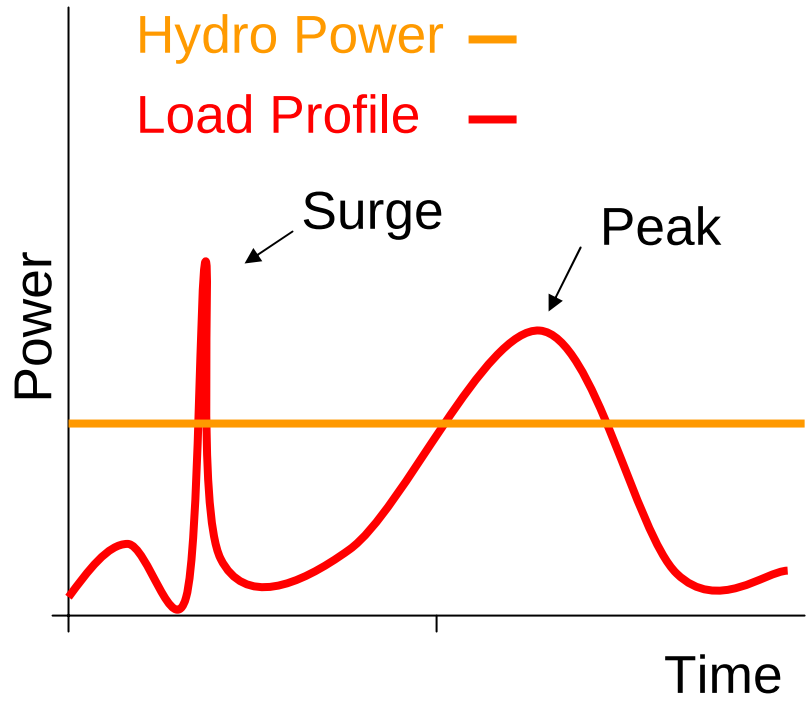
- Thomson and Howe Energy Systems Digital Load Control Governor for AC.
- Thyristor based.
- Does cause line noise.

Batteries and Charge Control

- Purpose of Batteries
- Storage Battery Terms
- Lead Acid Batteries
  - Battery Voltage
  - Battery Capacity
  - Battery Cycle Life and Float Life
- Battery Charge Control
  - Voltage set points
  - Three stage charging
  - Equalization
  - Temperature Compensation

Batteries Provide

- Peak capacity
  - Simultaneous loads
- Surge capacity
  - Motor starting



Diversion Charge Controllers

- Prevent battery overcharging.
- Manufacturers:
  - Xantrex/Trace C-60/40/35
  - Applied Power Enermaxer III
  - Solar Converters LDR.

Diversion Loads

- Heating elements
  - Water
  - Air
- Light bulbs can burn out.

Duty Ratings and Surge

- Inverters have both a **Continuous** rating and a **Surge** rating.
- Surge represents motor starting ability.
- Surge ability depends on input voltage.
- In general, a low frequency inverter has better surge characteristics.