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.
Impulse Turbines

- 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.
Multiple Runners

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

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<th>Turbine</th>
<th>Head (pressure)</th>
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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.