Micro Hydro Power

LECTURE 8:

ELECTROMECHANICAL COMPONENTS OF MICRO HYDRO

compliled by Er. Bibek Dahal

Speed Governing

- A governor or a speed limiter is a device used to measure and regulate the speed of a machine, such as a engine
- The speed governor in hydropower is a device which is used to keep the turbine speed constant because the speed fluctuates if there are changes in the load, water head or flow
- When electricity is generated at an isolated site by a synchronous generator, its frequency is determined by the speed of the generator and the number of poles
- If the speed changes the frequency generated also changes
- Electrical equipment is designed to operate at a specific voltage and frequency and if operated at other than the design values can cause serious damage
- Therefore some control of generator speed is therefore needed and generator speed depends on turbine speed thus speed of turbine is regulated by governing device

Why speed governing?

- As discussed earlier speed governing is mainly to maintain or regulate the voltage and frequency of an electrical system
- In order to specify a governor, it is necessary to find out the tolerance of the end use machinery to variations in frequency and voltage
- Although most electrical equipment can tolerate up to +_ 10% voltage fluctuation, frequency is usually held much closer to the nominal figure
- The effects of such variations and the allowed limits are described in below

Electrical Loads

Heating

Heating loads are most tolerant of variations in supply. Frequency variations do not affect these loads at all. Under-voltage increases the life of heating elements but reduces heat output. Over-voltage can generate excess heat and cause the elements to burn out. For example, an over-voltage of 10% can cause an increase of 21% in heating output.

Lighting

Incandescent bulbs are not affected by frequency. Under-voltage decreases light output very sharply but significantly increases bulb life, unless there are significant fluctuations in supply voltage. On the other hand, over-voltage greatly reduces bulb life. For example, an over-voltage of only 5% reduces the life of bulbs by up to 50%.

Fluorescent lamps are affected by both voltage and frequency variations. If voltage is more than 15% down, the lamp will not light. If the lamp is already operating, it will flicker more as voltage decreases. If voltage drops more than 25%, the lamp may go out.

Over-voltage may lead to the choke overheating, but this is likely to be less limiting than the effect of over-voltage on incandescent bulbs. Fluorescent lamps should operate correctly in the frequency range -5% to +10% of nominal frequency.

Motor loads

Induction motors and transformers are affected in similar ways. Under-frequency with steady voltage causes high currents and overheating. Under-voltage at steady frequency has a similar effect on both these and other types of motor.

Overvoltage at rated frequency should be limited for induction motors in the same way as for transformers. However, such motors may be operated at frequencies up to 10% above the rated value unless they drive loads whose torque increases rapidly with speed, such as fans. With such loads the frequency should not rise to more than 5% of the rated value.

Inductions motors take up to six times their rated current in order to produce their rated torque when starting. Thus manufacturers often specify that motors will start and operate satisfactorily if the voltage is within 10% of their rated value. However, motors in rural workshops have operated with completely ungoverned turbines; voltage momentarily drops significantly when a motor is switched on but as, during start-up, minimal loads are imposed on these motors, they come up to speed rapidly.

If a motor is started under a large load, such as a motor driving a compressor in a refrigerator, the longer period of low speed and high current may cause the windings of the motor to overheat and fail.

A large voltage drop may result in insufficient torque to start the motor. When considering voltage regulation, the effect of transmission line resistance must be included – where possible large motors should be placed close to the generator.

Transformers

Transformer losses appear as heat. As losses increase, so does the heat generated within the transformer and, consequently, its temperature.

At fixed frequency, all these losses are very approximately related to the square of the voltage. Over-voltage therefore can pose a problem, and voltage is usually allowed to increase about 5% at rated load. However, under-voltage does not pose a problem.

At fixed voltage, decreases in frequency lead to increased losses and heat generation and operation at below rated frequency at rated voltage should be avoided. Operation at up to 20% over the rated frequency presents no problem as losses decrease.

Specifying the Governor

- To specify the governor, it is necessary to find the tolerance of the end use machinery to variation in frequency and voltage. Following are some end use load and its tolerance level

Appliance	Sensitivity to frequency fluctuations	Sensitivity to Voltage Fluctuations
Heating	• None	• Not a lot
Lights (incandescent)	• None	• High V- bright and short lived • Low V- dim long
Transformers	• Low- Heat And Losses • High can get away with +20%	• Low- no problem • High heat and losses (can get away with +20%)
Motors	• Low- Heat and losses • High can get away with +5-10%	• Low- Torque reduction • High heat and losses (can get away with +10%) • DC motors go the wrong speed

Hence our aim is to maintain
. Voltage +-7% of rated value
. Frequency up to 5% above but not below the rated value

Types Of Governor

- There are two kinds of governor to control water flow (discharge) through turbine by operation of guide vane or to control the balance of load by interchanging of actual and dummy load as follows:

  - **Mechanical Type (speed Governor)**
  - **Dummy Load type (Dummy Governor)**

Mechanical Type (speed Governor)

- To control water discharge always with automatic operation of guide vanes according to actual load. There are following two types:
  - Pressure oil operating type of guide vanes
  - Motor operating type of guide vanes

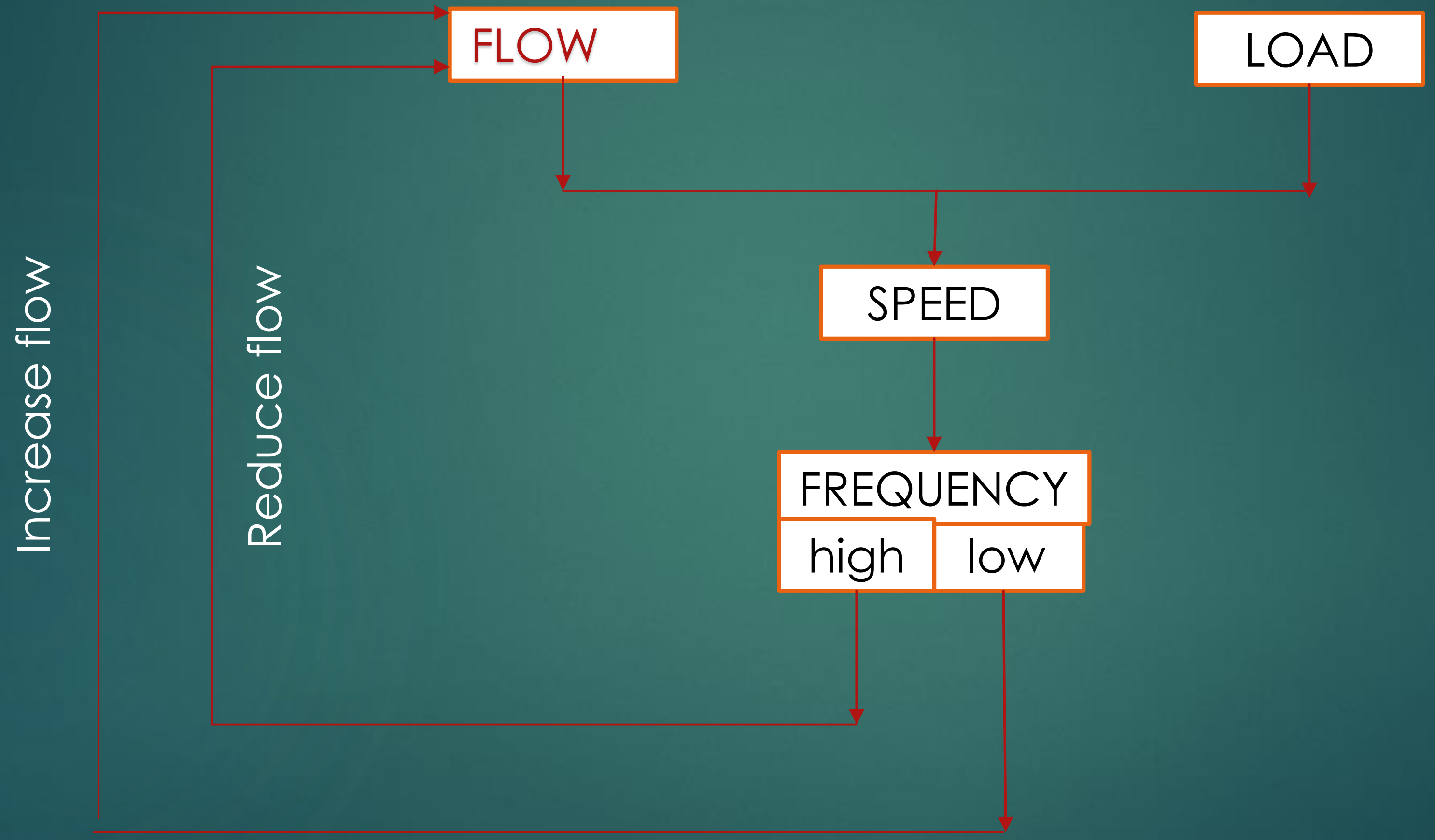
Dummy Load Type (Dummy Governor)

- To control the balancing of both current of actual load and dummy load by thyristor i.e. to keep the summation of both actual and dummy load constant always for the same output and speed of generators

Working principle of speed governor

- Rotational speed (frequency) is continuously transferred to the controller as a signal from the speed detector
- The transferred speed signal is compared with the preset signal corresponding to the rated speed
- If the speed drops i.e. when the load on the generator increase above rated power consumption the signal of “regulator open” is transmitted to the actuator of flow regulator
- Flow regulator continue to be opened until the frequency returns to the rated value opposite operation when load decrease

Flow diagram



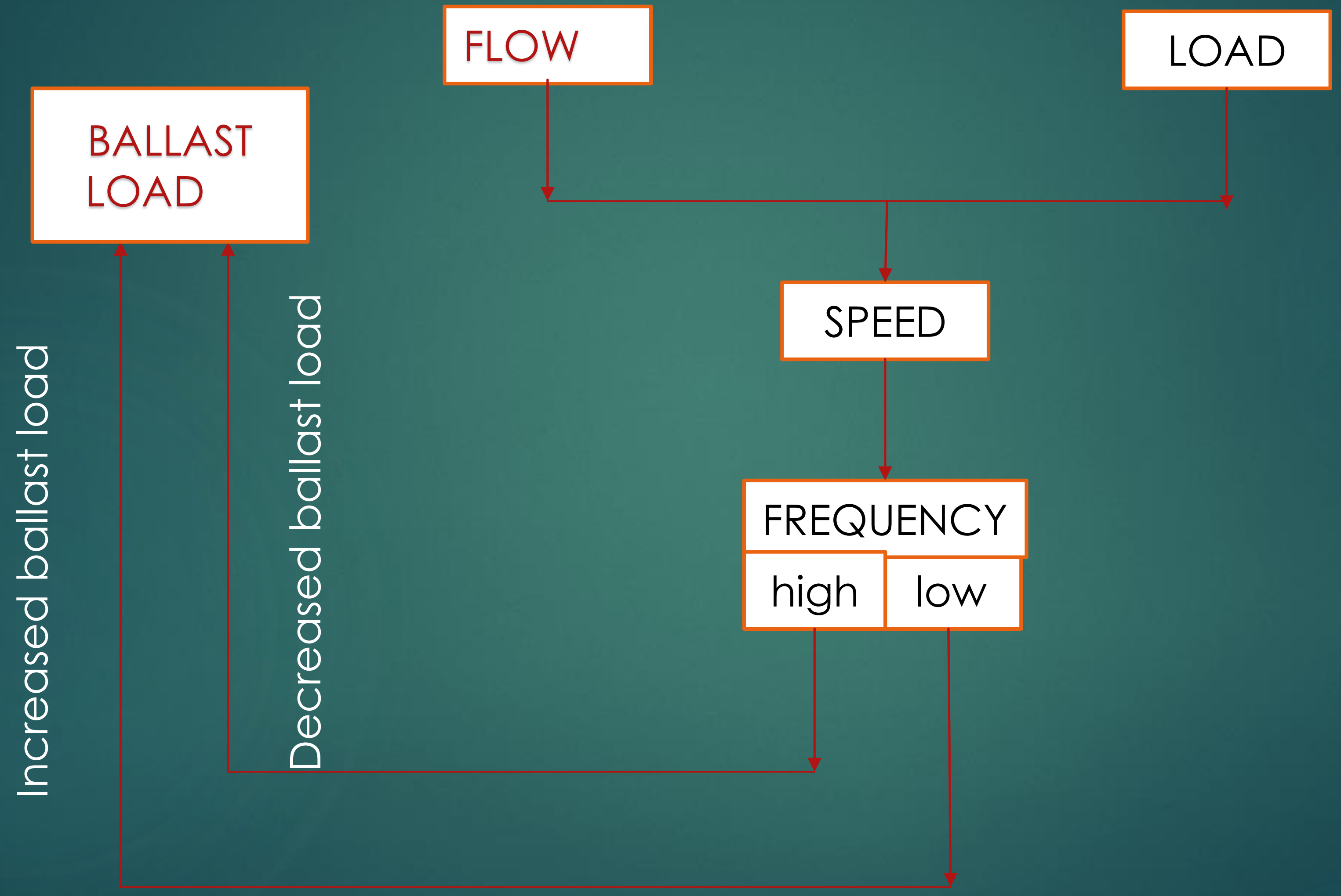
Working Principle of dummy load governor

- Frequency is kept constant by matching the total power consumption of actual loads and dummy loads to the generator output

$$P_g = P_{actual} + P_{dummy}$$

- Power consumption of dummy load is controlled by Electronic Load Controller (ELC)
- ELC adjust current to the dummy loads by phase shift control to keep the condition of $P_g = P_{actual} + P_{dummy}$ continuously

DUMMY LOAD GOVERNOR



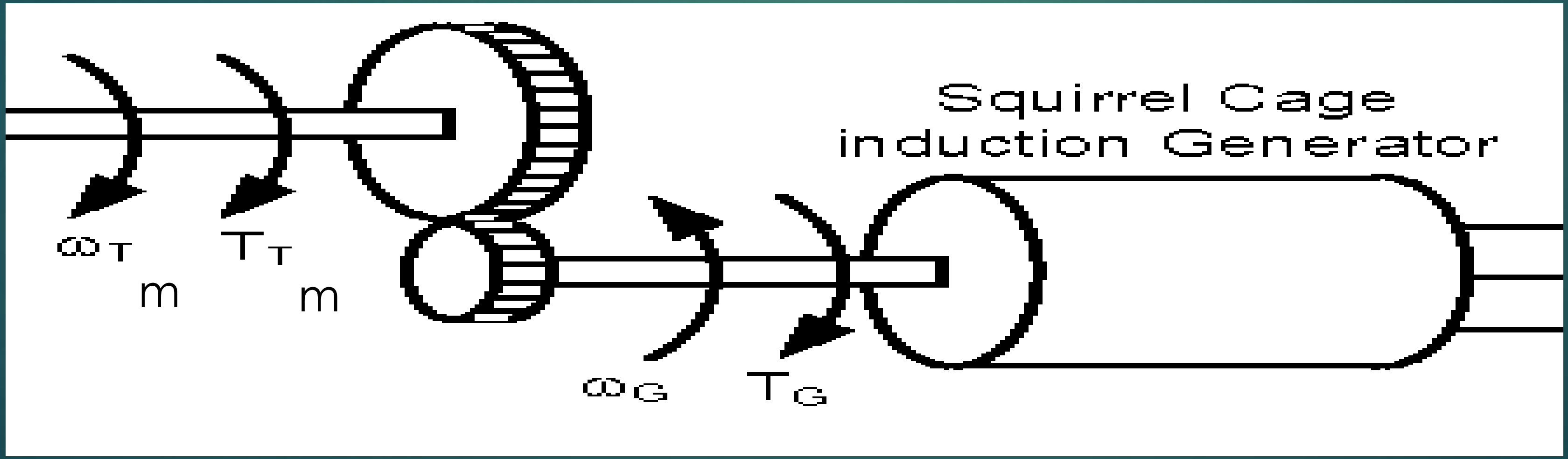
Comparison between Speed Governor and Dummy Load Governor

	Speed Governor	Dummy Load Governor
Advantage	• Sensitive control • No waste generating power	• No need for mechanism to adjust water flow • Reasonable relatively • Easy maintenance
Disadvantage	• Complicated structure • high maintainance • Need for driving device (electrical, hydraulic) • Costly	• Waste generating power
Applicability	• Small to large scale hydro	• Micro hydro

From above comparison, dummy load governor is suitable for rural electrification project by micro hydropower plant which is necessary for economy and high maintainability

Electronic Load Controller (ELC)

- Due to large number of components required and their complex arrangement, use of governing system becomes uneconomical for turbines rated less than 30 kW
- In such scenarios ELC can be used to maintain a constant frequency at the generator terminals



Tacceleration (Ta)=Tm-Te= 0

Electronic Load Controller (ELC)

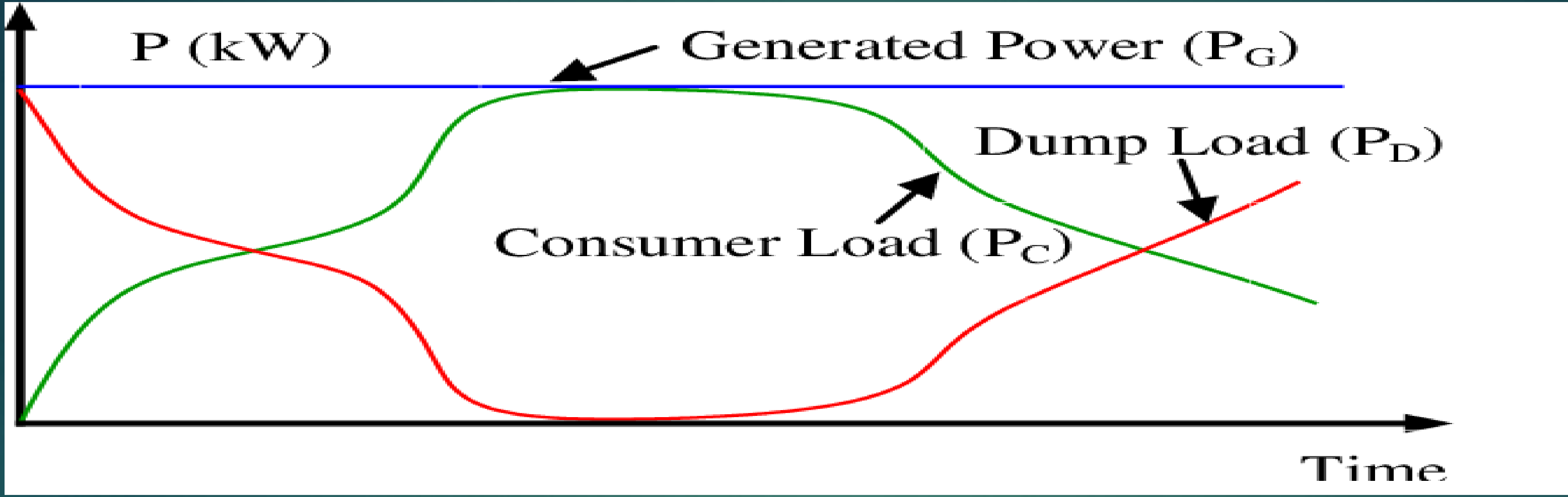
- During steady state conditions, the torque produced by the turbine **Tm** and the electrical torque produced by the generator **Te** are equal and in opposite direction
- Hence accelerating torque **Ta= Tm-Te =0**
- So the generator runs at constant speed

- But if the load across the generator is changed suddenly, Te (which is directly proportional to the load) also changes
- So the net accelerating Torque is no longer Zero
- If the load decreases, Te also decreases and Ia becomes positive
- So the generator experiences acceleration and frequency increases

Electronic Load Controller (ELC)

- In order to maintain constant frequency Ta should be made zero i.e. Tm should be changed accordingly
- In case of conventional governors, Tm is changed by varying the water input to the turbine
- Another way to ensure Ta is always zero by maintaining constant Te
- By doing so, Tm can be maintained constant i.e. water input to Turbine can be made constant
- This eliminates the need of governors
- Te can be maintained constant by maintaining the load across the generator constant.
- This is done by introducing artificial loads in the system
- As the consumer load increases or decreases, the artificial load (also known as ballast load) is adjusted accordingly

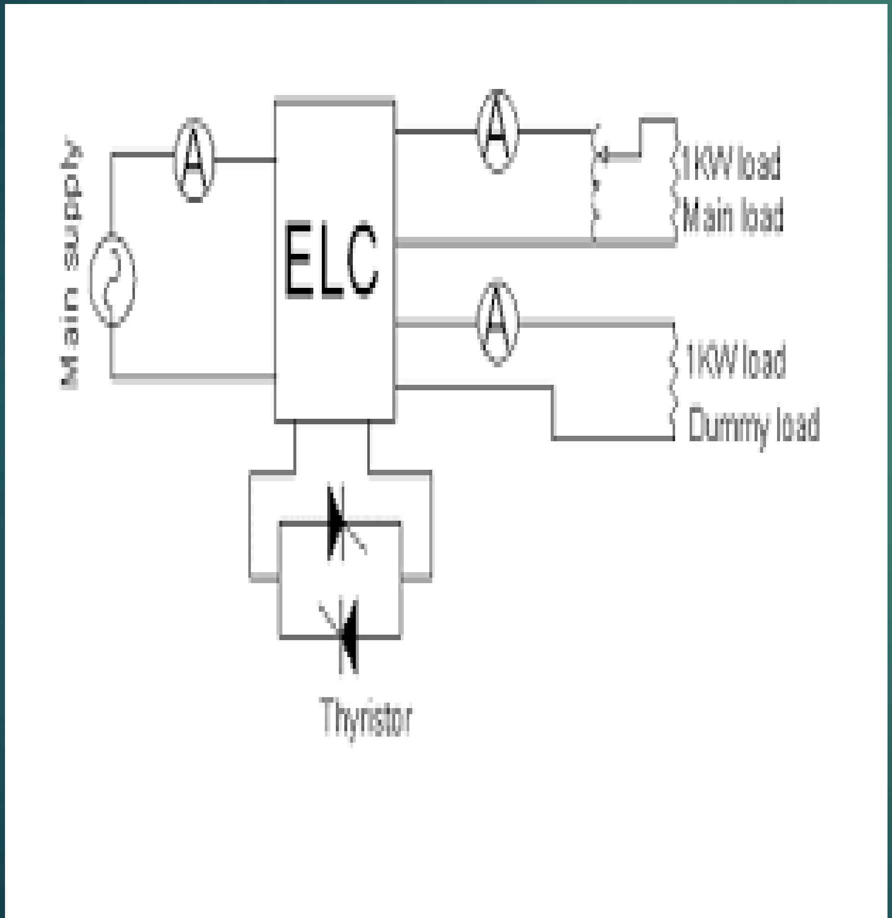
Electronic Load Controller (ELC)

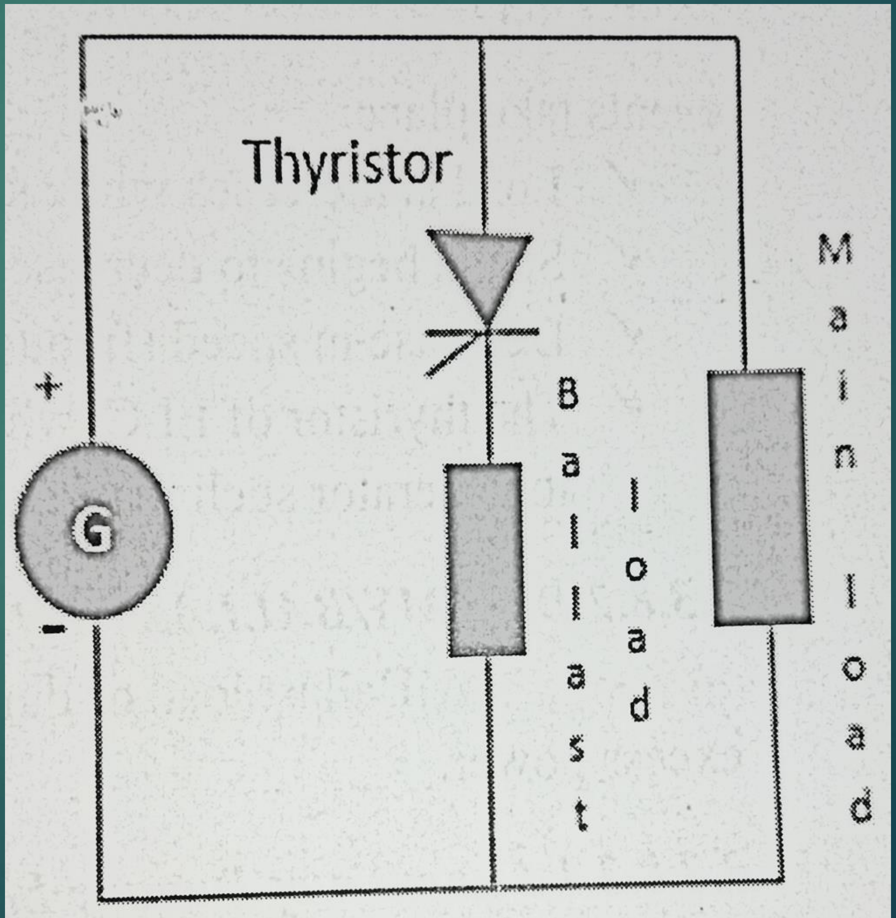


- Electronic load controller is a controller used in small hydro power generation to control the frequency of the generator by diverting excess power to dummy/ ballast load , thus the speed frequency and voltage of generator will be controlled at certain set point

Electronic Load Controller (ELC)

- Power diversion to Dummy Load is done electronically through thyristor as electronic switch which is controlled by ELC main board





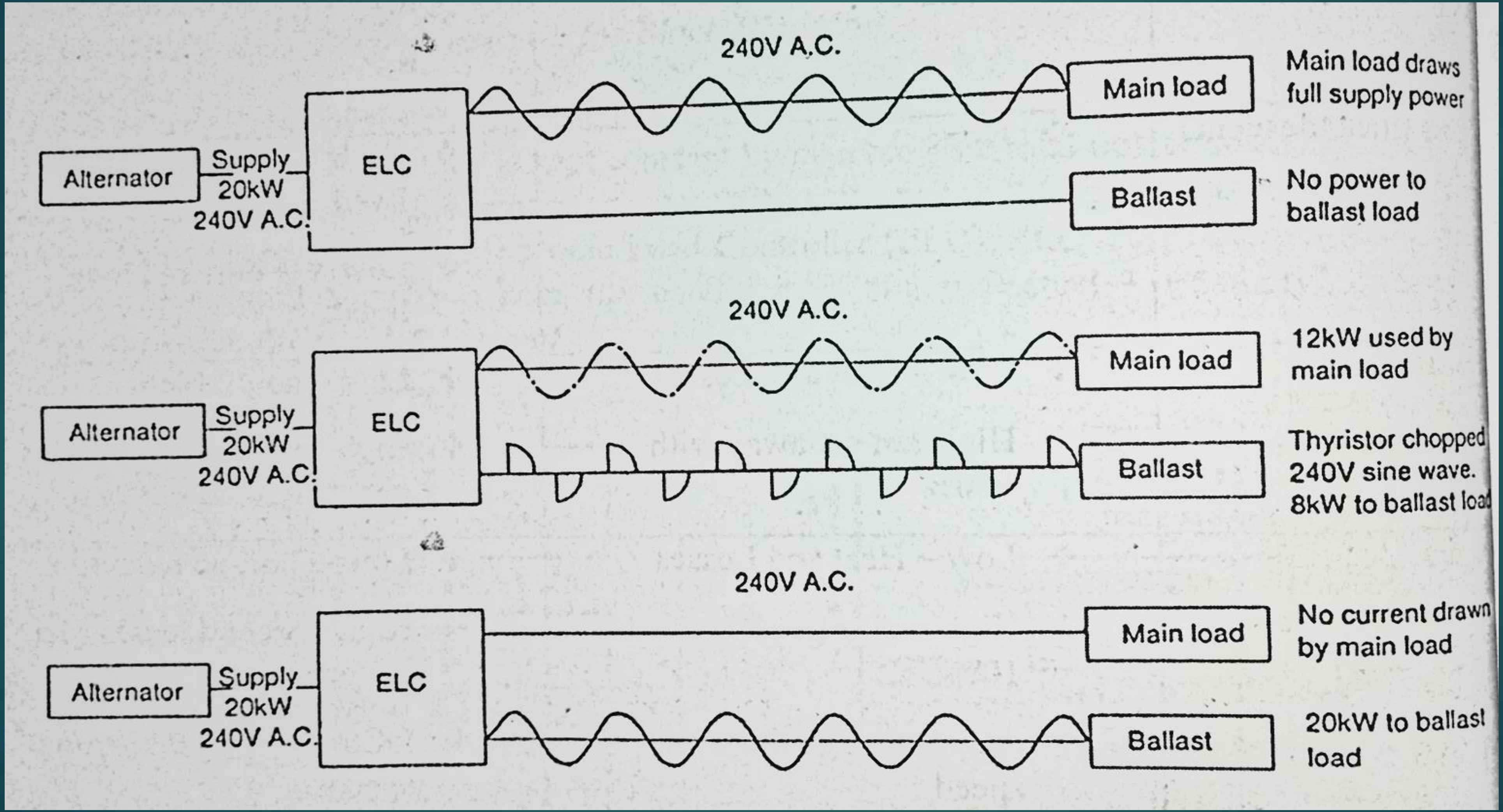
Operation of ELC

- The ELC consists of a thyristor in series with a ballast load
- This combination is connected across the generator in parallel with the main load
- The operation is summarized as follows:

- Suppose the consumer switches off some of his loads , then following events take place
  - Load is decreased while same water power is available
  - Speed begins to increase
  - Increase in speed (frequency) is sensed by the load controller
  - The thyristor of ELC, which acts as a chopper, adds a ballast load of sufficient resistance to generator (by increasing its on Time) to dissipate power equivalent to that which has been switched off.

compliled by Er. Bibek Dahal

Operation of ELC



Operation of ELC

- Suppose the consumer switches on some of his load when dummy load is operating, then following events take place
  - Load is increase while same water power is available
  - Speed begins to decrease
  - Decrease in speed (frequency) is sensed by the load controller
  - The thyristor of ELC, which acts as a chopper removes a ballast load of sufficient resistance to generator such that required power can be supplied to the costumer

Types of ELC