Governor Control Systems, Inc.

Prime Movers and Governors Basics
Agenda

- Introduction to Prime Movers
- Gas Turbines
- Steam Turbines
- Natural Gas Engines
- Diesel Engines
- Governor Basics
Introduction to Prime Movers
Prime Mover Introduction

Prime Mover Definition: An initial source of motive power (as a waterwheel, turbine, or engine) designed to receive and modify force and motion as supplied by some natural source and apply them to drive machinery.

Before we can understand what a governor is or how a governor works, here is a quick introduction of the prime movers that use governors.
Example of Hydro Turbine
Example of Hydro Turbine

- Hydro-electricity begins with a water source, which all or part is diverted through a powerhouse. This creates energy.

- The water flows down the penstock through the wicket gates. The governor controls the amount of water to the turbine blades, causing the rotation of the turbine which drives the load or generator.

- The distance the water falls (head) and the volume of the water source is directly related to the generating capacity.

- The water then leaves the powerhouse in a swirling motion, called tail water, and continues down river.
Example of a Steam Turbine

Steam Driven Turbine Generator

Boiler

Condenser

Turbine

Generator

High Pressure Steam From the Boiler 300 - 900 psig

Three Phase Power
Example of a Steam Turbine

- High pressure steam flows from the boiler at approximately 600 psi and 850 degrees Fahrenheit to the steam chest and onto the “Nozzles” or “First Stage”. The control system governs the amount of this steam flow.

- Nozzles then direct the steam flow to the rotating blades or “Buckets”. Between each rotating “Stage” is a fixed nozzle which directs the expanding steam to the next row of blades.

- Exhaust steam, reduced in pressure and temperature to about 35 psi and 340 degrees Fahrenheit is condensed back to water and returned to the boiler.

- There are many other types of steam turbines; Extraction, Double Extraction, Backpressure...
A simple gas turbine is comprised of three main sections:

- Air is drawn in the front of the turbine and compressed. The compressed air is then mixed with fuel, and burned. The control system governs the amount of fuel being burned.
- The resulting hot gas expands and is forced through the power turbine creating horsepower or work.
- The power turbine section is connected to the load.
- There are many other types of gas turbines; Aero Derivative, 2-Shaft, 3-Shaft ...
Example of a Natural Gas Engine

- Natural gas can be a single gas or a mixture of methane, ethane, propane, or other type of gases.

- Natural gas is brought in through a fuel mixer (carburetor) to the fuel manifold. The control system governs the amount of fuel being used by the engine.

- The air/fuel is brought into the cylinders on the Intake stroke, compressed on the Compression stroke, and ignited. This drives the piston down in the Power stroke, which rotates the crank shaft. The crank shaft drives the load.

- Exhaust is ported on the Exhaust stroke.
Example of a Diesel Engine
Example of a Diesel Engine

- The Intake stroke acts as a positive displacement pump and draws air into the piston.
- The piston then compresses the air on the Compression stroke.
- At the top of the Compression stroke, diesel fuel is injected, through injectors. The control system regulates the amount of fuel being delivered to the injectors. The Air-Fuel mixture ignites, expanding, and driving the piston down. This is called the Power stroke. Work is extracted from the piston on the power stroke.
- As the piston ascends, exhaust gasses are ported on the Exhaust stroke.
- The four cycles are then repeated.
- Other types of diesel engines are, Two-stroke, Turbo-charged, Naturally aspirated.
Section Two

- Why Do We Need Governors?
- What Is A Governor
- History of the Governor
- Simple Mechanical Governor
- Hydraulic-Mechanical Governor
- Droop and Isochronous
Introduction to Governors

- FlyBall Governor
- EGB-2P Act./Gov.
- EGB-13P Act./Gov.
- EG-3P Actuator
- L-Series Speed Control

- 2301A Load Sharing And Speed Control
- DPG Speed Control
- EPG Speed Control
- EPG Actuator

- 723 Plus Digital Control
- 2301D Load Sharing And Speed Control
- MicroNet Digital Control
- Atlas Control
What is a Governor?

**Governor Definition:**
- An attachment to a machine for automatic control or limitation of speed.
- A device giving automatic control (as of pressure or temperature).

A Governor is a device which controls the energy source to a prime mover to control its power for a specific purpose.

Basic governors sense speed and sometimes load of a prime mover and adjust the energy source to maintain the desired level.

Governors are often referred to as **Control Systems** and consist of an electronic control and an actuator.
Constant Load

DESIRED SPEED

ACTUAL SPEED

SPEED LIMIT 60
Constant Load

- The driver of the car is the control or governor.
- The speed limit sign is the desired speed setting.
- The speedometer senses actual speed.
- The driver compares desired speed to actual speed. If they are the same, fuel is held steady.
- If desired speed and actual speed are different, the fuel setting is adjusted by the driver to make actual speed equal desired speed.
- Fuel is held steady until a speed or load change occurs.
Increased Load
Increased Load

- The car starts up the hill, load increases, speed decreases.
- The actual speed is less than desired speed.
- Driver increases the fuel to increase the speed, which returns the actual speed to the desired speed.
- Before the actual speed reaches the desired speed, the driver reduces the fuel to prevent overshoot of speed. This is called Compensation and is adjusted to match the response time of the prime mover.
- It takes more fuel to pick up load than to maintain load.
Decreased Load
Decreased Load

- The car starts down the hill, load decreases, speed increases.
- Actual speed is greater than desired speed.
- Driver decreases fuel to decrease speed, which returns the actual speed to desired speed.
- Before the actual speed reaches the desired speed, the driver increases the fuel to prevent overshoot of speed. This is called Compensation and is adjusted to match the response time of the prime mover.
Closing the Loop

Control Of The Energy

Actual Speed or Load

Desired Speed or Load Reference
Closing the Loop

- The governor functions the same as the car driver.
- It automatically changes the Fuel Flow to maintain the desired speed or load.
- **Closed Loop Definition:** When used as an automatic control system for operation or process in which feedback in a closed path or group of paths to maintain output at a desired level.
- If parameter(s) of the loop change, it will effect the entire loop and fuel will automatically be corrected to maintain the desired set point.
History of the Governor

- James Watt, b. Jan. 19, 1736, d. Aug. 25, 1819, was a Scottish engineer and inventor who played an important part in the development of the steam engine as a practical power source.

- James Watt invented the centrifugal or flyball governor in 1788. The governor automatically regulated the speed of an engine. It embodied the feedback principle of a servo-mechanism, linking output to input, which is the basic concept of automation.
History of the Governor

- Amos Woodward patented his unique waterwheel governor in May 1870.
Oil Pump and Hydraulic Force

Positive Displacement Oil Pump

Supply Oil
Relief Valve

High Pressure Oil

29 Ft.- Lbs
13 Ft.- Lbs
3 Ft.- Lbs
Oil Pump and Hydraulic Force

- Positive Displacement Oil Pump
  - The positive displacement oil pump develops flow by carrying oil between the teeth of two meshed gears.
  - Oil is carried around the outside of the gears, and as the teeth mesh together, the oil is pressurized and forced out.

- Hydraulic Force
  - The amount of force a hydraulic cylinder can generate is equal to the hydraulic pressure times the “effective area” of the cylinder.
  - Using the formula $F = P \times A$ can determine the output work $F$, if $P$ressure and effective $A$rea are known.
Simple Droop Governor
Droop Curve

![Droop Curve Diagram](image)

- **SPEED**
- **LOAD**
- **50%**
- **100%**

The graph illustrates the droop characteristic of a system, showing how speed changes with varying loads. As load increases from 0% to 100%, the speed decreases accordingly.
Droop Curve

- **Droop Definition:** A decrease in desired speed setpoint for an increase in load or output servo position (feedback).

- **Droop Calculation:**

\[
\% \text{ Droop} = \frac{\text{No Load Speed} - \text{Full Load Speed}}{\text{Rated Speed}} \times 100
\]
Droop versus Isochronous

Droop or Isochronous?
Droop versus Isochronous

**Droop:**
- Isolated system load sharing with droop governors.
  - Isochronous - Droop Load Sharing
  - Droop - Droop Load sharing
- Droop Base Load to the Utility Grid with droop governors.

**Isochronous:**
- Used on Isolated or Islanded systems.
- Isochronous load sharing using electronic controls.
- Isochronous Base Load to the Utility Grid using electronic controls.
Isochronous Definition

- Isochronous
  - ISO + CHRONOS = SAME + TIME

- Constant Speed
  - No change in speed setting with a change in load.

- Usually used in isolated or islanded load applications (not tied to the utility grid).
Isochronous Curve

The diagram illustrates an isochronous curve with a constant speed across different load percentages. The x-axis represents load percentages (0%, 50%, 100%), and the y-axis represents speed. The curve remains horizontal across the load range, indicating that the speed is constant regardless of the load applied.
What Happens if I Don’t Have Droop?

Mechanical Flyball Governor

PRIME MOVER

Generator

Utility Tie Breaker

Utility

Utility Load

Slide 45
Generator Tied to Utility Grid

![Graph showing the relationship between frequency (Hz) and load percentage. The graph indicates that as the load increases, the frequency decreases.]
When the governor is in droop, as the speed reference is increased, fuel is applied to the engine, the engine converts the fuel to torque.

The torque is applied to the generator and current or power is produced.