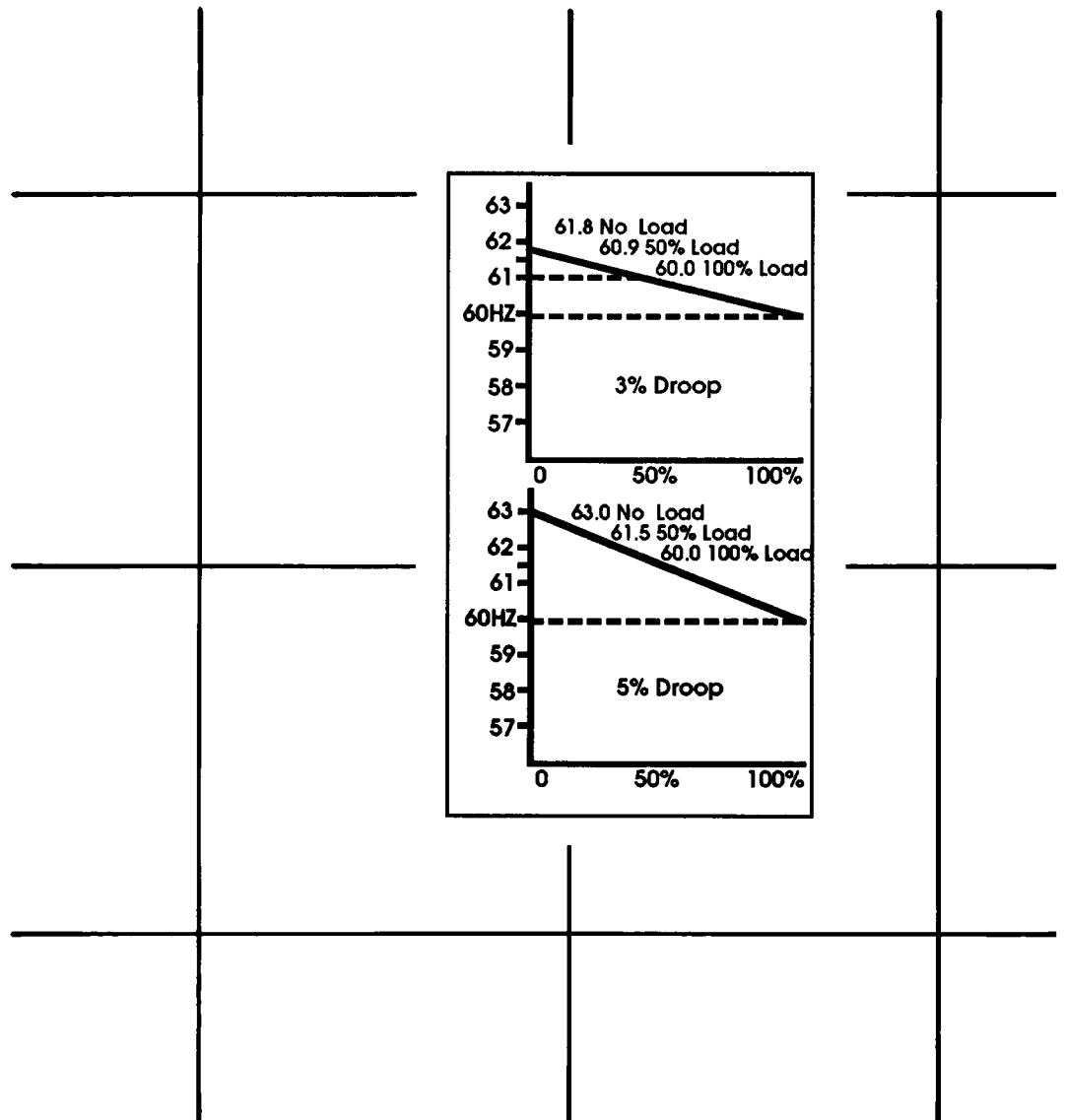




WOODWARD GOVERNOR COMPANY

ENGINE CONTROLS/TURBOMACHINERY CONTROLS
FORT COLLINS, COLORADO, U.S.A.

**SPEED DROOP
AND POWER GENERATION**



WARNING

Read this entire manual and all other publications pertaining to the work to be performed before installing, operating, or servicing this equipment. Practice all plant and safety instructions and precautions. Failure to follow instructions can cause personal injury and/or property damage.

The engine, turbine, or other type of prime mover should be equipped with an overspeed (overtemperature, or overpressure, where applicable) shutdown device(s), that operates totally independently of the prime mover control device(s) to protect against runaway or damage to the engine, turbine, or other type of prime mover with possible personal injury or loss of life should the mechanical-hydraulic governor(s) or electric control(s), the actuator(s), fuel control(s), the driving mechanism(s), the linkage(s), or the controlled device(s) fail.

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Droop Engine Control for Stable Operation

Speed droop is a governor function which reduces the governor reference speed as fuel position (load) increases.

All engine controls use the principle of droop to provide stable operation. The simpler mechanical governors have the droop function built into the control system and it cannot be changed. More complex hydraulic governors can include temporary droop, returning the speed setting to its original place after the engine has recovered from a change in fuel position. This temporary droop is called compensation.

The ability to return to the original speed after a change in load is called isochronous speed control. All electronic controls have circuits which effectively provide a form of temporary droop by adjusting the amount of actuator position change according to how much off speed is sensed.

Without some form of droop engine-speed regulation would always be unstable. A load increase would cause the engine to slow down. The governor would respond by increasing the fuel position until the reference speed was attained. However, the combined properties of inertia and power lag would cause the speed to recover to a level greater than the reference.

The governor would reduce fuel and the off speed would then occur in the underspeed direction. In most instances the off-speed conditions would build until the unit went out on overspeed.

With droop, the governor speed setting moves toward the offspeed as the fuel control moves to increase, allowing a stable return to steady state control. The feedback in the governor is from the output position. Since a minimal movement of the output position can cause major speed changes in an unloaded engine it is sometimes difficult to gain stability in unloaded conditions. Actuator linkage requiring more movement of the output to achieve a given amount of rack movement at the idle settings than at the loaded settings will often help achieve stability in the unloaded position. Setting a greater amount of droop in the governor is another solution.

In the case of isochronous (temporary droop) control the governor speed with which the engine returns to the predetermined speed reference is adjustable, allowing greater flexibility in achieving stable operation, even when unloaded.

The Droop Curve

Droop is a straight line function, with a certain speed reference for every fuel position. Normally a droop governor lowers the speed reference from 3 to 5 percent of the speed reference over the full range of the governor output. Thus a 3 percent droop governor with a reference speed of 1854 rpm at no fuel would have a reference speed of 1800 rpm at max fuel. (61.8 Hz at no fuel and 60 Hz at max fuel.)

(Notice that the feedback is over the full output- shaft rotation or fuel rod retraction of the governor. If only a portion of the output is used the amount of droop will be reduced by the same proportion. Likewise the same governor would only have a droop from 1827 to 1800 if half of the full output moved the fuel rack from no fuel to full fuel. (60.9 Hz droop to 60 Hz.) Probably not enough droop to provide stability.)

Figure 1 illustrates 3 and 5 percent droop governor speed curves, assuming the use of all of the servo movement. The speed figures given are theoretical since servo position and rack position are seldom absolutely linear.

Most complex hydraulic governors have adjustable droop. In these cases droop may be set between 0 and 5 percent. Droop is not adjustable in most mechanical governors, although some mechanical governors have provisions for changes in springs which will change the amount of droop. 5 percent droop is common in simple mechanical governors, although 3 percent and 10 percent droop is not uncommon.

Electric Generation

A single engine electrical generator can operate in isochronous, changing speeds only temporarily in response to changes in load. This system can also operate in droop, if a lower speed is permissible under loaded conditions. (See Figure 2.)

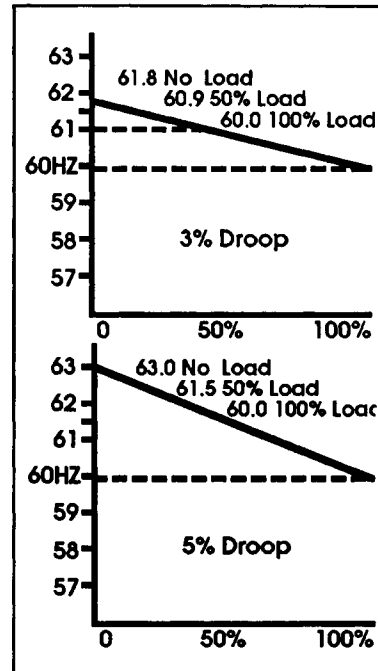


Figure 1. 3 and 5 Percent Droop Curves

Parallel with a Utility

If, however, the single engine generator is connected to a utility bus the utility will determine the frequency of the alternator. Should the governor speed reference be less than the utility frequency, power in the utility bus will flow to the alternator and motor the unit. If the governor speed is even fractionally higher than the frequency of the utility the governor will go to full load in an attempt to increase the bus speed. Since the definition of a utility is a frequency which is too strong to influence, the engine will remain at full fuel.

Isochronous governor control is impractical when paralleling with a utility because a speed setting above utility frequency, by however small an amount, would call for full rack since the actual speed could not reach the reference speed. Similarly, if the setting were even slightly below

actual speed, the racks would go to fuel off position.

Governors should not be paralleled isochronously with any system so big that the governed unit cannot affect the speed of the system.

Droop provides the solution to this problem. Droop causes the governor speed reference to decrease as load increases. This allows the governor to vary the load since the speed cannot change. (See Figure 3.)

Governor Speed Setting Determines Load

When paralleled with a bus the load on an engine is determined by the reference speed setting of the droop governor. Increasing the speed setting can not cause a change in the speed of the bus, but it will cause a change in the amount of load the engine is carrying. The graph shows that the amount of load is determined by where the droop line intersects

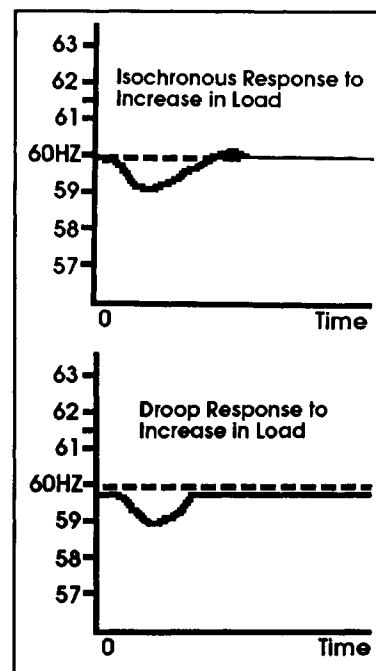


Figure 2. Response Curves of Isochronous and Droop Governors

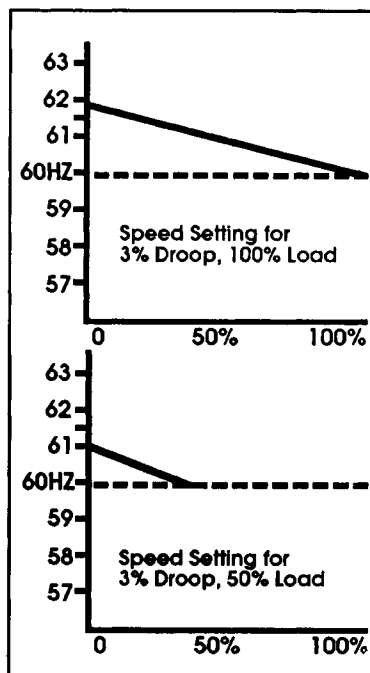


Figure 3. Comparison of 3% Droop Speed Settings for 50% and 100% Load

the speed of the bus. If the location of this line is moved, either by changing the reference speed or the amount of droop in the unit, the amount of load will also be moved.

Notice that the amount of droop set in the governor has little effect on the ability of the governor reference speed setting to determine the amount of load the engine will carry. The greater the droop the less sensitive engine load will be to speed setting. However, excessive droop presents the possibility of over speed, should the engine be removed from the bus thus becoming unloaded. In most cases 4 percent droop is adequate to provide stability and also allow for precise loading of the engine. (See Figure 4.)

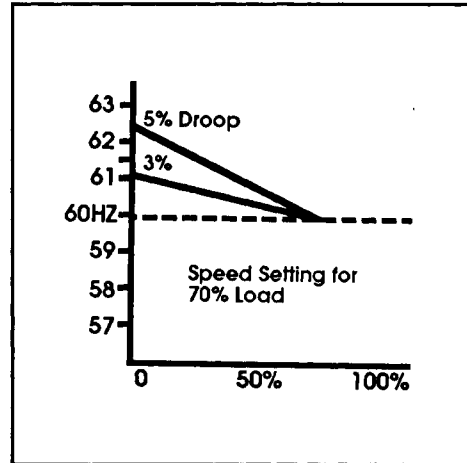


Figure 4. Speed Setting for 3 and 5 Percent Droop at 70% Load

Identical engines can show different characteristics if droop settings are not identical. An engine with more droop will require a greater change in the speed setting to accomplish a given change in load than will an engine with less droop in the governor. As explained in the following paragraphs, the amount of droop is also controlled by the amount of terminal shaft travel used between no load and full load. Both of these considerations should be investigated when apparently identical units show different responses to changes in the reference speed.

Output Shaft Movement

The amount of droop in a governor is also influenced by the amount of available output shaft movement used. The governor's speed reference is changed by feedback from the position of the governor output. A governor with 4 percent droop over the full travel of the output shaft will have an effective droop of only 2 percent if only half of the output is used from minimum to maximum fuel. Two percent droop is probably not enough to provide stability in many operations.

Using less than the optimum amount of terminal shaft movement will require a higher droop adjustment (knob or slider) than other engines increasing the danger of overspeed should the generator suddenly become separated from the bus (load). The low amount of governor travel may also cause the engine to be unstable.

Multiple Engine Isolated Bus

Droop may also be used to parallel multiple engines on an isolated bus. In this case the engines are capable of changing the frequency of the bus, and if all engines are operating

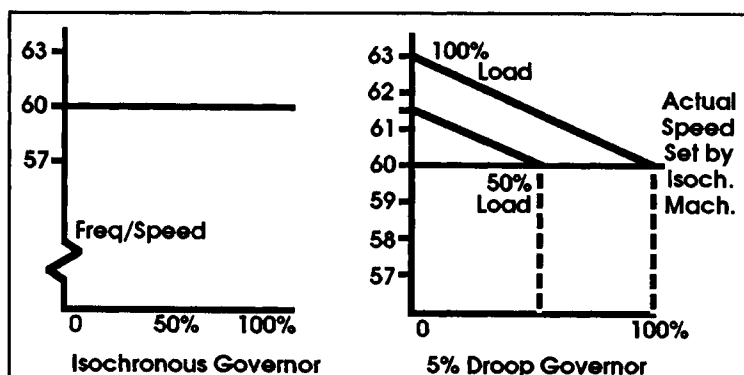


Figure 5. Use of Isochronous and Droop Units on an Isolated System

in droop the speed of the bus will change with a change in load. This is satisfactory only in cases where variations in the speed are acceptable.

Multiple engines can also be paralleled on an isolated bus with all but one of the engines in droop and that one engine in isochronous. These systems will be able to maintain a constant speed as long as the isochronous engine is capable of accommodating any load changes. (See Figure 5.)

In these cases, should load decrease below the combined load setting of the droop engines, the isochronous engine will completely unload and the system frequency will increase to the point that load equals the combined droop setting of the droop engines. The isochronous engine would be motored in this instance unless it was automatically removed from the bus.

If the load increases beyond the capacity of the isochronous unit the entire system will slow to the point where the combined droop of the other units meets the droop-speed position. In this case the isochronous unit would remain overloaded to a point where it was unable to achieve the governor reference speed.

Negative Droop

As has been stated, all mechanical governors use droop, either constant or in the case of isochronous governors temporary, to achieve stable engine control. It is possible to adjust negative droop (speed reference increases as load increases) into some governors. Satisfactory governor control (engine stability) cannot be achieved with negative droop adjusted into a governor.

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