# GENERATOR OPERATION

Generators may be operated stand-alone, in parallel with other similar sized units, or on a large bus. Regardless of the mode, only two controls are available. However, the results of control changes are very different.

## Governor
On the mechanical side, the governor controls the power (P) and speed (*w*) of the engine. A speed increase will directly increase the power (P) available from the driver, in relation to the available torque (*T*). Power is measured in watts.

$$P = T\,w \tag{1}$$

On the electrical side, the frequency (f) changes in proportion to the speed. Frequency is measured in Hertz (cycles / second).

$$w = 2\pi\,f \tag{2}$$

## Voltage Regulator
The voltage regulator manipulates the flux ($\phi$) on the exciter, which controls the internal voltage (E) of the generator. K is a constant for the machine. Voltage is measured in volts.

$$E = K\phi f \tag{3}$$

Outside the generator, the regulator also controls the power factor. This is the ratio of the power out of the machine divided by the voltage and current (I). The $\sqrt{3}$ is a conversion factor for three-phase power. Current is measured in amperes.

$$pf = P / \sqrt{3}\,EI \quad = P / S \; = P / P{+}jQ \tag{4}$$

It can be observed that with the power controlled by the governor, and the voltage fixed, then the power factor will decrease as the current from the generator is increased.

## Mode
When operating as a single stand-alone unit, the power and current requirements are set by the load connected to the generator. As a result, these are fixed. With the power (P) constrained in line 1, then a governor adjustment can only change speed (*w*) and the electrical frequency (f) in line 2. Similarly, investigate line 4. The power is fixed and the load current is fixed. The regulator only changes the voltage (E) from the generator.

When operating on a large bus, the reactions to the controls appear completely opposite. The large bus will consume as much power and current as can be delivered. The voltage and frequency of the bus are not substantially changed by a single generator. Therefore, adjusting the governor will change the power (P) but not the speed (*w*) as shown in line 1. Similarly, adjusting the regulator will change the reactive power and the power factor (pf).

When operating in parallel with similar sized units, a combination of the characteristics will be observed. The total of the power from all the machines will equal the power required by the load. One generator can be made to pick up more of the load by increasing that unit's governor speed (*w*) adjustment. If all the units' governors are raised, then the frequency will be increased. Likewise, adjusting the regulator on only one unit will change the reactive power and power factor from that machine. If all the regulators are adjusted then the voltage will be changed. Two units of similar size are more difficult to control. Any change in one will cause a swing in the other.

The power factor of the load can be changed by capacitors. This will reduce the current from the generator as shown on line 4. However, a power factor change will not impact the power delivered by the engine.

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