



**Droop versus isochronous load sharing between generators with respect to incorporation of renewable energy.**

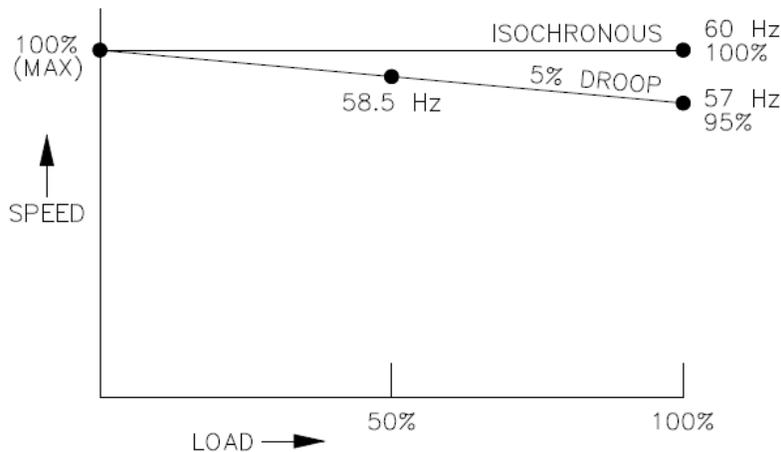
**Definitions**

**Load:** kWe (electrical active power) as experienced at the generator terminals.

**Transient load change:** kWe increase or decrease of sufficient level to overcome prevailing kinetic energy or cause the engine speed controller (governor) to increase / decrease fuel into combustion naturally incurring a delay in response as brake power (kWb) from within the engine develops. Typically, a +40% increase in load (within generating set rating) will incur a -2Hz speed loss; speed will return to rated speed within 1 to 1.5 seconds. Conversely a 40 % decrease in load will result in a speed rise (overshoot) as the engine responds to the governor decreasing fuel to the engine. Overshoot for this -40% transient can be expected to be +0.5 Hz; recovery to rated speed within 1 second. Transient performance will vary between engine manufacturers and engine types. Max permissible transient deviations and steady state limits are defined in ISO3046 to which most engine manufactures conform to, or have performances that better these values. A naturally aspirated engine by example will incur less transient deviation for a comparable % increase in load due to the absence of turbochargers, which require time to raise aspiration air pressure in response to exhaust gas increasing as a result of the governor increasing fuel into combustion. A longer piston stroke engine will have better load acceptance.

**Isochronous:** Engine governor will maintain rated speed from zero through 100% load and will return to rated speed following a transient load change.

**Droop:** Engine speed will droop between Zero and 100% load by typically up to 5% of rated speed. In the writers experience 4% is normal. With the advent of electronic (and hydraulic) engine governors isochronous speed control is the norm by a very high percentage (est. 99.9%). To attain stability with a mechanical governor the controlling device requires two points of reference, a) speed – position of centrifugal weights relative to start point and b) load – droop, i.e. speed loss against a mechanical curve with attendant damping methods, (springs and levers etc.). Traditionally, the greater the droop, the more stability.





Design by Initiative LLC

### **Isochronous load sharing:**

Load between generators is shared equally while maintaining rated speed, without speed droop. Note: generators will share load equally, proportional to speed difference at point of synchronism. Synchronize Gen 2 to buss 1% higher in speed than buss frequency, then Gen 2 will carry 1% greater load than on buss generators.

Load sharing between generators is achieved by measuring the kWe output of each generator, summing the total load and distributing kWe equally between generators via a communication facility between 'load share modules', most often referred to as paralleling lines.

### **Droop Load sharing:**

Droop load sharing relies on phenomena which can be simply referred to, in the educational context of generator load sharing, as 'the fastest machine will carry more load'. Understanding that droop incurs a speed loss (see above droop chart) and assuming that all synchronized machines started offload, at the same speed, with the same speed droop curve, generators will proportionately and stably share load as machines droop similarly for a given load. Stability is achieved from mechanisms within, whether electronic or mechanically derived. Should a droop curve, angle or shape differ, then the 'fastest of the machines will carry more load' proportionate to speed (fuel rate) variance. In reality it is not the 'fastest', (a term used to assist with this discussion) since the generator poles are locked to the same shaft speed, magnetically. In actually the machine with the higher fuel rate (governor) increasing engine power will attract more load as the magnetic bond shifts power to the machine with higher power availability.

### **Reverse Power**

Excessive variance between governor fuel rates to a point where a generator has a zero fuel rate (inactive machine) will result in a negative power on the inactive machine as result of it being 'motored' by the 'fueled' generator. This will be witnessed as load (and much reduced lagging power factor and high levels of VARS) generated by rotational resistance of the inactive machine. As negative load increases protective reverse power relays are designed to disconnect the inactive machine from the buss thereby preventing overload of normally operating machine(s). Typical reverse power relay settings are 8% negative power / 5 seconds of trip delay or 5% negative power 8 seconds trip delay. The writer has found either of these settings to be practicable for most installations.

### **PV Array invertors.**

Some PV array invertors prefer the generator system to run in droop mode since by virtue the inverter knows how much load is on the generator for a given frequency also making life easier, so to speak, in terms of sharing load between generators and inverter output. Getting past the concept of living with a variable frequency in today's quality of electricity expectations this is 'manageable' for single generator



Design by Initiative LLC

installation or multiple generators where no requirement to increase / decrease generating set capacity on a common buss exists.

In the case of generator installations which require capacity to match the load, automatically, then running generators in droop provides for a load sharing problem following synchronizing.

Scenario: Generator(s) on the buss operating 75% drooped (e.g. -2.25Hz from offload point) at 75% load. The generator synchronizing to the drooped buss is of course unloaded and thereby not 'speed drooped'. Following synchronizing the newly synchronized generator is 'atop' its droop curve and will therefore stay at offload levels since speeds are matched. Some load shift will result due to dynamic behavior which could equally result in a negative load potentially leading to reverse power (see above definition of reverse power) to the zero drooped machine.

External Intervention to the incoming governor by either: manual means by way of speed set point adjust, or automatically via load sensing and a speed potentiometer adjusting the speed set point, will need to occur to distribute load amongst machines on the buss. Once load has been equalized across machines buss frequency will rise above the 75% level by 0.38Hz to the 37.5% drooped speed since load per generator will drop to 37.5% (pending load increase). Of course Hz will drop proportionately as load rises on increased buss capacity.

The additional actions to stabilize load will of course increase time into a situation where additional capacity is reacting to rising load protecting the buss from overload - potentially placing the power grid at risk. It is true to say that capacity trigger settings can be calibrated to compensate, i.e. an earlier trigger point to initiate action from lower threshold / wider hysteresis, however experience demonstrates: a) envisaged settings may become widened such that benefits of capacity versus load matching are diminished and b) 'additional' external intervention equipment increases complexity and will, adversely affect system performance and load sharing accuracy. A fuel penalty will be incurred as energy is consumed by efficiency losses (magnetic bond) between generators due to unequal loadings.

In a situation where penetrations of renewable energy are at levels below where energy storage is required for power stability reasons and generators remain primary source of power then the design approach needs to be – energy from renewables should be viewed as fuel & emissions reduction / load shaving. Generator(s) see this benefit as reduced load and behave accordingly. In the case of automatic variable capacity generation cases, renewables shall share load isochronously independently of generator function and with such system gain that resonance between power sources is avoided. Generator control on detection of unrecoverable instability shall have the ability to shed renewable load.

Note: VAR sharing between generators uses voltage droop. Voltage can be expected to droop between 0 and 2.5% of rated voltage between zero and 100% of KVA rating.

C.G.Hough 3/6/13