

# **The Role of Load Banks in Gen-set Testing, and the Growing Need for Non-unity Power Factor Tests**

## ***Introduction***

Load testing is an important part of the proving of generating sets both at the time of manufacture and commissioning and later in the life of the set, as part of a managed maintenance plan. Load banks are used in the manufacturing plant and on site for acceptance tests, to prove that a gen-set will perform when needed, with its enclosure, cooling system, fuel and exhaust systems in place.

Standards and test criteria are well established, but are often not well understood by the people who should be applying them. There are misconceptions about what non-unity power factor loading really means, and the need for resistive and inductive load banks to truly prove gen-set performance.

Modern load bank systems are now available to do this job well, and new technology has been harnessed to collect the test results and analyse the data against the standards, giving simple reports showing the pass or fail criteria.

## ***The standards***

ISO 8528 (BS7698) part 6 is the standard for test methods of engine-driven generating sets. It sets out general test requirements and defines a functional test and an acceptance test. Functional tests must always be done and usually occur at the manufacturer's factory. Acceptance tests are optional, may be done on site and are often witnessed by the customer or his representative.

In all cases tests must be done with reference to the agreed specification of the generating set. Prior to operational tests, environmental data must be recorded and a preliminary inspection is specified. This includes safety checks, earth connections and guarding, insulation tests, fluid levels checks etc. On initial start-up emergency stop system must first be checked, followed by frequency, voltage and phase rotation checks, and an inspection for leaks and vibration.

Only after these preliminary checks are load tests started. These include load duration tests or a 'heat run', with recording of steady-state voltage and frequency followed by load acceptance tests, when transient responses to load changes are recorded.

The standard defines three performance classes - G1, G2 and G3. A further class, G4, is reserved for performance criteria which are agreed between the supplier and the buyer.

Each performance class has different criteria for a range of characteristics of the generating set. G1 is the least stringent and generally applies to small, simple generating sets intended to supply unsophisticated loads. G2 is broadly equivalent to commercially available power, while G3 is intended for sets which are powering strategically critical loads, or those which particularly require a stable and accurate power supply.

Engine governing is measured by testing frequency, and alternator voltage regulation is measured directly. Specified characteristics relating to frequency include steady-state variation, dip when maximum power increase is applied, rise when 100% power is removed and the time before the frequency returns within limits in both cases. Voltage characteristics again include the permissible dip when maximum power increase is applied, the rise when 100% load is removed and the recovery time.

Some of these criteria are as follows:

<i>Performance Class</i>	<i>G1</i>	<i>G2</i>	<i>G3</i>
Steady-state frequency band	2.5%	1.5%	0.5%
Maximum frequency dip	-15%	-10%	-7%
Maximum frequency rise	+18%	+12%	+10%
Frequency recovery time	10 seconds	5 seconds	3 seconds
Steady state voltage deviation	5%	2.5%	1%
Maximum voltage dip	-25%	-20%	-15%
Maximum voltage rise	+35%	+25%	+20%
Voltage recovery time	10 seconds	6 seconds	4 seconds

The maximum power increase for these tests, expressed as a percentage of the rated load of the set is determined by the characteristics of the engine, and the match between the engine and the alternator. Traditionally, naturally-aspirated engines were tested with 100% load acceptance, whereas turbo-charged engines were tested with a 60% power increase. However the standard defines a more complex formula based on engine parameters, and in practice this value is now usually determined by the manufacturer.

Other tests can also be specified, extending the scope of those set in the standards. These include cold-start load acceptance, simulated motor starting loads and synchronised parallel running, for example.

### ***Non-unity power factor testing***

In practice, almost all generating sets see a non-unity power factor load when in normal use. Virtually all typical loads of any but the tiniest generating sets include inductive and motor loads. Even loads such as florescent lighting, which have capacitive components, have ballast chokes to ensure that their power factor is near unity or slightly lagging.

Almost all but the smallest generating sets are designed and rated at a lagging power factor, usually 0.8, and virtually all set builders operate quality systems to ISO9001:2000. While this standard allows for organisations to set their own systems and procedures, it is difficult to argue against the concept that a product can be fitted with a rating plate, stating a load capacity at a power factor of 0.8 if it has not been tested at the name plate rating.

When professional engineers and consultants are involved in specifying a power supply for a project, they are becoming increasingly aware of this, and require that a set is tested to the standards, and at the nameplate rating. This means non-unity, or resistive/inductive load testing. ISO 8528 specifies that test reports should note if tests have been done at a power factor which is different than the rated one. Usually this means that tests done with a purely resistive load can be considered incomplete.

### ***Why test at non-unity power factor?***

Most generating sets are designed and specified at a power factor of 0.8, and the engine is therefore not capable of delivering full kVA at unity power factor. For example a 500kVA gen-set rated at 0.8 power factor, would only be able to deliver 400kW into a purely resistive load. Testing using a resistive load will usually result in full load test of the prime mover (i.e. the engine), but not of the alternator, which will be tested to only 80% of its rated current. This means that the alternator and its control system are not tested to their rated limit.

A non-unity power factor load affects the way that an alternator responds to load because, with inductive loads, the load current is not exactly in phase with the output voltage. The field within the magnetic circuit of the alternator is distorted and the automatic voltage regulator

(AVR) and excitation circuit must provide a higher current to maintain the set output voltage. So the relative losses within the alternator increase when operating at non-unity power factor and there is therefore more heat dissipation within the alternator laminations and windings.

The result of all this is that the alternator would run significantly cooler if the generating set is tested solely at unity power factor. This is both because the current is lower, and because the current is exactly in phase with the voltage (i.e. unity power factor). So the thermal performance of the generating set as a whole will not be tested as it would if the rated, non-unity power factor load were applied.

Many engineers who test generating sets consider that this is not very important, since usually the alternator is of proven design. Their main concern is to prove that the prime mover is in a serviceable condition, and is able to accept load without instability, or even stalling. There is no doubt that resistive-only tests do give valuable and useful data, but they cannot give the whole story. The electrical parts of the generating set, the alternator and ancillary components such as circuit breakers, current detectors, connections and wiring, meters and instrumentation, are clearly not being tested to their limit when a resistive-only test is done.

### ***The availability of non-unity power factor load test equipment***

Non-unity power factor load banks are now readily available in a wide range of load capacities and ratings. This, combined with increasingly comprehensive controls and high quality dedicated instrumentation, has been the most significant growth area for load testing over recent years.

### **Lagging (inductive) load**

This is by far the most common type of non-unity power factor load test equipment. Units are available as combined resistive/reactive load, or as purely reactive load for use in combination with separate resistive load banks. Modern systems, such as the Froment Proofloader fitted with the Sigma control system allow fully variable power factor to be selected. Older systems operated at only one fixed power factor by switching resistive and inductive load elements together. These older systems had serious limitations and could not readily be used to test at different rated frequencies, 60Hz for example, if the load bank were originally configured for 50Hz.

Resistive/inductive load banks are not just for large or specialised testing, but are needed for all sizes of tests from a few tens of kVA to multi-megawatt tests. They are now commonly available in the smaller size ranges, as well as the large units, when up to 6MVA is available conveniently packaged in 20ft ISO shipping containers. These in turn can be connected in multiple set-ups with a common control and instrumentation system using a simple daisy-chain data link. Tests with capacity of up to 50MW have been set up on numerous occasions in recent years by several organisations, when large turbine installations have been proof-tested. These big tests have often been in conjunction with arrays of power transformers since such supplies are usually at 11 or 13.8kV.

PC-based load control and data capture systems, such as the Froment Sigma PC system will meet almost all of the record-keeping requirements of the ISO standard, and will give clear pass/fail reports of the quite-complex transient response criteria including recovery times, etc.

### **Leading (capacitive) load**

Capacitive load banks are rarer and used for more specialised testing of AC power supplies.

There is a risk that leading power factor loads could result in the AVR of a generating set losing control of the output voltage, since the inductive windings of the alternator will interact with the capacitive load to generate power even if there is no excitation at all from the control system. Such loading must therefore be carefully avoided.

Leading power factor (capacitive, or resistive/capacitive) load banks are used to test the susceptibility of generating sets and other power supplies to this type of load. They are also used to test solid-state UPS systems which often supply data system and telecoms loads. These can incorporate numerous switched mode power supplies that introduce large amounts of distortion and harmonics due to the electronic switching of the waveform.

## ***Conclusion***

Both quality standards and the ISO 8528 for engine-driven gen-set testing demand that complete testing is carried out. Professional engineers and consultants have responded by specifying such tests. The equipment, with control, instrumentation, data capture and analysis systems are now available from load bank specialists such as Froment.

There is no doubt that in the future more tests will be done to ensure that generating sets comply with specification, will accept load in service under a managed maintenance regime, and will operate in an environmentally acceptable way with optimum fuel efficiency and minimum pollution.

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