

**Test Procedure for
Emission measurement from
Variable Speed Diesel Engines
for Power generating set Application.**



CENTRAL POLLUTION CONTROL BOARD
(Ministry of Environment, Forests and Climate change)
Parivesh Bhawan, East Arjun nagar, Delhi-32

This document may be read in conjunction with main document

“System & Procedure for Diesel Engines (**upto gross mechanical power 800 kWm**) for Genset applications”. All provisions made in the main document shall apply until and unless it is specifically mentioned in this document.

Major contributor:

Power Train Engineering Division
The Automotive Research Association of India
Pune India

UPCD Division, Central Pollution Control Board

Background

The Emission Limits for new diesel engines (upto 800 KW) for Generator Sets (GENSETS) were notified by the Environment (Protection) Amendment Rules 2002 vide GSR 371(E), dated 17th May 2002 at Sl. No. 95 and as amended vide GSR 520(E), dated 1st July 2003, GSR 448 (E) dated 12th July, 2004, GSR 520(E) dated 12th August 2004 and GSR 280(E) dated 11th April, 2008 under Environment (Protection) Act, 1986.

These limits were revised vide GSR 771(E) dated 11th December 2013.

At the time of initial notification, Genset engines with constant rated speed 1500 rpm were being manufactured. For these type engines, CPCB has developed "System & Procedure for Diesel Engines (upto gross mechanical power 800 kWm) for Genset applications" in consultation with "The Standing Committee" constituted in reference to GSR 371(E) dated 17th May 2002 with the active participation of ARAI, Pune and ICAT, Manesar. For these Type of engines D2 duty cycle was prescribed. The process of revision started by the year 2009. By the time of revision of these rules, there were a few manufacturers who were manufacturing Genset engines with rated speed 3000 rpm. These engines were also tested on D2 five mode Cycle. From the date of revision of these rules, CPCB is poured with the request to develop System and Procedure for variable speed engines. These type of Gensets / Genset engines are in demand due to low fuel consumption and optimum power output. A large segment of these type Gensets are being imported to India as a complete unit.

Variable Speed Genset Engine

Normally all equipment operating at 30% below its maximum power uses a fictitious dummy load resistance to prevent damage; whereas these type of equipments can operate at 30% below its maximum power without any problem.

Variable speed hybrid generator sets that reduce fuel consumption by 40% compared to a standard generator set and 20% when compared with other fixed speed, hybrid Gensets currently available on the market and extend maintenance periods up to 1000 hours. These hybrid Gensets provide 48 DC for telecom applications. In addition, these equipment has a 230 AC auxiliary power output. No doubt, these type of Gensets are perfectly designed to meet the needs of the telecommunications sector, optimising resources, reducing consumption, ensuring an Eco-friendly system, extending maintenance periods and lengthening the useful life of the product.

TEST PROCEDURE

1.0 Introduction

In the present scenario of application of Diesel Genset Engines, the requirement of variable speed diesel genset is increasing where variable frequency of electricity is converted into constant frequency and better fuel economy is anticipated. Hence, a test procedure is required for emission compliance testing of variable speed diesel genset engines/Gensets.

2.0 Variable Speed Diesel Genset System Description

Variable speed diesel generating set consists of a variable speed diesel engine, axial flux Permanent Magnet Generator or Alternator (PMG or PMA) and power electronic converters. An electronic controller (DSP processor) controls output three phase sinusoidal voltage and adjusts engine speed according to actual load demand. For variable speed genset system, power electronic converters are used to convert variable-frequency variable-voltage output to a constant voltage constant frequency output.

The block diagram of overall variable speed power generation system is shown in Figure 1 and Figure 2. A Permanent Magnet Generator or Alternator (PMG or PMA) is driven by a variable speed engine and it generates a variable frequency and variable amplitude AC voltage which is fed to power electronic converters (AC/AC converter, Rectifier, Inverter, Transformer etc.). The converter produces constant frequency three-phase sinusoidal constant voltage which is used for end load. Some part of this electricity is used as internal load to run engine fan, cooling motor, control panel etc. A system controller is used to control and monitor complete generating set. When no load is applied then the engine operates at a predefined minimum speed. When load increases then the controller runs the engine at an optimum speed to get best fuel consumption assuring a balance between power demand and power delivered by the engine.

The advantages of these sets over constant speed conventional generating set are mainly lighter in weight, smaller in size and enhanced fuel economy.

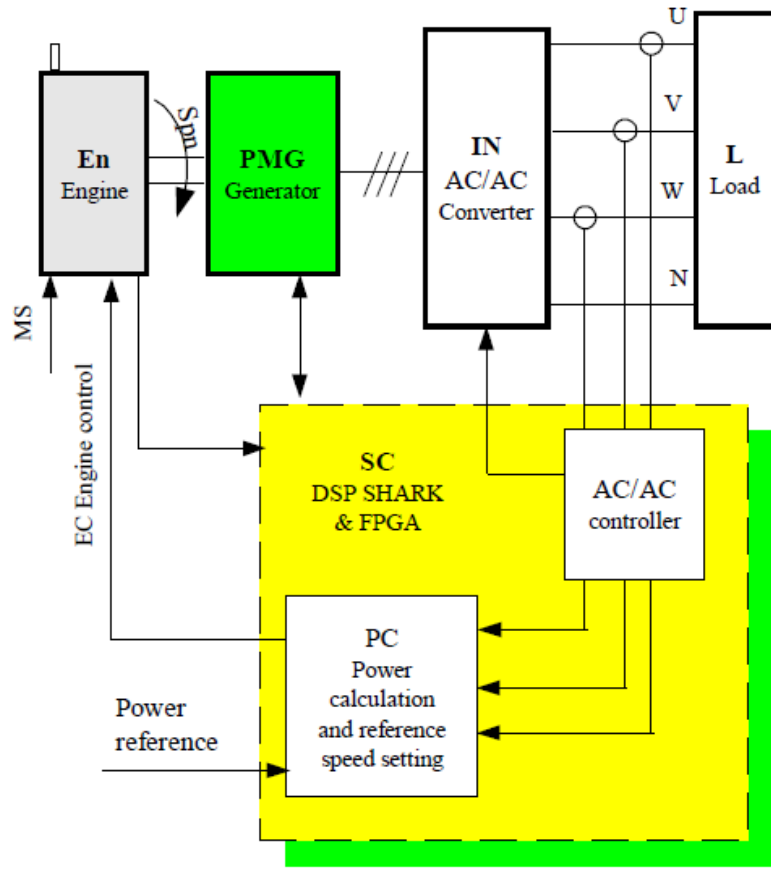


Figure 1. Block diagram of overall variable speed power generation system

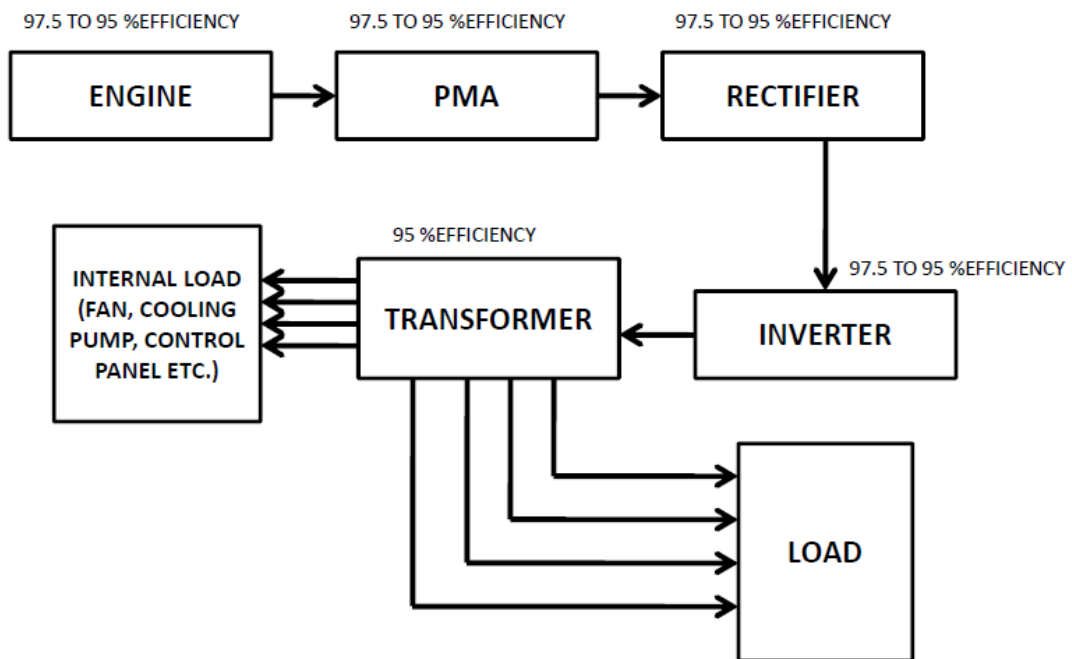


Figure 2. Block diagram of a variable speed diesel genset system

3.0 Test Cycle, Procedure & Equipment

3.1 The testing shall be done on engines with engine dynamometer. In case of import of complete genset, the engine shall be decoupled to test with engine dynamometer. The testing shall be done as per the following 5-mode cycle.

Mode No.	Engine speed	% Power	Weighting Factor
1	Declared speed (rated speed)	100	0.05
2	Declared speed	75	0.25
3	Declared speed	50	0.30
4	Declared speed	25	0.30
5	Declared speed	10	0.10

3.2 The engine manufacturer shall declare rated speed, rated power and part load speeds of the engine. The part loads shall be as mentioned in above table. The part load speeds shall be verified on actual working condition at manufacturer's place by Certification Agency before dismantling the set and submitting the engine for emission test. All the electronic equipment used for the measurement various testing shall be duly calibrated. The calibration requirement of the equipments other than mentioned in ISO 8178 -1 in this testing activity shall be as per IS 1248.2.2003 and IS 1248.4.

3.3 The engine shall be mounted on engine dynamometer and testing will be done as per the above cycle.

3.4 Testing shall be done with reference diesel fuel as per the specification given in **annexure I** of the main document. The fuel inlet temperature shall be maintained at 38 ± 5 Deg C throughout the test.

3.5 Declared rated corrected Power

(i) For Type Approval:

- For single cylinder engines, $\pm 5\%$ at rated & part load power points
- For all other engines, $\pm 4\%$ at rated & part load power points

(ii) For Conformity of Production:

- For single cylinder engines, at rated & part load power point, $\pm 6\%$ of the type approved figure
- For all other engines, at rated & part load power point, $\pm 5\%$ of the type approved figure

Declared rated and part load speeds shall vary within ± 1%

3.6 Calculation of gross mechanical power at rated speed

Manufacturer has to declare the gross mechanical power and final electrical power (kVA rating) for testing the engine on test bench considering the losses at all stages up to final output. Losses at PMG/PMA, Rectifier, Inverter, Transformer + Internal load if any (Fan, Cooling pump, control panel) etc. to be considered

Total Efficiency = Efficiency of PMA/PMG x Efficiency of Rectifier x Efficiency of Inverter x Efficiency of Transformer x Efficiency of any other power electronic converters

Gross mechanical power in kW = (kVA x PF)/ (Total Efficiency) + (Internal Load in kW)/ (Total Efficiency)

Where,

kVA = Electrical power output

PF = Power Factor

Electrical Power output, at all declared speed and load conditions of the variable speed generator set with all necessary power electronic converters will be verified on actual working condition at manufacturer's place by certification agency. Manufacturers shall submit supporting documents (duly certified and attested by the manufacturer/supplier) for efficiencies of various power electronic converters connected in the line starting from engine end upto final output. This data is required to calculate the gross mechanical power of the engine to be set for emission test on test bench.

The actual electrical power output at all the test points shall be verified at manufacturer's place should be within ± 5 % (for single cylinder engines) or ± 4 % (for all other engines) of the declared electrical power (kVA rating).

Example:

Electrical power output at rated speed = 50 kVA

Efficiencies:

Efficiency of PMA = 0.97

Efficiency of Invertor = 0.95

Efficiency of Transformer = 0.96

Total Efficiency = 0.97 x 0.95 x 0.96 = 0.885

Power Factor (PF) = 0.95

Internal Load in kW:

Fan, Cooling pump, control panel = 5 kW

Gross mechanical power in kW = $(50 \times 0.95)/0.885 + 5/0.885 = 59.3$ kW

Manufacturer has to declare gross mechanical power in such a way that both “gross mechanical power in kW as observed on the engine test bench” and “calculated gross mechanical power (calculated by efficiencies applied to the observed electrical power at rated speed as declared by the manufacturer)” should remain within $\pm 5\%$ (for single cylinder engines) or $\pm 4\%$ (for all other engines) of the declared gross mechanical power.

3.7 Test Equipment, setup, procedure, calculation method and other relevant technical details to be used shall be as mentioned in the main document “**SYSTEM & PROCEDURE FOR COMPLIANCE TO EMISSION LIMITS FOR NEW DIESEL ENGINES (UP TO 800 KW) FOR GENSET APPLICATIONS**”, except where it is mentioned, specifically, in this document.

Note: As the number of variable speed generating set engines in the field are very few, the document, test cycle and the test procedure for these engines is prepared based on the actual usage pattern conditions on the set in the site with a limited data availability. Hence this document, test cycle and test procedure shall be reviewed and revised if found necessary based on the testing experience.