Chapter 3.9: DG Sets

Part-I: Objective type questions and answers

1.	The compression ratio in diesel engines is in the range of: a) 10:1 to 15:1 b) 14:1 to 25:1 c) 5:1 to 10:1 d) 1:2 to 3:1
2.	Which of the following is the last step in diesel engine operation? a) Induction stoke b) Compression stroke c) Ignition stroke d) Exhaust stroke
3.	The power requirement of the DG set is determined by: a) base load b) Maximum load c) Partial load d) Zero load
4.	Present specific fuel consumption value of DG sets in industries is about _____. a) 220 g/kWh b) 100 g/kWh c) 160 g/kWh d) 50 g/kWh
5.	The efficiency of diesel generating set falls in the region of: a) 35 – 45% b) 50 – 60% c) 65 – 70% d) Above 80%
6.	Auxiliary power consumption of DG set at full load in its operating capacity is about _____. a) 1 - 2% b) 5 – 6% c) 10 - 12% d)Above 15%
7.	The rating required for a DG set with 500 kW connected load and with diversity factor of 1.5, 80% loading and 0.8 power factor is _____ a) 520 kVA b) 600 kVA c) 625 kVA d) 500 kVA
8.	The starting current value of DG set should not exceed__% of full load capacity of DG set. a) 100 b) 200 c) 150 d) 300
9.	The maximum permissible percentage unbalance in phase loads on DG sets is____ a) 5% b) 15% c) 10% d) 1%
10.	The permissible percentage overload on DG sets for 1 hour in every 12 hours of operation is____ a) 5% b) 15% c) 10% d) 1%
11.	Designed power factor of a DG set is generally at: a) 1.0 b) 0.8 c) 0.9 d) 1.1
12.	Lower power factor of a DG set demands_____ a) Lower excitation currents b) Higher excitation currents c) No change in excitation currents d) None of the above
13.	Which of the following losses is the least in DG sets: a) cooling water loss b) exhaust loss c) frictional loss d) alternator loss
14.	The waste heat potential for a 1100 kVA set at 800 kW loading and with 480 °C exhaust gas temperature is ____ a) 4.8 lakh kCal/hr b) 3.5 lakh kCal/hr c) 3 lakh kCal/hr d) 2 lakh kCal/hr

15.	Typical exit flue gas temperature of 5 MW DG set operating above 80% load is of the order of ____. a) 550 to 560 °C b) 210 to 240 °C c) 340 to 370 °C d) 400 to 450 °C
16.	The maximum back pressure allowed for DG sets is in the range of____. a) 100 – 200 mm WC b) 250 – 300 mm WC c) 400 – 500 mm WC d) above 500 mm WC
17.	The operating efficiency of DG set also depends on: a) turbo charger b) Inlet air temperature c) % loading d) all the above
18.	For a DG set, the copper losses in the alternator are proportional to the: a) Current delivered by the alternator b) Square of the current delivered by the alternator c) Square root of the current delivered by the alternator d) None of the above
19.	The jacket cooling water temperature for DG sets should be in the range of _____ a) 40 – 50°C b) 30 – 40°C c) 80 – 90°C d) 45 – 60°C
20.	The main precaution to be taken care by the waste heat recovery device manufacture to prevent the problem in DG set during operation is: a) Temperature raises b) Back pressure c) Over loading of waste heat recovery tubes d) Turbulence of exhaust gases

Part-II: Short type questions and answers

1.	Briefly Explain the principle of 4 stroke diesel engine. The 4 stroke operations in a diesel engine are: induction stroke, compression stroke, ignition and power stroke and exhaust stroke. **1st :** Induction stroke - while the inlet valve is open, the descending piston draws in fresh air. **2nd :** Compression stroke - while the valves are closed, the air is compressed to a pressure of up to 25 bar. **3rd :** Ignition and power stroke - fuel is injected, while the valves are closed (fuel injection actually starts at the end of the previous stroke), the fuel ignites spontaneously and the piston is forced downwards by the combustion gases. **4th :** Exhaust stroke - the exhaust valve is open and the rising piston discharges the spent gases from the cylinder.
2.	Name the components of diesel generating system: A diesel generating set as a system consists of the following components or blocks. Successful functioning of the set depends upon the well matched performance of these components. a) The diesel engine and its accessories. b) The AC Generator. c) The control systems and switchgear. d) The foundation and power house civil works.

	e) The connected load with its own components like heating, motor drives, lighting etc.
3.	List down the factors that need to be considered for DG set selection? Factor need to be considered for proper selection of DG set are: a. Loading b. Speed c. Cooling system d. Environmental conditions e. Fuel quality f. Control system, starting equipment g. Drive type h. Ambient temperature, altitude, humidity etc
4.	Estimate the DG set rating in kVA for a connected load of 1600 kW with a diversity factor of 1.88. Consider 85% loading and power factor as 0.8. Connected load : 1600 kW Diversity factor : 1.88 Maximum demand : 1600/1.88 = 850 kW % loading : 85% Set rating : 850 / 0.85 = 1000 kW At 0.8 pf, rating : 1250 kVA
5.	Which type of cooling is better for DG set - 'Air Cooling' or 'Water Cooling'? Why? Water cooled set is better than an air cooled set, as most users are worried about the overheating of engines during summer months. This is to some extent is true and precautions have to be taken to ensure that the cooling water temperature does not exceed the prescribed limits.
6.	What is the reason for not operating small DG-set parallel with grid? The grid is an infinite bus and paralleling a small capacity DG set would involve operational risks despite normal protection like reverse power relay, voltage and frequency relays.
7.	What is the likely effect of unbalanced loads on DG set operation? It is always recommended to have the load as much balanced as possible, since unbalanced loads can cause increased losses, heating and decrease in efficiency. It also results in unbalanced output voltages. The maximum unbalanced load between phases should not exceed 10 % of the capacity of the generating sets.
8.	Explain the effect of operating DG sets at low power factor? Lower power factor demands higher excitation currents and results in increased losses. Over sizing A.C. generators for operation at lower power factors results in lower operating efficiency and higher costs.
9.	Give a typical energy balance of a DG set. A typical Energy Balance in a DG set indicates following Break-up: Input : 100% Thermal Energy Outputs : 35% Electrical Output 4% Alternator Losses

	33% Stack Loss through Flue Gases 24% Coolant Losses 4% Radiation Losses
10.	Estimate the waste heat potential for a 1500 kVA DG set at 1000 kW loading and with 520 deg. C exhaust temperature. Waste heat potential = 1000 x 8 x 0.25 x (520 – 180) = 6.8 lakh kCal/hr
11.	What factors affect waste heat recovery from flue gasses? The factors affecting Waste Heat Recovery from flue Gases are: a) DG Set loading, b) Temperature of Exhaust flue Gases after turbo charger c) Hours of Operation d) Back Pressure on the DG Set
12.	What is the significance of back pressure in the flue gas path while recovering waste heat in a DG set? The back pressure in the flue gas path is caused by addition pressure drop in waste heat recovery unit. The maximum pressure drop allowed is 250 – 300 mmWc and the heat recovery unit should have a pressure drop lower than that.
13.	In a DG set, the generator is rated at 1000kVA, 415V, 1391A, 0.8PF, 1500 rpm. If the full load specific energy consumption of this DG set is 4.0 kWh per litre of fuel, then how much fuel is consumed while delivering full load output for one hour. Full load power = rated kVA x PF = 1000 kVA x 0.80 pf = 800 kW. Units of energy generated in one hour = 800 kWh. Specific energy consumption at full load = 4.0 lts / kWh. Fuel consumed per hour = 800 / 4.0 = 200 liters.
14.	Name two waste heat recovery options from DG sets flue gas? a) Waste heat recovery boiler for steam generation b) Waste heat recovered in the form of hot water used in vapour absorption system
15.	Give typical examples of application of Waste Heat Recovery Systems for DG sets. Various waste heat recovery equipments for DG sets are available for the recovery of the otherwise wasted energy. Some of the possible applications are listed below: • In waste heat boilers for steam generation • For preheating combustion air for heaters/furnaces near by • To heat air for drying purpose • To generate hot water for process • To heat thermal oil for process • For vapour absorption refrigeration systems • For preheating stock for furnaces

16.	Name 5-typical instruments that has to be deployed and its purpose for carrying out an energy audit of a DG set • Fyrite kit for measuring CO_2% in Flue gas • Temperature indicator with sensors* • Vane Anemometer is used to measure the Radiator air velocity • Tachometer is used to measure the speed of the engine • Power analyser / Load manager is used to measure electrical parameters like Voltage, Current, kW, kVA and Power Factor
17.	List out any four energy conservation opportunities for a DG system. The following energy conservation opportunities are highlighted in DG operating systems • Waste heat recovery system to recover heat from flue gas • Improvement in load factor • Option of parallel operation among DG sets for improved loading and fuel economy • Improve air filtration
18.	What parameters need to be analysed to assess the DG set performance? a) Average alternator loading. b) Average engine loading. c) Percentage loading on alternator. d) Percentage loading on engine. e) Specific power generation kWh/liter.
19.	What steps one need to consider while selecting DG set with non linear loads? – Special loads like rectifier / thyristor loads, welding loads, furnace loads need an application check. The manufacturer of diesel engine and AC generator should be consulted for proper recommendation so that desired utilisation of DG set is achieved without any problem. In certain cases of loads, which are sensitive to voltage, frequency regulation, voltage wave form, consideration should be given to segregate the loads, and feed it by a dedicated power supply which usually assumes the form of DG motor driven generator set. Such an alternative ensures that special design of AC generator is restricted to that portion of the load which requires high purity rather than increasing the price of the D.G.set by specially designed AC generator for complete load.
20.	What precautions should be taken while sequencing of loads on DG sets? Great care is required in sequencing the load on D.G.set/s. It is advisable to start the load with highest transient kVA first followed by other loads in the descending order of the starting kVA. This will lead to optimum sizing and better utilisation of transient load handling capacity of D.G.set.

Part-III: Long type questions and answers

1.	What are the points to be considered while selecting an engine in a DG set? Explain their importance? Several factors are to be considered regarding while selecting a particular type of engine most suitable for a specific application. The two most important are the power and the speed of the engine.

engine.

The power requirement is determined by the maximum load. The engine power rating should be 10-20 % more than the power demand imposed by the end use. This prevents overloading the machine by inadvertently adding extra load, during starting of motors or some types of lighting systems or as wear and tear on the machinery pushes up its power consumption.

Another important factor when choosing an engine is speed. An engine will operate over a range of speeds, with diesel engines typically running at lower speeds (1300 - 3000 rpm) and petrol engines at higher speeds (1500 - 5000 rpm). There will be an optimum speed at which fuel efficiency will be greatest. Engines should be run as closely as possible to their rated speed to avoid poor efficiency and build up of engine deposits due to incomplete combustion, which will lead to higher maintenance and running costs. To determine the speed requirement of an engine, one has to again look at the requirement of the load.

There are various other factors that have to be considered when choosing an engine for a given application. These include the following: cooling system, abnormal environmental conditions (dust, dirt, etc.), fuel quality, speed governing (fixed or variable speed), poor maintenance, control system, starting equipment, drive type, ambient temperature, altitude, humidity, etc.

2. Write the advantage of adopting Diesel Power Plants. Compare Diesel Set with combined GT & ST and conventional Steam plant for the following:

i. Thermal Efficiency

ii. Auxiliary power consumption

iii. Start-up time from cold

Advantages adopting Diesel power plants are as follows:

1. Low installed cost
2. Short delivery periods, hence shorter periods of installation
3. Higher efficiency (as high as 43-45%)
4. More efficient plant performance behaviour under part loads
5. Suitable for poorer grades of fuels such as low sulphur heavy stock and heavy petroleum stock
6. Minimum cooling water requirements can be adopted with air cooled heat exchanger in areas where water is not available
7. Short start-up time

Comparative analysis

Description	Units	Combined GT & ST	Conventional steam plant	Diesel Engine power plant
Thermal efficiency	%	40 – 46	33 – 36	43 – 45
Auxiliary consumption	%	2 – 4	8 – 10	1.3 – 2.1
Start-up time from cold	Min	about 10	120 – 180	15 - 20

3. List all the advantages of using a DG set compared to other types of power generation?

Diesel engine power plants are most widely applicable for small and medium power (non-utility) generation upto 15MW. The main reason for their extensive use is the higher efficiency of the diesel engines when compared with gas turbines and small steam turbines in the output range considered and also operational independence when compared with mini hydel and micro hydel plants where availability of water at a height is essential. In applications requiring low captive power, without much requirement of process steam, the ideal method of power generation would be by installing diesel generator plants. The fuels burnt in diesel engines range from light distillates to residual fuel oils. Diesel engines up to 30 MW have been built, however the most frequently used sizes are in the 4 to 15 MW ranges.

Advantages of adopting Diesel Power Plants are as follows:

- Low installed cost,
- Short delivery periods, hence shorter periods of installation
- Higher efficiency (as high as **43 -45** %)
- More efficient plant performance behaviour under part loads
- Requires comparatively lesser space area,
- Requires comparatively lesser auxiliary power consumption,
- Suitable for poorer grades of fuels such as low sulphur heavy stock and heavy petroleum stock
- Minimal cooling water requirements, can be adopted with air cooled heat exchanger in areas where water is not available
- Short start up time,
- Ease of use,
- More reliable and dependable source of power generation.

For continuous operation, medium and low speed diesel sets are economical and are recommended.

A brief comparison of different types of captive power plants is given in table below. In this comparison of the three different types of captive power stations from the point of view of thermal efficiency, capital cost, cost of generation, cooling water requirements etc., are indicated.

Description	Units	Combined GT & ST	Conventional Steam Plant	Diesel Engine Power Plants
Thermal Efficiency	%	40-46	33-36	43-45
Initial Investment per kW	Rs/kW	8,500-10,000	15,000-18,000	7,500-9,000
Space requirement		125 % (App.)	250 % (App.)	100 % (App.)
Construction time	Months	24-30	42-48	12-15
Project period	Months	30-36	52-60	12
Auxiliary Power Consumption	%	2–4	8-10	1.3–2.1
Plant Load Factor	kWh/kW	6000-7000	5000-6000	7200-7500
Start up time from cold	Minutes	about 10	120-180	15-20

4. Explain the possible energy saving measures for DG sets.

a) Ensure steady load conditions on the DG set, and provide cold, dust free air at intake (use of air washers for large sets, in case of dry, hot weather, can be considered).

b) Improve air filtration.

c) Ensure fuel oil storage, handling and preparation as per manufacturers' guidelines/oil company data.

d) Consider fuel oil additives in case they benefit fuel oil properties for DG set usage.

e) Calibrate fuel injection pumps frequently.

f) Ensure compliance with maintenance checklist.

g) Ensure steady load conditions, avoiding fluctuations, imbalance in phases, harmonic loads.

h) In case of a base load operation, consider waste heat recovery system adoption for steam

	generation or refrigeration chiller unit incorporation. Even the Jacket Cooling Water is amenable for heat recovery, vapour absorption system adoption. i) In terms of fuel cost economy, consider partial use of biomass gas for generation. Ensure tar removal from the gas for improving availability of the engine in the long run. j) Consider parallel operation among the DG sets for improved loading and fuel economy thereof. k) Carryout regular field trials to monitor DG set performance, and maintenance planning as per requirements.
5.	Name and describe few characteristics of load which influences the efficient use of DG set? Some of the load characteristics influence efficient use of D.G set. These characteristic are entirely load dependent and cannot be controlled by the DG set. ▪ Power Factor: The load power factor is entirely dependent on the load. The A.C. generator is designed for the power factor of 0.8 lag as specified by standards. Lower power factor demands higher excitation currents and results in increased losses. Over sizing A.C. generators for operation at lower power factors results in lower operating efficiency and higher costs. The economical alternative is to provide power factor improvement capacitors. ▪ Unbalanced Load: Unbalanced loads on A.C. generator leads to unbalanced set of voltages and additional heating in A.C. generator. When other connected loads like motor loads are fed with unbalanced set of voltages additional losses occur in the motors as well. Hence, the load on the A.C. generators should be balanced as far as possible. Where single phase loads are predominant, consideration should be given for procuring single phase A.C. generator. ▪ Transient Loading : On many occasions to contain transient voltage dip arising due to transient load application, a specially designed generator may have to be selected. Many times an unstandard combination of engine and A.C. generator may have to be procured. Such a combination ensures that the prime mover is not unnecessarily over sized and thereby adds to capital cost and running cost. ▪ Special Loads: Special loads like rectifier / thyristor loads, welding loads, Furnace loads need an application check. The manufacturer of diesel engine and A.C, generator should be consulted for proper recommendation so that desired utilisation of DG set is achieved without sacrifice/ hindrance, In certain cases of loads, which are sensitive to voltage, frequency regulation, voltage wave form, consideration should be given to segregate the loads, and feed it by a dedicated power supply which usually assumes the form of D.G. motor driven generator set. Such an alternative ensures that special design of A.C. generator is restricted to that portion of the load which requires high purity rather than increasing the price of the DG set by specially designed A.C. generator for complete load.