OPTC TRAINING COURSE

BOOK 3 – ENERGY EFFICIENCY IN ELECTRICAL UTILITIES
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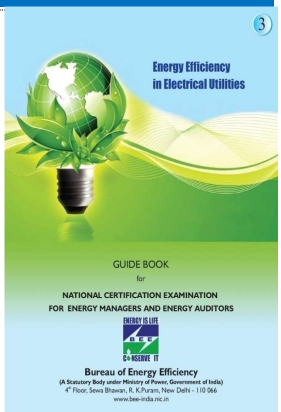

Chapter-9 Diesel/Natural Gas Power Generating System
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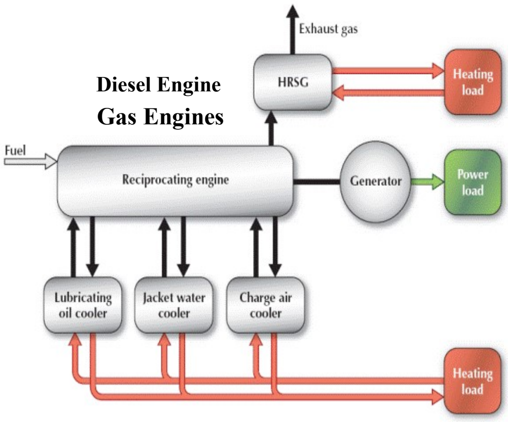
1 Introduction

- **In addition to Power generation**, useful heat can be recovered from the exhaust gas using a heat recovery for steam/hot water (Fig).
- Heat can also be recovered from the lubricating oil cooler, the jacket water cooler , and this "waste" heat can be provided to a heating load.
- In this case, the reciprocating engine power plant would be operating in a Combined Heat & Power (CHP) or cogeneration mode.



Reciprocating Engine Cogeneration

A DG set should be considered as a system

A diesel generating set (Fig) should be considered as a system since its successful operation depends on the well-matched performance of all components/sub systems

a. **Diesel engine and its accessories.**
b. **AC Generator.**
c. **Control systems and switchgear.**
d. **Foundation and house civil works.**
e. **Connected load like heating, motor drives, lighting etc.**

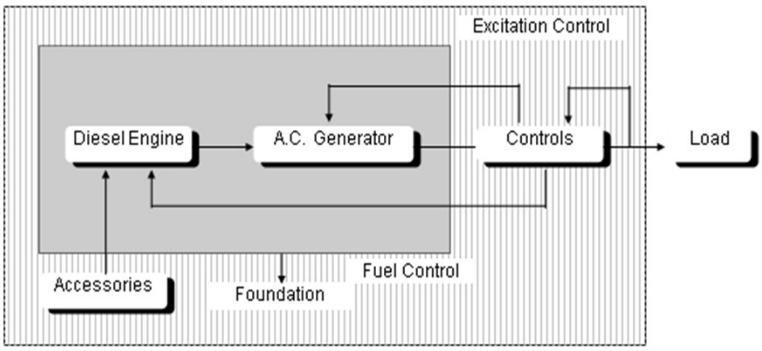


Figure 9.4 DG Set System

Comparison of different types of captive power plants

Table 9.1 Comparison of Different Types of Captive Power Plant				
Description	**Units**	**Combined GT & ST**	**Conventional Steam Plant**	**Diesel Engine Power Plants**
Thermal Efficiency	%	40 - 46	33 - 36	43 - 45
Initial Investment of Installed Capacity	Rs./kW	8,500 - 10,000	15,000 -18,000	7,500 - 9,000
Space requirement		125 % (Approx.)	250 % (Approx.)	100 % (Approx.)
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

Operational Factors

Load Pattern & DG Set Capacity

- Diesel engines are designed for 10% overload for 1 hour in every 12 hours of operation.
- A.C. generators are designed to meet 50% overload for 15 seconds
- The D.G.sets selection should be such that the overloads are within the above specified limits.
- alternator loading, engine loading in terms of kW or BHP, needs to be maintained above 50%.

Sequencing of Loads

- DG set has certain limits in handling the transient loads and applies to both kW (on the engine) and kVA (on the generator).
- It is advisable to start the load with highest transient kVA first followed by other loads in the descending order of the starting kVA. for better utilisation of transient load handling capacity of D.G.set.

Load Pattern

- In many cases, the load will not be constant throughout the day.
- If there is substantial variation in load, then consideration should be given for parallel operation of D.G.sets.
- Determine loads in first, second and third shifts.
- By parallel operation, D.G. sets can be run at optimum operating points , for optimum fuel consumption and additionally, flexibility is built into the system.
- loads can be segregated as critical and non-critical to provide standby power to critical load only.

Load Characteristics

- **Power Factor:**A.C. generator is designed for the PF of 0.8 lag as specified by standards. Lower PF 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. to provide capacitors.
- **Unbalanced Load:** Unbalanced loads on A.C. generator leads to unbalanced set of voltages and additional heating. Hence, the load on the A.C. generators should be balanced
- **Special Loads:** Special loads like rectifier / thyristor loads, welding loads, furnace loads need an application check. Solution are Segrication of loads or D.G.set should be specially designed AC generator for match load.

Energy Balance for Reciprocating Engine N.Gas and Diesel Engine DG sets

	Conventional cooling system		Cooling system with engine jacket and exhaust heat recovery		
500-kW natural gas engine generator*					
Electric power	30%			30%	
Jacket-water heat	38%	70% wasted		38%	54% recoverable
Exhaust heat	24%		Exh recoverable	16%	
			Exh lost	8%	16% wasted
Radiated heat lost to atmosphere	8%			8%	
	100%			100%	
500-kW diesel engine generator†					
Electric power	35%			35%	
Jacket water	32%	65% wasted		32%	48% recoverable
Exhaust heat	24%		Exh recoverable	16%	
			Exh lost	8%	17% wasted
Radiated heat lost to atmosphere	9%			9%	
	100%			100%	

Waste Heat Recovery (WHR) potential

In relation to quantity, temperature margin, in kcal/hr as:

Potential WHR=(kWh Output/hour) × (8 kg Gases / kWh Output)

× 0.25 kcal/kg°C × (t_g – 180°C)

t_g - gas temperature after Turbocharger, *(limit exit gas temperature cannot be less than 180°C, to avoid acid dew point corrosion)*,
0.25 -specific heat of flue gas and ,kWh output unit generation per hour.

Example: For a 1100 kVA set, at 800 kW loading, and with 480°C exhaust gas temperature, the waste heat potential works out to:

800 kWh × 8 kg gas generation / kWh output × 0.25 kcal/kg °C

× (480 – 180), i.e., 4,80,000 kcal/hr

Factors affecting Waste Heat Recovery from flue Gases

Typical Flue Gas Temperature and Flow Pattern in a 5-MW DG Set at various Loads		
100% Load	11.84 kg/sec	370°C
90% Load	10.80 kg/sec	350°C
70% Load	9.08 kg/sec	330°C
60% Load	7.50 kg/sec	325°C

If the normal load is 60%, the flue gas parameters for waste heat recovery unit would be 325°C inlet temperature, 180°C outlet temperature and 27180 kg/hour gas flow.

At 90% loading, however, values would be 350°C and 32,400 kgs/Hour, respectively.

Energy Performance Assessment of DG Sets

Conduct a 2 hour trial on the DG set, and log data at 15 minutes intervals.

- Fuel consumption (dip /flow)
- Amps, volts, PF, kW, kWh
- Intake air temperature, RH
- CW, exhaust temperature, Turbocharger RPM
- Charge air pressure
- Cooling water temperature before and after charge air cooler
- Stack gas temperature before and after turbocharger
- The fuel oil/diesel analysis

And DO Analysis: kWh/liter.

Table 9.7 Typical Format for DG Set Monitoring

DG Set No.	Electricity Generating Capacity (Site), kW	Derated Electricity Generating Capacity, kW	Type of Fuel used	Average Load as % of Derated Capacity	Specific Fuel Cons. Lit/kWh	Specific Lube Oil Cons. Lit/kWh
1.	480	300	LDO	89	0.335	0.007
2.	480	300	LDO	110	0.334	0.024
4.	200	160	HSD	89	0.325	0.003
5.	200	160	HSD	106	0.338	0.003
13	400	320	HSD	75	0.334	0.004
14.	400	320	HSD	65	0.349	0.004
16.	400	320	HSD	70	0.335	0.004
17.	400	320	HSD	80	0.337	0.004
18.	880	750	LDO	78	0.345	0.007
19.	800	640	HSD	74	0.324	0.002
20.	800	640	HSD	91	0.290	0.002
21.	880	750	LDO	96	0.307	0.002
22.	920	800	LDO	77	0.297	0.002

9.5 Energy Saving Measures for DG Sets

1. Ensure steady load conditions on the DG set,
2. provide cold, dust free air at intake
3. Improve air filtration.
4. Calibrate fuel injection pumps frequently.
5. Ensure compliance with maintenance checklist.
6. Ensure steady load conditions, avoiding fluctuations, imbalance in phases, harmonic loads.
7. For base load operation, consider waste heat recovery system steam generation or vapour absorption system adoption.
8. Consider parallel operation among the DG sets for improved loading
9. Carryout regular field trials to monitor DG set performance

Solved Example:

a) A 180 kVA, 0.80 PF rated DG set has diesel engine rating of 210 BHP. What is the maximum power factor which can be maintained at full load on the alternator without overloading the DG set? (Assume alternator losses and exciter power requirement as 5.66 kW and there is no derating of DG set)

Ans:

Engine rated Power = 210 x 0.746 = 156.66 kW

Rated power available for alternator = 156.66 – 5.66 = 151 kW

Maximum power factor possible = 151 /180 = 0.84

b) A DG set is operating at 600 kW load with 450°C exhaust gas temperature. The DG set generates 8 kg of exhaust gas/ kWh generated. The specific heat of gas at 450°C is 0.25 kcal/ kg°C. A heat recovery boiler is installed after which the exhaust temperature drops to 230°C. How much steam will be generated at 3 kg/ cm^2 with enthalpy of 650.57 kcal/ kg. Assume boiler feed water temperature as 80°C.

Ans:

Waste Heat Recovery = **600 kWh x 8 kg gas** gented/ **kWh** output x **0.25** kcal/ kg °C x (**450°C-230 °C**)

=2,64,000 kcal/hr

Steam generation = 2,64,000 kCal/hr / (650.57 – 80)

= 462.7 kg/ hr.

QUESTIONS

Objective Type Questions

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.	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
3.	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
4.	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
5.	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

Thank You

ENSAVE

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