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Maximum Single Load on DG Set

The starting current of squirrel cage induction motors is as much as six times the rated current for a few seconds with direct-on-line starters. In practice, it has been found that the starting current value should not exceed 200 % of the full load capacity of the alternator. The voltage and frequency throughout the motor starting interval recovers and reaches rated values usually much before the motor has picked up full speed. In general, the HP of the largest motor that can be started with direct on line starting is about 50 % of the KVA rating of the generating set. On the other hand, the capacity of the induction motor can be increased, if the type of starting is changed over to star delta or to auto transformer starter, and with this starting the HP of the largest motor can be up to 75 % of the KVA of DG set.

Unbalanced Load Effects

It is always recommended to have the load as much balanced as possible, since unbalanced loads can cause heating of the alternator, which may result in unbalanced output voltages. The maximum unbalanced load between phases should not exceed 10 % of the capacity of the generating sets.

Neutral Earthing

The electricity rules clearly specify that two independent earths to the body and neutral should be provided to give adequate protection to the equipment in case of an earth fault, and also to drain away any leakage of potential from the equipment to the earth for safe working.

Site Condition Effects on Performance de-rating

Site condition with respect to altitude, intake temperature and cooling water temperature de-rate diesel engine output as shown in following Tables

TABLE 9.3 DERATING DUE TO AIR INTER COOLER WATER INLET TEMPERATURE

Water Temperature °C	Flow %	Derating %
25	100	0
30	125	3
35	166	5
40	166	8

Operational Factors Load Pattern & DG Set Capacity

The average load can be easily assessed by logging the current drawn at the main switchboard on an average day. The 'over load' has a different meaning when referred to the DG set. Overloads, which appear insignificant and harmless on electricity board supply, may become detrimental to a DG set, and hence overload on DG set should be carefully analyzed. Diesel engines are designed for 10% overload for 1 hour in every 12 hours of operation. The A.C. generators are designed to meet 50% overload for 15 seconds as specified by standards. The DG set selection should be such that the overloads are within the above specified limits. It would be ideal to connect steady loads on DG set to ensure good performance. Alongside alternator loading, the engine loading in terms of KW or BHP, needs to be maintained above 50%. Ideally, the engine and alternator loading conditions are both to be achieved towards high efficiency. Engine manufacturers offer curves indicating % Engine Loading vs fuel Consumption in grams/BHP. Optimal engine loading corresponding to best operating point is desirable for energy efficiency. Alternators are sized for KVA rating with highest efficiency attainable at a loading of around 70% and more. Manufacturer's curves can be referred to for best efficiency point and corresponding KW and KVA loading values.

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Sequencing of Loads

The captive diesel generating set has certain limits in handling the transient loads. This applies to both KW (as reflected on the engine) and KVA (as reflected on the generator). In this context, the base load that exists before the application of transient load brings down the transient load handling capability, and in case of A.C. generators, it increases the transient voltage dip. Hence, great care is required in sequencing the load on DG set. 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 utilization of transient load handling capacity of DG set.

TABLE 9.2 ALTITUDE AND INTAKE TEMPERATURE CORRECTIONS

Correction Factors For Engine Output				
Altitude Correction			Temperature Correction	
Altitude Meters over MSL	Non Super Charged	Super Charged	Intake °C	Correction Factor
610	0.980	0.980	32	1.000
915	0.935	0.950	35	0.986
1220	0.895	0.915	38	0.974
1525	0.855	0.882	41	0.962
1830	0.820	0.850	43	0.950
2130	0.780	0.820	46	0.937
2450	0.745	0.790	49	0.925
2750	0.712	0.765	52	0.913
3050	0.680	0.740	54	0.900
3660	0.612	0.685		
4270	0.550	0.630		
4880	0.494	0.580		

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 DG sets. In such a situation, additional DG set(s) are to be switched on when load increases. The typical case may be an establishment demanding substantially different powers in first, second and third shifts. By parallel operation, DG sets can be run at optimum operating points or near about, for optimum fuel consumption and additionally, flexibility is built into the system. This scheme can be also be applied where loads can be segregated as critical and non-critical loads to provide standby power to critical load in the captive power system.

TABLE DERATING DUE TO AIR INTER COOLER
WATER INLET TEMPERATURE

Water Temperature °C	**Flow %**	**De-rating %**
25	100	0
30	125	3
35	166	5
40	166	8

Load Characteristics

Some of the load characteristics influence efficient use of DG set. These characteristics are entirely load dependent and cannot be controlled by the DG set. The extent of detrimental influence of these characteristics can be reduced in several cases.

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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 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 non-standard 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 which 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 AC generator should be consulted for proper recommendation so that desired utilization 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 DG set by specially designed AC generator for complete load.

Waste Heat Recovery in DG Sets
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

Among these, stack losses through flue gases or the exhaust flue gas losses on account of existing flue gas temperature of 350°C to 550°C, constitute the major area of concern towards operational economy. It would be realistic to assess the Waste Heat Recovery (WHR) potential in relation to quantity, temperature margin, in kcals/Hour as:

Potential WHR = (KWh Output/Hour) x (8 kg Gases / KWh Output) x 0.25 kcal/kg°C x (tg – 180°C)

Where, tg is the gas temperature after Turbocharger, (the criteria being that limiting exit gas temperature cannot be less than 180°C, to avoid acid dew point corrosion), 0.25 being the specific heat of flue gases and KWh output being the actual average unit generation from the set per hour. For 1100 KVA set, at 800 KW loading, and with 480°C exhaust gas temperature, the waste heat potential works out to:

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800 KWh x 8 kg gas generation / KWh output x 0.25 kCal/kg°C x (480 – 180) = 4,80,000 kCal/hr
While the above method yields only the potential for heat recovery, the actual realizable potential depends upon various factors and if applied judiciously, a well configured waste heat recovery system can tremendously boost the economics of captive DG power generation.

The factors affecting Waste Heat Recovery from flue Gases are DG Set loading, temperature of exhaust gases, Hours of operation and Back pressure on the DG set

Consistent DG set loading (to over 60% of rating) would ensure a reasonable exit flue gas quantity and temperature. Fluctuations and gross under loading of DG set results in erratic flue gas quantity and temperature profile at entry to heat recovery unit, thereby leading to possible cold end corrosion and other problems.

TABLE 9.4 TYPICAL FLUE GAS TEMPERATURE AND FLOW PATTERN IN A 5-MW DG SET AT VARIOUS LOADS

100% Load	11.84 kgs/Sec	370°C
90% Load	10.80 kgs/Sec	350°C
70% Load	9.08 kgs/Sec	330°C
60% Load	7.50 kgs/Sec	325°C

If the normal load is 60%, the flue gas parameters for waste heat recovery unit would be 320°C inlet temperature, 180°C outlet temperature and 27180 kgs/Hour gas flow.
At 90% loading, however, values would be 355°C and 32,400 kgs/Hour, respectively

Number of hours of operation of the DG Set has an influence on the thermal performance of waste heat Recovery unit. With continuous DG Set operations, cost benefits are favorable. Back pressure in the gas path caused by additional pressure drop in waste heat recovery unit is another key factor. Generally, the maximum back pressure allowed is around 250–300 mmWC and the heat recovery unit should have a pressure drop lower than that. Choice of convective waste heat recovery systems with adequate heat transfer area are known to provide reliable service.

The configuration of heat recovery system and the choice of steam parameters can be judiciously selected with reference to the specific industry (site) requirements. Much good work has been done regarding waste heat recovery and one interesting configuration, deployed is installation of waste heat boiler in flue gas path along with a vapor absorption chiller, to produce 8°C chilled water working on steam from waste heat. The favorable incentives offered by Governments for energy efficient equipment and technologies (100% depreciation at the end of first year), make the waste heat recovery option. Payback period is usually about 2 years

Energy Performance Assessment of DG Sets

Routine energy efficiency assessment of DG sets on shop floor involves following typical steps:
1) Ensure reliability of all instruments used for trial.
2) Collect technical literature, characteristics, and specifications of the plant.
3) Conduct a 2 hour trial on the DG set, ensuring a steady load, wherein the following measurements are logged at 15 minute intervals.

a) Fuel consumption (by dip level or by flow meter)
b) Amps, volts, PF, KW, KWh
c) Intake air temperature, Relative Humidity (RH)
d) Intake cooling water temperature
e) Cylinder-wise exhaust temperature (as an indication of engine loading)
f) Turbocharger RPM (as an indication of loading on engine)

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g) Charge air pressure (as an indication of engine loading)
h) Cooling water temperature before and after charge air cooler (as an indication of cooler performance)
i) Stack gas temperature before and after turbocharger (as an indication of turbocharger performance)

4) The fuel oil/diesel analysis is referred to from an oil company data.
5) Analysis: The trial data is to be analyzed with respect to:
a) Average alternator loading.
b) Average engine loading.
c) Percentage loading on alternator.
d) Percentage loading on engine.
e) Specific power generation KWh/liter.
f) Comments on Turbocharger performance based on RPM and gas temperature difference.
g) Comments on charge air cooler performance.
h) Comments on load distribution among various cylinders (based on exhaust temperature, the temperature to be □} 5% of mean and high/low values indicate disturbed condition).
i) Comments on housekeeping issues like drip leakages, insulation, vibrations, etc.

A format as shown in the table is useful for monitoring the performance

TABLE 9.5TYPICAL 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
3.	292	230	LDO	84	0.356	0.006
4.	200	160	HSD	89	0.325	0.003
5.	200	160	HSD	106	0.338	0.003
6.	200	160	HSD			
7.	292	230	LDO	79	0.339	0.006
8.	292	230	LDO	81	0.362	0.005
9.	292	230	LDO	94	0.342	0.003
10.	292	230	LDO	88	0.335	0.006
11.	292	230	LDO	76	0.335	0.005
12.	292	230	LDO	69	0.353	0.006
13	400	320	HSD	75	0.334	0.004
14.	400	320	HSD	65	0.349	0.004
15.	880	750	LDO	85	0.318	0.007
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

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, vapor 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.

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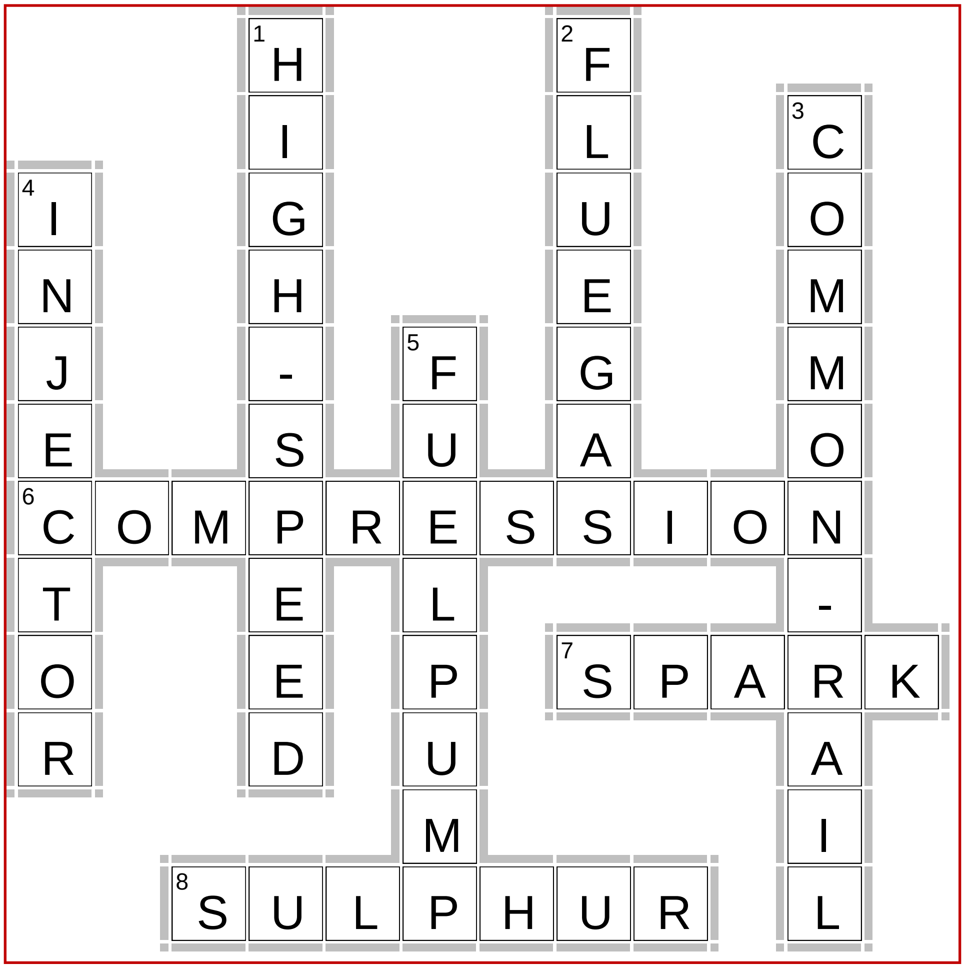
Solution for Last fortnight Techuzzle



Across

6. **COMPRESSION**—Diesel Engine works on _____ ignition principle
7. **SPARK**—Petrol engine works on ____ ignition principle
8. **SULPHUR**— This chemical, present in fuel, acts as lubricant

Down

1. **HIGH-SPEED**—HS means _____ in HSD, the common engine fuel
2. **FLUEGAS**—Exhaust temperature is also referred as _______ temperature
3. **COMMON-RAIL**—CR means _____ in CRDI engines
4. **INJECTOR**—Diesel is pushed into cylinder using ____
5. **FUELPUMP**— The device supplying HSD at high pressure is ______

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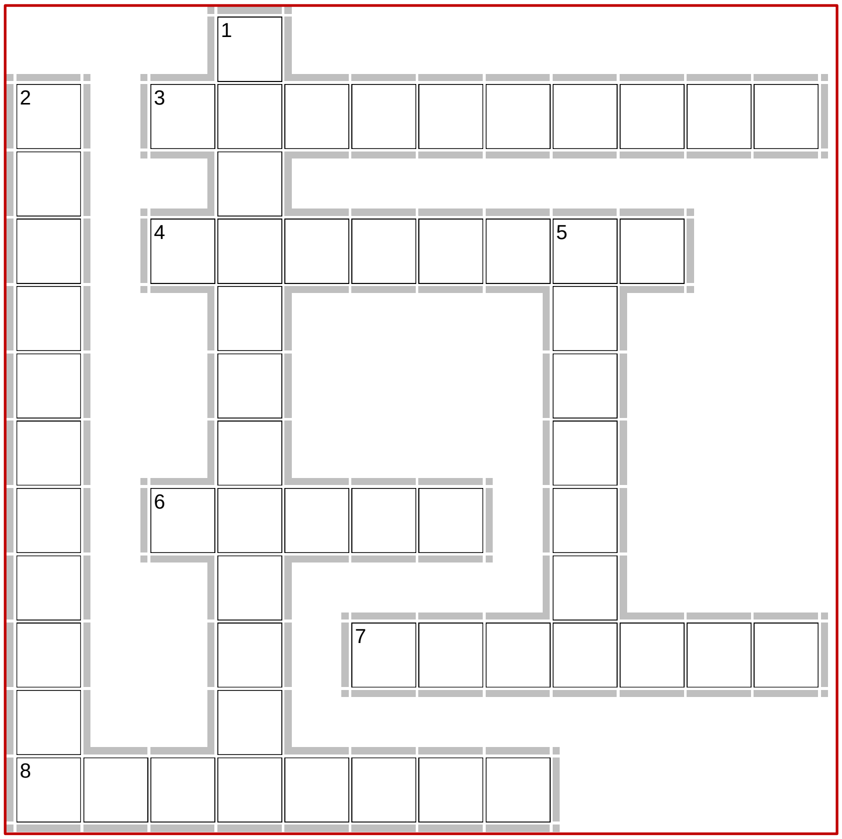
This fortnight Techuzzle



Across

3. HS means ______ in HSD, commonly used Diesel Fuel
4. Residential, Industrial, Commercial - They are fitted to exhaust line
6. Third or Expansion stroke
7. Principally, first stroke of a diesel engine
8. N stands for _____ in NOx, the exhaust gas composition

Down

1. 1-6-5-4-3-2 What is this on a six-cylinder engine?
2. Second Stroke
5. Fourth Stroke

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TA - Turbocharged After cooled

Turbo charging is a technology in which the air sucked by engine, during suction stroke, is "compressed" and its velocity is increased using a "compressor." This compressor is driven by energy of exhaust gases coming from engine. Since exhaust gas is considerably hotter "turbo charged" air is normally made to pass thru radiator or a water cooling jacket, depending on engine design, before it is being fed into engine. The turbo charger rotates at extremely high speeds, in the range of 10000 RPM. The impeller rotates in housing and its clearance is usually lubricated by engine oil itself. If there is a restriction either to intake air flow or exhaust gases, severe backpressure will be created in turbo charger. Under such circumstances, usually, the turbo charger becomes red hot and after continued operation under such condition, it might cease. After-cooling is a method of reducing suction air temperature. If temperature of air is not reduces, its density reduces and combustion efficiency reduces. Hot air does not burn well with Diesel. Turbo charging is also used on modern and expensive petrol engines as well.

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Alfred Buchi - Invented Turbocharger

In 1905, Dr. Algred Buchi, a Swiss engineer received patent 204630 from German Patent office and hence he is being remembered as the inventor of turbochargers, also called turbo compressors. His invention, later was improvised by many automobile companies and the technology came to be known as VTG or Variable Turbine Geometry. Invention of turbo chargers, obviously changed the automotive industry but make wonderful changes in engines used on ships, for power generation and for other purposes. Today, no diesel engines are made without turbo charges. They not only increase fuel efficiency, but reduce emission, improve engine acceleration and to some extent, also reduces noise, which is so much a problem on diesel engines.

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