Optimization of Diesel Consumption in Small Paper Mills based On D.G. Sets

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ABSTRACT

The load of various electrical equipments vary with operational conditions and operating time cycle, while some other equipments operate at constant load. It was observed during the operation of a small waste paper based paper mill that the load can easily be maintained smooth by using the load-time characteristics of various equipments and improvement in power factor. This not only results in increase of life of D.G. Sets and motors, but also reduces the diesel consumption as the set is now supposed to operate at constant load and no energy is being wasted to shift to new load conditions. This paper describes how can the diesel consumption be reduced by using the load-time characteristics and improvement in power factor.

INTRODUCTION

Today, the paper industry is shifting from grid power to D.G. sets and other alternates of power are being sought out such as co-generation, thermal power etc. The present power scenerio has put the paper industry in a tough state being it a power intensive industry. While many of the large mills have shifted to co-generation, and others are thinking of going for the same, the small paper mills, particularly the waste paper mills are becoming in more trouble due to high cost of production due to frequent shutdowns and high cost of grid power, and now many of the mills have started their efforts to depend on D.G. sets.

At this juncture, proper planning of suitable size of D.G. set is very important, if not procured already. In case, it is not possible to replace D.G. set and the existing sets are over or under sized, it becomes very essential to optimise the diesel consumption with the existing sets. The present paper presents some useful tips for the same.

D.G. LOAD BEHAVIOUR

The D. G. set has two functions to perform during operation-firstly to rotate its crankshaft so that the attached parts and accessories e.g. pistons, water pump, nozzle pullenzers, fuel pump, lube pump and exciter may perform their functions; and secondly to provide mechanical power to the alternator field so that the electrical power may be generated. It is,

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therefore, extremely important to understand the behaviour of D.G. set.

Total Power input = Power to rotate parts etc.

+ Power to generate electrical power

+ Loss of energy as thermal energy

+ Mechanical Losses

+ Electrical Losses

The input power can be calculated as,

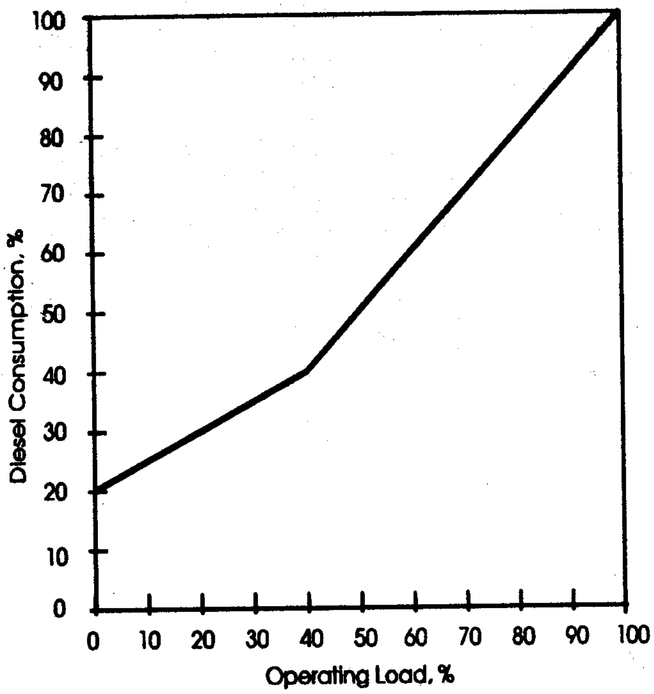
Total Power input = Fuel Consumption x Caloriefic value of fuel.

Here, it is interesting to note that the most D.G. sets operate only at 33-35% efficiency, and the rest power is transmitted to atmosphere as heat energy with exhaust air.

In a typical set, the D.G. was modelled for its power generation efficiency described as under -

The loss of energy as thermal energy also depends on the D.G. load factor for a typical 380 KVA engine (Cummins Model KTA-1150-G) the exhaust gases flow and temperatures are given as under -

Fig. 1 : Diesel Consumption Vs Operating Load



$$\text{Power Generation Efficiency \%} = \frac{\text{Electrical power generated}}{\text{Total power input}} \times 100$$

Load Factor (%)	Exhaust Flow (Lit./Sec)	Exhaust Temp (°C)
50	715	434
75	925	480
100	1133	518

If we analyse this data, we observe that the heat losses per unit of electricity decrease with increase in load. But, on the other hand, the enthalpy of fuel increase in temperature during passing through hotter engine parts. The power required to make the accessories etc. perform their functions may be considered as constant. With this, one may consider that the fuel consumption in a set is linearly proportional to the electrical power generated. In absence of continuous exhaust flow and temperature measurement facilities, the efficiency of power generation was studied by analysis of fuel consumption vs load curve.

The fuel consumption vs load curve (Fig.1) indicates that the diesel consumption is nearly 20% at no load, and it increases linearly to 40% at 40% load. After 40% of load, the consumption increases linearly with load, reaching to 100% at full load. The behaviour at overload conditions could not be studied due to equipment safety reasons.

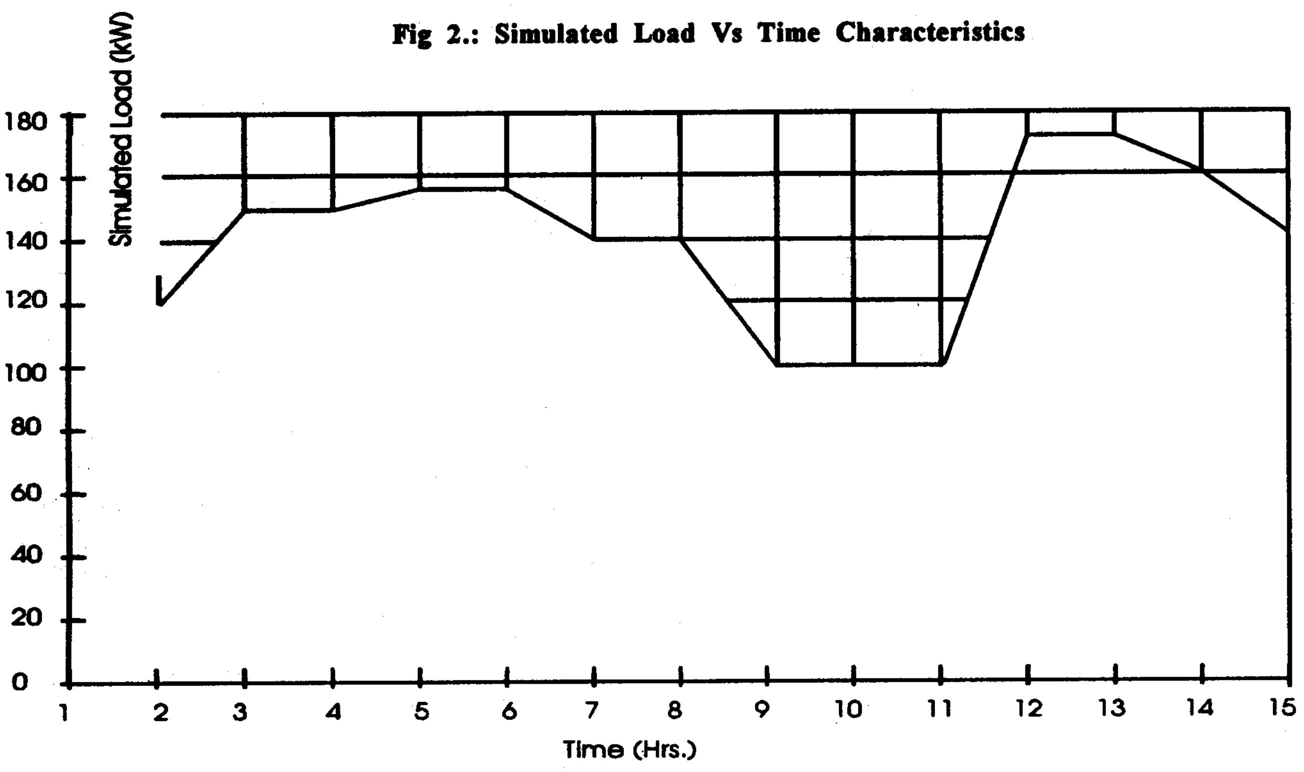
Since, in most cases D.G. manufacturers suggest not to operate the sets at loads below 40% due to technical reasons, such as lube dilution, acidification of lube and hence pitting on crankshaft etc., we may consider the behaviour to be linear.

Some manufacturers indicate the specific fuel consumption in gms./BHP (say 150-154 gms./BHP), for the simplicity of understanding, this unit was converted to Electrical Units/lit and its value was obtained 3.68 Units per lit. As indicated earlier, the figure remains constant at any load between 40% to 100%, the value being 3.60 for a practical case.

PROCESS LOAD BEHAVIOUR

The paper mill consistes of many equipments, motored with different power, and their operations is done as per the process requirement. To model a

Fig 2.: Simulated Load Vs Time Characteristics



small paper mill for the purpose of electrical load distribution, we can divide the motors in three groups.

- The motors of continuous operation e.g. fan pump, vacuum pump etc.
- The motors of intermittent operation e.g. couch pit pump, rewinder, I.D. fan, pulper etc.
- The motors of rarely use. e.g. motors for the equipments which are used for manufacture of lesser demand qualities.

In practical cases, the load on a particular motor is constant, hence the load on a set may be considered as sum of motor load multiplied by average loading time for that motor. But, with this, a possibility arise that all the intermittant start motors are running at a time, resulting in overload on the set as well as all the such motors stopped at a time resulting in underloaded set. to overcome this the process load should be plottted against time, and summed up for all the equipments to generate the simulated load time plot (Fig.2) for all the equipments.

Most of the sets are designed to operate at 10% overload for upto an hour. In any case the connected load should be below 10% oeverload operation. Furthermore, The On-Off cycle time of some motors may be very high, such as pulper etc., while for others it may be low such as the case of I.D. fan. In such cases, the total load should be considered assuming the long On-Off cycle time motors at operating loads and low On-Off cycle time as effective operating loads.

Many a times, it becomes necessary to shift some equipments from one D. G. to the other one. The intermittant operating motors which are independent of other equipments are best suited for the same. The rewinder, sheet cutter, storage chest agitators atc. are good example of these. The dependent motors, such as refiner etc, should be placed on the same D.G. set on which their feed pumps are located. For the same common changeover swich system is a good idea.

ENERGY CONSERVATION THROUGH OPTIMIZATION

Effect of Low Operating Load

Today, the mills pay a lot of attention in reducing energy consumption for the papermaking. But, a D.G. set working at proper operating conditions saves in maintenance costs, In short runs, though the mill may observe same results by running the D.G. set at reduced load conditions, in the longer run, the nozzles start getting choked, thus resulting fuel handling capacity of the nozzles and the fuel system needs more energy to pump the diesel. Furthermore, if the nozzles of one of the cylinder are fully or partially blocked, the other nozzles have to feed the remaining fuel, thus overloading the other cylinder and hence increased fuel consumption. That is why, in a typical case, where two sets were in operation, with one working at about 90% continuous load, and the other at about 50% load, the diesel consumption in second set increased by about 3.5% When computed this figure at normal 90% load conditions, this amounted to about Rs. 2.00 Lac. per year (about 20% of the cost of the set).

EFFECT OF JERK LOAD

Jerk load affects the fuel consumption adversely. Let us consider a set working at normal load. As some big motor is started, the starting current may be as high as 10-12 times the normal full load current of motor. The starting power creates a jerk on the D.G. crankshaft, and the piston in the movement gets slower, and hence desired pressure in the cylinder cannot be met. Thus the fuel fed to the set is wasted.

The jerk effect is high at the time of underload condition, hence, the big motors should be started preferably when the set is running at a minimum of 35-40% load. Slow loading is also a good arrangement for the same purpose, such as the case of pulper starting. The pulper should be started at minimum level and the waste paper loading to be started increasing the loading rate to normal in a few minutes.

EFFECT OF POWER FACTOR

The paper mills working on D.G. sets often suffer from the low power factor. The fear against damage to equipments due to installed capacitors contributes most to the reluctancy in this area. Some trials were conducted at different loading rates, and it was observed that in some cases, the sets were operating at extremely low power factor even at 0.65 to 0.70. In a typical case installation of capacitors improved the power factor to 0.9.

One thing to be kept in mind while installing capacitors is that the power of the alternators as per design is kept at 0.80. Installation of capacitors should not increase the power factor beyond this and if it is done, the load should be suitably reduced in terms of amperage so that the total KW on the D.G. alternator does not increase beyond the rated one. The KW load can be calculated by the formula-

$$KW = \sqrt{3}.V.I.\ \cos\phi$$

where, V is line voltage,

I. is line current and $\cos\phi$ is the power factor.

In a typical case, on a 125 KVA set the amperage were reduced from 240 to 174, and the KW reduced from 122 to 120 on installation of capacitors. This saving of load was due to reduction of I^2R losses (line losses) due to reduced current in alternator, line, and motors. Furthermore, this resulted in reduced temperature of motors, and hence improved motor life; improved alternator life, safety to motor and alternator insulation, and a possibility to increase the load on D.G.

EFFECT OF MOTOR LOADING

During normal operation it was observed that the some of the motors were running at very low load. All such motors were found to be a significant reason for low power factor. Data from some motor manufacturers revealed that underloading of motor results in reduction in motor efficiency, and power factor. Replacement of such motors with low powered motors was found very useful and the plant operating load was reduced from 1100 Amp. to 1000 Amp., roughly resulting in 9% diesel saving alongwith some increase in power factor.

CONCLUSION

Saving energy and protecting environment is the need for today. A properly distributed load with improved power factor and suitably loaded D.G. sets can save even upto 10-15% of diesel. In a typical case, such measures have resulted in nearly 5-7% diesel saving without affecting the process. With further improvement, the saving is expected to increase further.