

Energy Conservation in Boiler by Variable Speed Drives (VSD)

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Abstract: Applications of technologies have tremendous potential to reduce industrial energy use. Industrial energy use can also be reduce using variable speed drive in motor operated system, high efficient motors, efficient nozzles in compressed-air system, waste heat recovery system in boilers. Energy saving by management including energy audit, training programs and housekeeping beside some energy management practices in the world has been reviewed. Energy saving technologies, such as use of high efficiency motors (HEMs), variable speed drives (VSDs), economizers, leak prevention and reducing pressure drop has been reviewed. Based on energy saving technologies results, it has been found that in the industrial sectors, a sizeable amount of electric energy, emissions and utility bill can be saved using these technologies. Payback periods for different energy savings measures have been identified and found to be economically viable in most cases. Finally, various energy-saving policies for few selected countries were reviewed.

Keywords: Introduction of boiler, Boiler system, Variable speed controller in a boiler

I. INTRODUCTION

Energy cost is a significant factor in economic activity, on par with factors of production like capital, land and labour. The imperatives of energy shortage call for energy conservation measures, which essentially mean using less energy for the same level of activity. A boiler is an enclosed vessel that provides a means for combustion heat to be transferred into water until it becomes heated water or steam. The hot water or steam under pressure is then usable for transferring the heat to a process. Water is a useful and cheap medium for transferring heat to a process. When water is boiled into steam its volume increases about 1,600 times, producing a force that is almost as explosive as gunpowder. This causes the boiler to be extremely dangerous equipment that must be treated with utmost care. The process of heating a liquid until it reaches its gaseous state is called evaporation. A boiler is said to be efficient, if it converts all the chemical energy in the fuel into heat energy and also transfer them fully to the incoming water.

II. BASIC BOILER SYSTEM

The boiler system comprises of feed water system, steam system and fuel system. The feed water system provides water to the boiler and regulates it automatically to meet the steam demand. Various valves provide access for maintenance and repair. The steam system collects and controls the steam produced in the boiler. Steam is directed through a piping system to the point of use. Throughout the system, steam pressure is regulated using valves and checked with steam pressure gauges. The fuel system includes all equipment used to provide fuel to generate the necessary heat. The equipment required in the fuel system depends on the type of fuel used in the system. A typical boiler room schematic is shown in Figure 1.

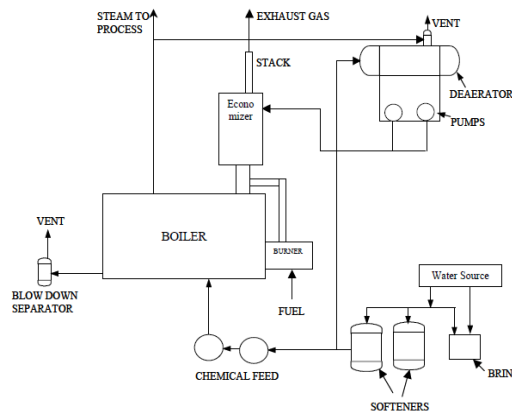


Figure 1. A typical boiler room schematic

The water supplied to the boiler that is converted into steam is called feed water. The two sources of feed water are: (1) Condensate or condensed steam returned from the processes and (2) Makeup water (treated raw water) which must come from outside the boiler room and plant processes. For higher boiler efficiencies, the feed water is preheated by economizer, using the waste heat in the flue gas.

A. Required qualities for a satisfactory boiler

- Should be capable of quick start-up
- Should meet large load functions
- Occupy less floor space
- Should afford easy maintenance and inspection
- Various joints should be accessible for inspection and should be away from direct flame
- Tubes should be sufficiently strong to resist wear and corrosion

B. Factors to be considered for selecting a boiler

- Power required to be generated
- Operating pressure
- Fuel quality and type
- Water availability and its quantity
- Probable load factor
- Cost of operation and maintenance
- Cost of installation
- Availability of floor space

C. General rules (“Rules of Thumb”)

- 5 percent reduction in excess air increases boiler efficiency by 1 percent (or 1 percent reduction of residual oxygen in stack gas increases boiler efficiency by 1 percent).
- 22 °C reduction in flue gas temperature increases the boiler efficiency by 1 percent.
- 6 °C rise in feed water temperature brought about by economizer/condensate recovery corresponds to a 1 percent savings in boiler fuel consumption.
- 20 °C increase in combustion air temperature, pre-heated by waste heat recovery, results in a 1 percent fuel saving.
- A 3 mm diameter hole in a pipe carrying 7 kg/cm² steam would waste 32,650 liters of fuel oil per year.
- 100 m of bare steam pipe with a diameter of 150 mm carrying saturated steam at 8 kg/cm² would waste 25 000 liters furnace oil in a year.
- 70 percent of heat losses can be reduced by floating a layer of 45 mm diameter polypropylene (plastic) balls on the surface of a 90 °C hot liquid/condensate.
- A 0.25 mm thick air film offers the same resistance to heat transfer as a 330 mm thick copper wall.
- A 3 mm thick soot deposit on a heat transfer surface can cause a 2.5 percent increase in fuel consumption.
- A 1 mm thick scale deposit on the waterside could increase fuel consumption by 5 to 8 percent.

III. VARIABLE SPEED CONTROLLER IN A BOILER

VSD is used, which is a way of the most efficient control method. It provides only the power necessary to overcome system resistance at a given condition. Currently, variable speed drives are commonly used in modern industrial and commercial boilers. The modern boiler systems are designed, equipped and practiced with the described method at present time. It is particularly effective when operating conditions call for frequent low load periods. With mechanical cam control and with basic electronic fuel/air ratio control processor sacrifice combustion efficiency at low fire to achieve an improvement in burner turndown. Some air dampers leak and even air flow is fully closed can be significant. In effect, processors can reduce the fuel valve setting but cannot reduce the air to match. Combustion efficiency can be improved at low fire if the fan speed is reduced.

The fan motor speed control is an easy to add option on some electronic controls. By adding fan motor speed control, burner turndown can be increased without compromising efficiency, and additional fuel savings can be achieved. The benefit of variable speed drive by using an inverter to slow down an AC electric motor causes electrical energy saving. By adding a driver to the system, and controlling the fan motor speed, electrical energy is saved and by restricted excess air rate, stack losses are minimised. Hence, not only will boiler efficiency be increased, but operating the motor with variable speed will also save electrical energy. Oxygen trim saves fuel, reduces emissions and extends the life of the boiler plant. Ambient air temperature is also an important parameter that affects all types of combustion equipment. It can have a dramatic effect on boiler efficiency.

The speed of a motor can be adjusted by changing the frequency applied to the motor. The motor speed can also be adjusted by changing the number of poles, but this is a physical change to the motor. It would require rewinding, and result in a step change to the speed. So, for convenience, cost-efficiency, and precision, changing the frequency is the best solution. In order to change the motor torque the volts per Hertz ratio must be changed. A drive provides many different frequency outputs.

In many commercial and industrial environments, the application of variable speed drive is cost effective. Energy savings are possible due to reduced power consumption by the motors; as the system power requirements are reduced, the power consumed by the equipment can be reduced by an amount significantly greater than can be achieved with the existing controls. The variable frequency drive is a device that controls the motor speed by regulating the frequency of the power supply. The speed of driven equipment is proportional to the frequency. Power used to drive pumps and motors varies with the cube of the speed, making energy savings very significant for even modest decreases of speed. In order to obtain constant maximum torque, the ratio of applied motor voltage to supply frequency is held constant by increasing motor voltage directly with frequency. This type of control is generally termed constant volts per Hertz.

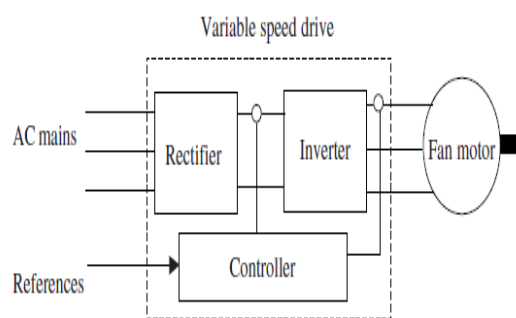


Figure. 2 variable speed drive control system

Benefits of the variable speed drive summarized as reducing of electricity consumption, elimination of requirements of a separate motor starter, improvements in fan control and extending of equipment life. A variable speed drive operated fan for the boiler not only save electricity but also maintains high fuel efficiency for part load conditions by controlling the excess air more precisely.

A. Working laws of VSD

Symbols

- D = Fan size
- N = Rotational speed
- P = Pressure
- Q = Volume flow rate
- W = Power
- ρ = Gas density

1) Fan Law 1

The first fan law relates the airflow rate to the fan rotational speed: Volume flow rate, Q, is directly proportional to the fan rotational speed, N.

$$(Q_1/Q_2) = (D_1/D_2)^3 (N_1/N_2)$$

2) Fan Law 2

The second fan law relates the fan total pressure or fan static pressure to the fan rotational speed: Total or static pressure, P, is proportional to the square of the fan rotational speed, N.

$$(P_1/P_2) = (D_1/D_2)^2 (N_1/N_2)^2 (\rho_1/\rho_2)$$

3) Fan Law 3

The third fan law relates the total or static air power (and the impeller power), W, to the fan rotational speed: Power, W, is proportional to the cube of the fan rotational speed, N.

$$(W_1/W_2) = (D_1/D_2)^5 (N_1/N_2)^3 (\rho_1/\rho_2)$$

B. Calculation

To see the effect of VSD on energy consumption we have chose the motor of 3HP.
 Total working hours per year = 2920 (8 hr shift/day * 365 day)
 From the tables , it is seen that energy consumption is lesser in case of use of VSD.
 Table 4 shows the saving in energy per year.

Table:-1 Energy consumption without VSD

operating speed%	Time (A) hr	Power load (B) kW	Energy use = (A*B) kWh/yr
10%	2920	2.9	8468
20%	2920	2.9	8468
30%	2920	2.9	8468
40%	2920	2.9	8468
50%	2920	2.9	8468
60%	2920	2.9	8468
70%	2920	2.9	8468
80%	2920	2.9	8468
90%	2920	2.9	8468
100%	2920	2.9	8468
			Total=84680

Table:-2 Energy consumption with VSD

operating speed%	Time (A) hr	Power load (B) kW	Energy use = (A*B) kWh/yr
10%	2920	0.5	1460
20%	2920	0.9	2628
30%	2920	1	2920
40%	2920	1.1	3212
50%	2920	1.2	3504
60%	2920	1.4	4088
70%	2920	1.9	5548
80%	2920	2.2	6424
90%	2920	2.6	7592
100%	2920	2.9	8468
			Total=45844

Table:- 3 Energy Consumption comparison

operating speed%	Time hr	energy use kWh/yr	energy use kWh/yr	Saving Kwh/yr
10%	2920	8468	1460	7008
20%	2920	8468	2628	5840
30%	2920	8468	2920	5548
40%	2920	8468	3212	5256
50%	2920	8468	3504	4964
60%	2920	8468	4088	4380
70%	2920	8468	5548	2920
80%	2920	8468	6424	2044
90%	2920	8468	7592	876
100%	2920	8468	8468	0

Table 4 Energy saving at actual operated speed

load %	Time hr	Power load (Without VSD) Kw	energy use kWh/yr	Power load (With VSD) kW	energy use kWh/yr	Saving KWh/yr
100	400	2.9	1160	2.9	1160	0
80	900	2.9	2610	2.2	1980	630
70	800	2.9	2320	1.9	1520	800
60	820	2.9	2378	1.4	1148	1230
Total	2920		8468		5808	2660

IV. OVERALL RESULTS

The overall energy saving using VSD per year is 2660 KWh/yr. Considering per Kwh charge of Rs. 5.70, per year saving of Rs. 15160 can be achieved.

V. CONCLUSION

It can be concluded that VSD is a good option in energy conservation in a boiler. It can also be concluded that as the HP of the motor increases, the energy saving also increases.

VSD installation also helps in controlling of following factors ,

- **Control excess air** and as per thumb rule 1) - 5 percent reduction in excess air increases boiler efficiency by 1 percent (or 1 percent reduction of residual oxygen in stack gas increases boiler efficiency by 1 percent).
- **Control stack temperature** air and as per thumb rule 2) - 22 °C reduction in flue gas temperature increases the boiler efficiency by 1 percent.
- **Air/fuel ratio control**

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BIOGRAPHY



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