Strategic Study and Approach of Energy Saving Opportunities in Process Industries through Application of Variable Frequency Drive and Practical Case Study Carried Out in Finchaa Sugar Factory

Mekonnen Shewarega
B.Sc. in Electrical Engineering, M.Sc. in Electrical Engineering (Rochester Institute of Technology, RIT, New York)
Senior Electrical and Industrial Instrumentation Engineer

Abstract:- In process industries like sugar factories and other processing plants, there are lot and various types of fans, pumps and material process that are installed to accomplish process objectives. The existing operation trends and system arrangements of most process industries are not effective from energy saving perspectives, whereas there is a big room for energy use saving if the feasibility of such aspects are made visible. In this regard, many white papers are issued proving and indicating that process industries can gain energy saving by studying their current operation trend and implementing proper automatic systems. To this effect, a practical energy saving study is conducted in above mentioned sugar factory for its boiler "Draught Control System" equipped with ID (Induced Draft) fan running in fixed speed arrangement versus the Variable Frequency Drive (VFD) enabling to adjust the speed of ID fan in line with the actual demand. The study revealed that significant amount of energy saving is obtained resulting a minimized CO2 emission as well and the study has also incorporated the economic and cos-benefit analysis.

***Keywords*:-** *VFD (Variable Frequency Drive), CO2 emission, Energy Saving, Induced Draft Fan (ID Fan), Boiler Plant, Draught Control System, Bagasse.*

I. INTRODUCTION

ACEEE (American Council for an Energy-Efficient Economy), in its one of white paper pointed out " since Fans and Pumps systems provide opportunities for energy savings and account for 40 % of the electric motor systems energy use (see figure 1), they are a prime target for energy efficiency effort". Actually, most of the available savings from fans and pump systems require understanding of the market place and good application-specific engineering study.

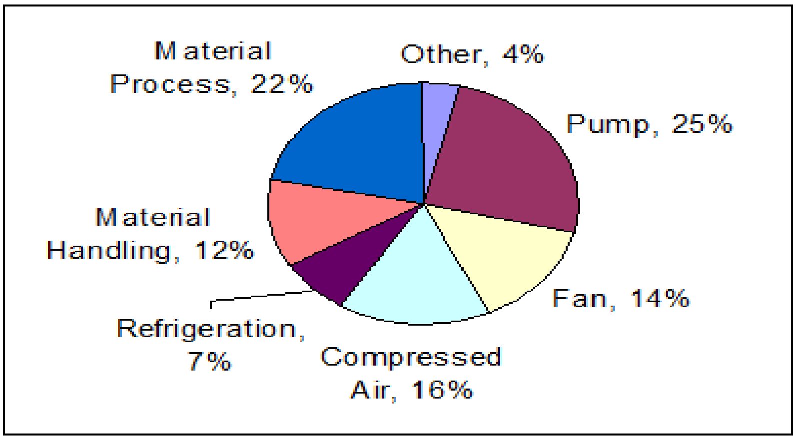

Fig 1:- Motor Systems and use (Source; ACEEE)

Fans and pumps motor energy use varies as the cube of the motor speed **($P \alpha n^3$).** Small changes in motor speed can have large impacts on energy use. Motor speed can be changed through the use of Adjustable Speed Drive (ASD), also known as Variable Frequency Drive (VFD). VFD is capable of generating a variable frequency that enables motor to rotate at any point of speed within its allocated range. Hence, VFD makes it possible to operate fan motor or pump motor at a speed needed for the capacity required. Without the ability to adjust the speed and the kW of the motors in response to the variance in load demands, the drive motor runs at constant speed wasting a lot of energy.

The evolution of VFD technology has seen many changes in a relatively small time frame. The reputation of VFD, as reliable and cost effective method of variable speed control was poor if one looks back some 20 to 25 years ago. But, in recent years, the technology of VFD has evolved into highly digital microprocessor control, which has led to significantly advanced capabilities from the ease of programmability to expanded diagnostics. The two important significant benefits from the evolution in the technology are:

- That of cost and reliability;
- Significant reduction in physical size when compared to the VFD products on the market of old time (20 to 25 years back), which were expensive, unreliable and physically large.

This paper focused on strategic approaches and identification methods of energy savings in process industries related to pumps, fans and other drives which provide large opportunities for energy savings and account for motor system energy use through implementation of appropriate variable frequency drives (VFD). The study further presented a practical study of energy saving conducted in boiler plant (Induced Draft fan motor) of Finchaa Sugar Factory.

II. SYSTEMATIC APPROACHES AND IDENTIFICATIONS OF ENERGY SAVING OPPORTUNITIES IN PROCESS INDUSTRIES

Mostly, any processing plants do have fans, pumps, material processes, which do have room for energy savings. In practicing review of process industries for energy saving schemes with subsequent development of recommendations, a systematic approach and identification techniques are required in order to arrive at practical results. The first step of the systematic approaches is to identify the critical operating points of trend, which includes capacity information, energy usage (kW) and information affecting efficiency of equipment. After having identified the critical operating points, the following approaches are to be followed:

- Trends are to be established to collect operating data on ½ hr or 1 hr basis.
- Modelling of the actual sequencing strategies of plant operation that are implemented.
- Gathering operating information that is available from the individual system components using microprocessor based Data Acquisition System (DAS) instruments for various electrical and process measuring quantities.
- Identification of saving opportunities through detailed analysis of specific site and system operation, and understanding of current design, selection and operation and maintenance practice.
- Proper evaluation is essential to accessing and correctly applying VFD. VFD makes it possible to operate pumps, fans and compressor motors at a speed needed for the capacity required. Without the ability to automatically adjust the speed and the kW of the motors in response to the actual load demands, the drive motor runs at constant speed wasting a lot of energy. In addition, there could be a great potential for energy savings if the original design philosophy was set for the worst case maximum water flow, air flow or other media flow conditions.
- Development of baseline of operations through the established modelling, identification of energy saving opportunities areas and points.
- The most significant opportunities related to current operation trends that may provide energy saving by implementing proper automatic sequencing systems.
- The accuracy of calculation of the energy savings shall depend on the enhanced models developed from operation trends.
- Evaluation using life cycle costing techniques.
- The economic evaluation needs to consider the installed cost, change in maintenance cost and system service life.
- Indication of the annual cost reduction per year through implementation of the energy saving system.
- Indication of the annual cost per year that is used to maintain and install the monitoring units.
- Estimation of installed cost with its service life and indication of the Net value resulted from implementing the above energy saving mechanisms.
- Indication of projected payback period of the installed systems (like VFD, automatic sequencing system, etc…)

III. PRACTICAL CASE STUDY OF ENERGY SAVING CONDUCTED FOR SPECIFIC PLANT (BOILER INDUCED DRAFT FAN MOTOR) OF FINCHAA SUGAR FACTORY

A. The Selected Energy Saving Area in the Factory

Finchaa Sugar Factory do have two boiler plants each with steam flow capacity of 65 tone/hr at temperature and pressure of 400^0c and 30 bar. The steam is utilized at various plants of the factory for the purposes of electric power generation through steam turbines, direct drive of mills and shredder, and other heat exchanging applications. In order for the respective boilers to sustainably feed the plants in steady and controlled manner, various control systems are involved, i.e. Feed water control system, Oxygen trim, Combustion control system, draft control system, in the like. The respective boiler system is equipped with Distributed Control System (DCS), which is microprocessor based system with modular architecture having peer-to-peer communication capability to share data asynchronously among modules. All control and data calculations are executed in the modules and the respective interface outputs go to different slave units (like dampers, control valves, drives, etc.)

The practical energy saving study is conducted on the “Draught Control System” which is equipped with ID (Induced Draft) fan with variable frequency drive (VFD) of General Electric origin ACG2000G series, Though this VFD is capable of generating a variable frequency (0 – 50 Hz) that enables ID fan motor to rotate at any required point of speed, the automatic speed varying capability was not functional and reliable. Hence, the operation trend of this VFD is altered to run the ID fan motor at a fixed speed and the control of the furnace draught is manipulated through varying the damper opening. To this effect, if the operation trend of this VFD were to use the automatic speed varying capabilities or other current and cost effective VFD were implemented, the energy saving opportunity that may be obtained from this specific operation of fan alone could have been high.

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B. The Energy Saving Estimate

- *The Boiler ID Fan Operating Energy Cost*

With the current operation trend of the boiler plant, the ID fan motor (rated capacity of 400 hp) is running at fixed speed. Whether the boiler plant operates at its minimum or maximum capacity of steam production, the ID fan motor is operating at fixed speed without the adjustment of the actual power demand and hence wasting energy.

Therefore, with electricity at about 0.04375 USD/ kWh, the boiler ID fan with 70 % load factor (average load factor record) in continuous operation, driven by an A.C. induction motor of 400 hp, consumes energy of (400 hp X 0.746 kW/hp X 4620 hrs/year (campaign hrs) X 0.7 X 1/0.967 (motor efficiency) = **997,958.22 kWh** and generates cost of 997,958.22 kWh X 0.06 USD/kWh = **59,877.49 USD/Year.**

As sugar factory produces its own electricity from Bagasse (residue of sugar cane) energy, it may be essential to put it in terms of kg Bagasse consumed. As per the operational and nominal design parameters of boiler and turbo-alternator of the factory, 0.25 kWh can be generated through 1 kg Bagasse. Thus, 997,958.22 kWh X 4 kg Bagasse/ kWh = **3,991.83 Tonnes of Bagasse /Year.**

- *The Operating Data for Boiler ID fan Motor, 400 HP*

The operating data are collected from the factory operation log book which records the hourly operation status and parameters of the plant. Based on the standard correlations of load and air flow profiles, the actual electric power requirement of the ID fan drive is computed from the hourly recorded data of load, air flow and other related boiler parameters. The actual power requirement consumed by the ID fan motor would have been per the operation data depicted in table below, had the VFD of the fan motor utilized the automatic speed varying capability by providing the actual capacity required for the instant load demand.

Operating time, hrs	Motor ratings, kW	Energy, kWh
184.8	264.49	48,877.75
693	192.81	133,617.33
1155	135.42	156,410.10
1386	90.72	125,737.92
924	57.13	52,788.12
277.2	33.06	9,164.23
Total hrs 4620		**526,595.45 kWh**

Table 1:- Operating Data of ID fan drive, computed from recorded boiler parameters and nominal designs.

- *Energy Savings from Adjusting Fan Speed*

For various operating periods of the ID fan (Table 1), the kWh consumptions are inferred from the actual records of the boiler operation parameters. These are summed up to obtain the annual kWh demand of the fan drive. The difference between this total and the annual power required for continuous full-speed motor operation represents the energy saving obtained from variable speed operation of the motor. The total estimated kWh of the ID fan drive (if it were operated by the variable speed control) is 526,595.45 kWh (in Table 1). The annual saving in terms of electric power: (**997,958.22 kWh** minus **526,595.45 kWh**)= **471,362.77 kWhr/Year**.

In terms of the bagasse saving, with 4 kg Bagasse per 1 kWh generation, 526,595.45 kWhr X 4 kg Bagasse/ kWhr = **2,106.38 tonnes of Bagasse /Year.** The difference between the annual energy required fro continuous operation and the annual required for variable speed is the annual saving, which in terms of Bagasse: (**3,991.83 minus 2,106.38) = 1,885.45 Tonnes of Bagasse /Year**,

- *Energy Saving Calculator and VFD sizing & selection Software*

VFD manufacturers like ABB, Honeywell, etc. release some user-friendly energy calculator software which enables to compute and find out respective cost-benefit, energy saving and CO_2 emissions minimization. ABB, one of the VFD manufacturers in the world produces various types of VFD for different applications and the VFD manufacturer (ABB) product is utilized to merely substantiate the actual energy saving analysis made in sections 3.2.1 and 3.2.3. The output of the calculated energy saving is shown in figure 2, keyed in with design & operation parameters of the fan drive.

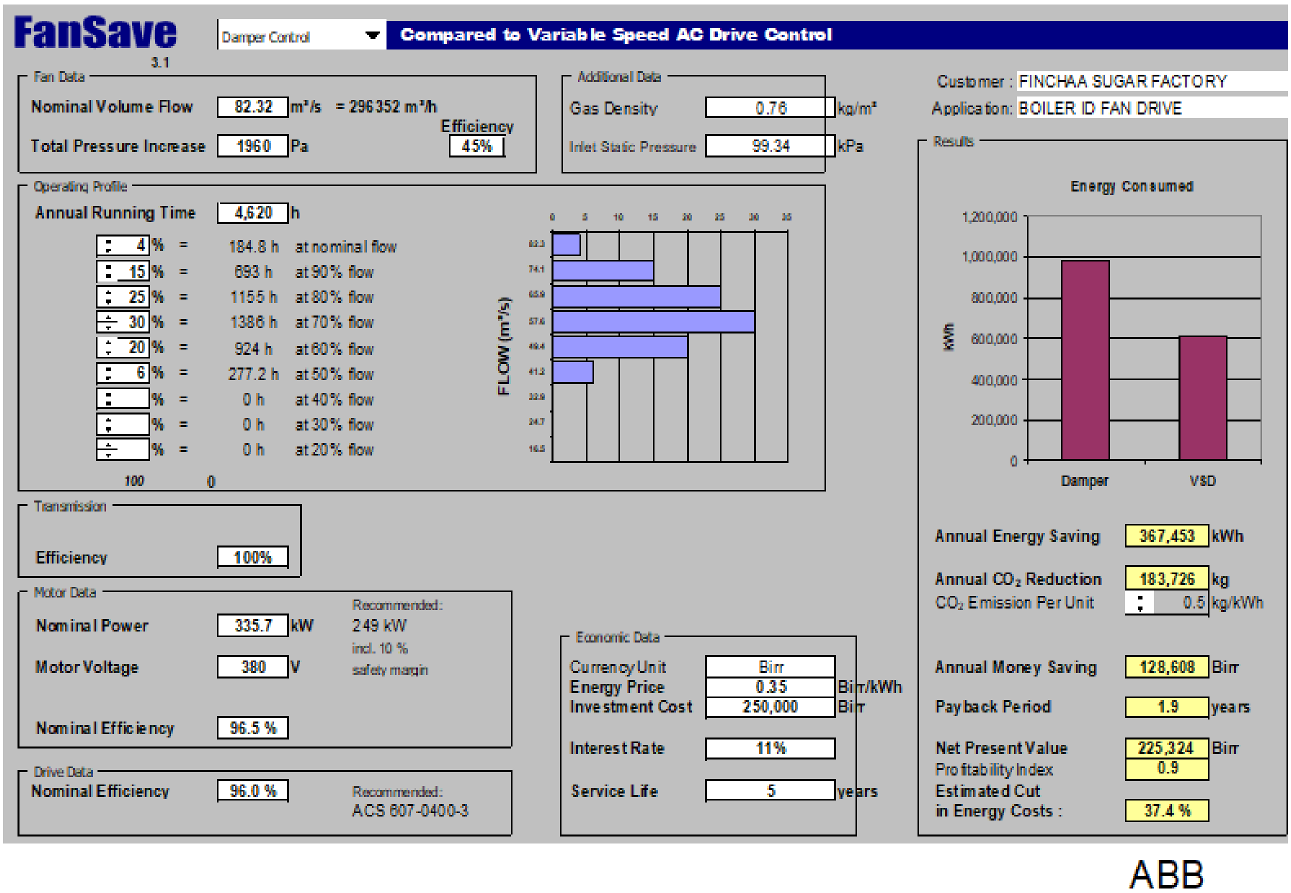

Fig 2

IV. CONCLUSION

In brief, energy saving opportunities within process industries do have various dimensional aspects. The Variable Frequency Drive (VFD), which is emerged as result of the recent technology advancement have become one of the energy saving opportunities potential in addition to its functional advantage. However, the energy saving potentials associated with VFDs are not well-known due to the poor availability of application-specific and system-specific information regarding applicability of VFDs. In various countries, for instance, some process industries like sugar factories introduced VFD technologies outlaying huge investments. Whereas, the maximum application benefits, which can be harvested from the technology with respect to energy savings, are not usually practiced.

The study has stretch out emphasis to the energy saving aspect of VFD technologies and its parallel advantage in resulting in minimized CO2 emissions for power plants of the above types associated with CO2 emissions in the boiler plants and provided glimpse of energy saving and environmental impacts to the professionals in the area of energy audit, specifiers, designers, consultants and end-users so that this aspect can get due emphasis during overall energy audit studies and recommendations, specification and design phases of process industries and buildings accompanied with HVAC systems.

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