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Energy Audit In Industrial Drives

Energy saving and Payback period

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Abstract—**In industrial sector majority of the loads are inductive loads, which results in losses and low efficiency of the power system. New method of energy conservation using speed control methods of motors which improves energy saving and makes efficient speed control of motors.**

Previously throttling the damper of the motor did the speed control and this method is energy inefficient as a part of energy supply to the fan is the lost across the damper. After this varying the rotor resistance in the motor circuit makes the speed controlling. Doing so rotor slip energy is wasted in the form of heat energy hence a search for new technology started in the arena of control systems.

In the advent of modern control systems the art of slip power recovery system (SPRS) is introduced as a speed/ flow control mechanism for the slip ring induction motors. It recovers and delivers the slip dependent rotor power from the motor to grid as in the regenerative braking. But due to low efficiency of the slip ring induction motor, high maintenance cost, high installation cost, use of transformer and more equipment involvement made the industrial sector to search for another new method. This search resulted in introduction of Variable Frequency Drives (V/F Drives). Which are more efficient and flexible than that of other methods discussed above.

The study emphasizes the practical application of the Variable Frequency Drives and Energy conservation by using these drives.

I. Introduction

"THE MODIFIED PRINCIPLE OF ENERGY CONSERVATION IS WESHOULD MINIMIZE THE LOSSES OR USE EFFICIENTLY"

The Indian power sector more than tripled its installed capacity for 30GW in] 981 to over 110GW in2003-04. However our country still plagued by severe peaking and energy shortages. These shortages exacerbated by in-efficiencies in power generation, distribution and end use system (mostly in induction motor). The Inefficiencies in the end use system are due to irrational tariff, technological obsolescence of industrial equipment and lack of awareness in nascent energy service industry and inadequate drivers.

When we consider the present energy scenario in India, the following points are important,

Installed capacity nearly 110000MW
36% of installed capacity wasted now.
70% of the population lives in villages.
70% of power consumption is in cities.
70,000 of villages have no electric poles.

India is taking continuous effort on this area like energy conservation act 2001, energy conservation day, and bureau of energy efficiency. This article presents an analysis of partial loaded induction motor with reference to power electronics.

Power electronics is one of the broadest growth areas of electrical technology. Today electronics energy processing circuits computer systems, every digital industrial system of all types, automobiles, home appliances lamps and lightning equipment, motor controllers are just about every possible application of electricity.

In recent years the field of power electronics has experienced large growth due to confluence of general factors. Revolutionary advances in semiconductor fabrication technology have made it possible significantly to improve the voltage and current handling capability and the switching speed of power semiconductor devices, industrial and power system applications. At one time, the growth was pushed by energy conservation goals.

In many applications constant speed operation, induction motors operate under no load or light load for prolonged periods. Such as pressing machine, conveyors rock crushers, centrifugal, drill presses; wood saw some machine tools in such applications, saving in energy can achieved by operating motors at low voltages. While running in no loads and light loads.

When a motor operates at full voltages at no load core loss as a large value reduction in voltage increases copper losses but reduces core loss by large amount therefore net loss is reduced. At some voltage when core loss becomes equal to copper loss, the loss has minimum value and efficiency is high. Any increase or decrease of voltage from this value increases the loss there fore for each loading there is an optimum value of voltage for which the loss is low. Energy saving is achieved by operating the induction motor at optimum voltage values.

II. Need for Study:

Many VFD's now have an energy optimizing future incorporated in their design, which can be useful with slowly varying loads. This feature reduces the output voltage at low loads and thus reduces the iron losses. The energy saving, this is in the addition to that from slowing down the load, is difficult to estimate. Although it is unlikely that the saving from the energy-optimizing feature alone would be sufficient to justify the purchase of a VFD, they do provide a useful bonus at little or no additional cost when at low speeds. There is particularly time for the application where the motor is oversized.

Recent introductions of equipment with in built VFD have several advantages and are available for the pumps, fans, and air-conditioning units. The advantages of these units are

- Lower cost than conventional Drives.
- Reducing wiring time.
- No electromagnetic interference emissions from the motor side inverter leads, cables.
- Optimum matching of motor to VFD.

III. METHODS OF SPEED CONTROL / FLOW CONTROL:

There are two types of speed control mechanism,

- By using Rotor Resistance.
- By using the Drive Mechanism.

ROTOR RESISTANCE METHOD:

In starting days of industrial applications for the speed of the motor is controlled by addition of rotor resistance into the motor circuit. By doing so, rotor slip energy is wasted in the form of heat energy through resistance and hence the speed of motor is controlled.

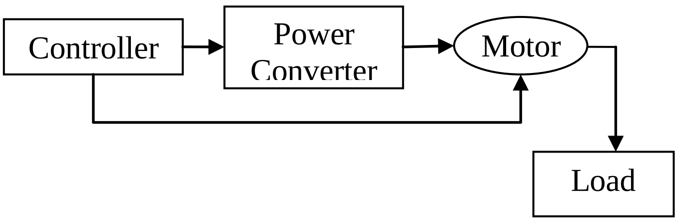
But in this method there exists higher losses, higher vibrations and also there is poor speed regulation in the system.

DRIVE MECHANISM:

An electric motor together with its control equipment and energy-transmitting device forms an Electric Drive. An electric drive together with its working machine constitutes an electric drive system. The different types of drives are as follows.

- Fixed Speed Drives. (SPRS)
- Variable Speed Drives.
- DC Drives
- AC Drives

The following figure shows a simple drive mechanism that uses a feedback network for controlling the speed of the given motor.



IV. SPEED CONTROLLING & ENERGY RECOVERY SYSTEM:

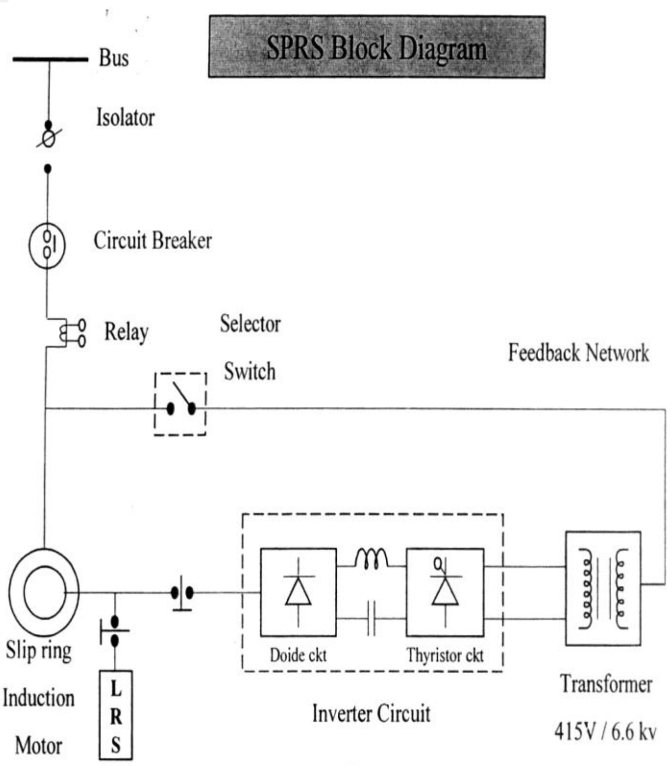
In industries like cement, steel, power etc majority of powers are fan type conventionally the fans are controlled by throttling the suction damper to meet the required flow the operation of centrifugal fan by throttling the damper is energy inefficient as part of the energy supply to fan is lost across the damper. To conserve the energy install a drive to meet the variable flow capacity.

The state-of-the-art of SPRS is a variable speed drive for slip ring induction motors. It recovers and delivers the slip, dependent on rotor power from the motor to the grid. The basic operational principle of SPRS, the diode rectifier converts the rotor voltage to dc voltage. A line commutated inverter counter balances the rectifier rotor voltage. By controlling the counter balancing meter voltage the rotor current is controlled. Hence the rotor speed is regulated thus slip power collected at the slip ring is fed back to the grid through inverter.

Features: -

- Designed for tropical conditions.
- Conceived for process stability.
- Environment friendly configuration.
- Safety of induction motor.
- Supply voltage fluctuations.
- Safety to mechanical system.

V. FIXED SPEED DRIVES (SPRS):



BRIEF DESCRIPTION OF SPRS: -

The state of art of slip power recovery system will act as a flow control mechanism for the motors (Slip ring induction motors) used in the industrial purpose. The system will recovers the slip dependent rotor power from the motor and delivers it back to the grid through a feedback network.

The basic operation principle of SPRS is the power is recovered from the slip rings and this will fed to the inverter circuit where the diode circuit will rectifies the varying 3-phase Ac to DC output, these ripples are eliminated by using the filter circuit.

The fully rectified DC converted into constant 415 V, 50 Hz 3-phase AC supply by using the thyristorised converter circuit. This 415 V 3-phase 50 Hz supply is fed to a feedback transformer (415V/6.6 KV) to step up this voltage to 6.6 KV and deliver the recovered back to the supply mains.

LRS (Liquid Resistance Starter) is used to keep the rotor resistance to suit the starting torque and restrict starting current to 1.5 times to that of the full load current. The various locations where the LRS is placed are as follows

- Kiln stirring fan
- Calciner stirring fan
- Raw mill
- Coal mill
- Bag house fan

Advantages of SPRS:-

- It is especially designed for tropical conditions.
- Conceived for the process stability.
- This method is environmental friendly.
- It assures safety to the Induction Machine.
- Supply voltage fluctuations can be controlled.

Disadvantages of SPRS: -

- Speed control through this method is not so efficient.
- The slip ring induction motor is less efficient than the Squirrel-cage-induction-motor.
- The maintenance cost is more.
- This system occupies more floor area.
- Even though 100% efficient dampers are used there exists-6%-loss-in-the-airflow.
- Remote operation of this system is not possible.

THEORITICAL PRINCIPLES OF SPRS: -

The power delivered to the rotor across the air gap equal to the mechanical power delivered to the load and the rotor copper loss,

Rotor power = (Power delivered) + (Rotor copper loss)

$P_r = W_{st}\, P_m + P_c$

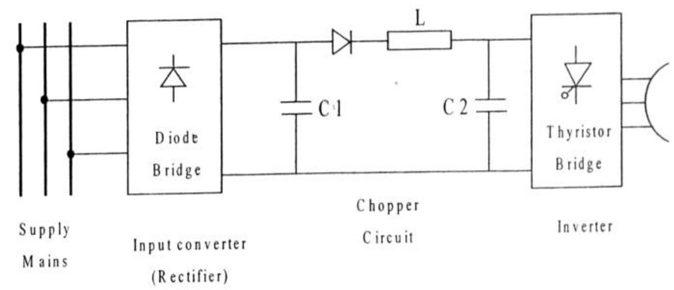
$P_r = W_{st}$

$P_m = W_t$

Hence, $P_c = S \times W_{st} = S \times P_r$ and $P_m = (l\text{-}S)_{Pr}$

VI. VARIABLE FREQUENCY DRIVES:

Block diagram of VFD drive



The key to maximizing advantages of adjustable drives is applying the proper type of drive system.

Most of the drives systems are composed of three major components

- Input transformer
- The frequency converter
- Ac machine.

Additional components may include dc link reactors harmonic filters, Output filters etc.

WHY ALL AC DRIVES ARE CALLED V/F DRIVES: -

Voltage induced in stator is proportional to the product of supply frequency and air Gap flux. If stator drop is neglected, terminal voltage can be considered proportional to the product of frequency and flux. Any reduction in the supply frequency, without a change in the terminal voltage, causes an increase in the air gap flux. Induction motors are designed to operate at the Knee point of the magnetization characteristic to make full use of the magnetic material. Therefore the increase in flux will saturate the motor. This will increase the magnetizing current, distort the line current and voltage, increase the core loss and the stator copper loss, and produce a high pitch acoustic noise.

While an increase in flux beyond the rated value is undesirable from the consideration of saturation effects, A decrease in flux is also avoided to retain the torque capability of the motor. Therefore the variable frequency control below the rated frequency is generally carried out at rated air gap flux by varying terminal Voltage with frequency so as to maintain (V/F) ratio constant at the rated value

“To maintain constant flux in motor ratio of voltage to frequency is always maintained constant so that motor can deliver rated torque throughout the speed range."

Advantages of VFD DRIVE:

- Speed up to 10000 rpm attainable eliminating gears.
- Free choice in protection class including explosion.
- The construction of motor, simple and rugged is simple
- Less maintenance.
- High availability.
- Compact size.
- High efficiency in the system.
- Higher power, weight ratio.

Drawbacks of AC DRIVES:

- Higher harmonics hence de-rating of motor required.
- Pulsating torque at low frequencies, operation is unstable at low frequencies.
- Complex inverter circuit as forced commutation is involved.

VII. ENERGY SAVING &PAY BACK PERIOD

COMPARISION BETWEEN DAMPER AND VFD SAVINGS:

POWER CONSUMED BY USING SPRS

Let the required flow rate be = Q cu.mt/sec

Let the Pressure required for the given rate of flow be = P mm of Hg

Normally when the damper is fully opened the pressure on the flow is = 760mmof Hg

Now at pressure P ^percentage of damper opened is = (P/760)* 100

The pressure across damper is = AP = (760 - P) mm of Hg

The total power consumed = (Q * 760)/ 102 Kw =X Kw

Energy saving potential by using damper control = (AP/760)* motor rated power = Y KW

Total energy consumed by using SPRS = (X-Y) Kw = A Kw

POWER CONSUMED BY USING VFD

Let the required flow rate be = Q cu.mt/sec

Let the Pressure required for the given rate of flow be = P mm of Hg

The atmospheric pressure of the flow is = 760mmof Hg

** Here in VFD there will be no damper and hence using the speed of the fan can vary the pressure,

Therefore, N. cc JP

The synchronous speed Ns= 1500 rpm (4-pole, 50 Hz, induction machine) Let the required synchronous speed to produce pressure P is = N rpm = (P 7760) * Ns. The frequency at the speed N is given by, f = (N * Poles)/120 Hz.

To get the pressure P the motor should be operated at the above frequency f Hz

From the basic principle of VFD, V/f cc O Where, O is the constant flux.

As the frequency is varied to produce the required pressure, the voltage along with synchronous speed will vary to maintain the constant flux.

Hence voltage V is given by V = 4.44.K O N f volts

The current at this load is = I amps

The power consumed by using VFD is B = VI cos(O Kw)

Energy saved by using VFD over SPRS is = (A - B) Kw

SAVING:

The potential energy savings from installing a VFD is illustrated in the following example. Here, a 40 hp motor is used in an HVAC system with a flow-control damper. The system operates 365 days a year with The load/time profile shown in Table. The damper is removed and a VFD installed. The estimated annual energy savings realized from the use a VFD is shown in Table 1

Airflow Volume (percent of maximum	Dairy Operating time (hours)	Energy Consumed using Damper (kWh/year)	Energy Consumed Using VFD (kWh/year)	Difference in Energy Consumption (kWh/year)
50%	2	18500.	4800	13700
60%	3	29300	9800	19500
70%	6	61700	26800	34900
80%	6	63300	35900	27400
90%	4	44200	32600	11 600
100%	3	34200	35200	-1 000
Total	24	251 200	145 100	106 100

The above example shows a possible electrical energy saving of 106 100 kWh per year, resulting from replacement of the existing damper-control system with a VFD. Savings would be less if the existing flow-control system used variable inlet vanes. At energy rates of Rs.3.00/kWh, annual savings are Rs.3, 18,300/-

VIII. ENERGY SAVING EQUATION & PAY BACK PERIOD:

To control the air flow there are two methods

- By using SPRS system
- By using V/F control

Let the rating of the motor be M kW Let the Energy consumed by using the damper = D kWh Let the Energy consumed by using V/F control = F kWh Hence, Energy saved by using V/F control in a Day is given by = (F>F) kW/day. Let the Investment spent on installing the V/F control system be = Rs. I /-Energy Saved per Day = (D-F) kWh Energy Saved per Year = (D-F)* 24* 3 65 kWh/year. As the Cost of Unit = Rs. 3/-

Total Amount Saved in a Year is given by, S = Rs, [(D-FJ*24*365*3] There Fore Amount Saved by Using V/F Control = Rs. S/-Pay Back Period = (Investment/A mount Saved)* 12. = (I/S)* 12 Months.

NOTE: - Any Company Will Accept the Project only if the Pay Back Period is Less than 2 Years.

IX. APPLICATIONS OF AC DRIVES IN OTHER INDUSTRIES:

IN WIND ENERGY SYSTEM:

The wind is a re-generative source of energy that, thanks to modern technology, leads itself to particular efficient exploitation.

“Variable speed models with rotor blade adjustment and double feed asynchronous machinery with a frequency converter in the rotor power circuit have established themselves on the market for plant categories in excess of 1 MW”.

The technical function of a wind farm of this kind may be classified in four sections

With its adjustable blades the rotor converts the kinetic energy of the wind into rotational energy. At the same time modern drive system align each individual rotor blade according to the strength of the wind, thus capturing maximum drive energy. Adjustment of rotor blades is affected either by means of hydraulic or electric drive system.

In the drive train with wind tracking speed and torque are mostly converted using a planetary gear system. A high level of stress is applied particularly to the tooth flanks and bearings. The use if of a closed loop control hydraulic disk break ensures load minimized breaking of a rotor in the event of an emergency stop. The electrical or hydraulic wind direction tracking also has a major effect on the life of the plant.

In electrical system conversion from mechanical to electrical energy takes place by means of generator. In most cases a variable speed dual feed asynchronous machine is used in a frequency converter in the rotor power circuit.

By using four-quadrant converter the quality of electricity as regards ideal power requirement, flickers and top shaft content is considerably improved by comparison to the multiple speed asynchronous machines. In addition mechanical stress in the drive train is reduced, leading to a longer life or longer service intervals. The immanent speed variability speed ensures more efficient operation with different wind speeds.

The open loop control with sensor mechanism cross links the actuators, ensuring maximum possible plant efficiency at minimum operating stresses by means of intelligent operation control strategies, something which guarantee sustained operation. Here the trend is towards status oriented services and maintenance. Remote monitoring is used to determine and transmit the degree of wear on significant components and to alert the service teams necessary when required The construction of large wind farms has how ever created yet another challenge. When there is a high %of wind power in a power grid the entire wind farm with all of its individual turbines must be controllable so that it can continue to operate even if there are malfunctions in the power grid. A hydraulic cylinder that engages an eccentric at the root of the blades rotates the rotor blades. "The cylinder contains an integrated positioned transducer for position controlling. The control block is built directly on the cylinder".

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