UNIT IV

ENERGY EFFICIENT SYSTEMS:

(A) ELECTRICAL SYSTEMS: Energy efficient motors, energy efficient lighting and control, selection of luminaire, variable voltage variable frequency drives (adjustable speed drives), controls for HVAC (heating, ventilation and air conditioning), demand site management.

(B) MECHANICAL SYSTEMS: Fuel cells- principle, thermodynamic aspects, selection of fuels & working of various types of fuel cells, Environmental friendly and Energy efficient compressors and pumps.

Outcome: Elaborate on ocean, geothermal, electrical and Mechanical systems

DEMAND SIDE MANAGEMENT

DSM, also known as energy demand management or demand-side response (DSR) is the curtailing of the client's energy demand by numerous strategies, including behavioral changes (through awareness) and financial benefits. The objective of DSM is to inhibit consumers from depleting less energy during the peak time frame or from shifting the energy use to an off-peak time frame such as weekends or nighttime. This does not necessarily reduce overall energy usage. On the contrary, it focuses on reducing the need for investing in power plants or networks excessively for meeting the optimal demands, for example, conserving the energy storage during off-peak hours and discharging it during peak hours. The latest strategy of DSM to overcome power consumption is to assist the grid operators in stabilizing intermittent generation from solar and wind sources, especially when the amount and timing of energy demand do not coincide with the renewable energy production.
There are four types of DSM

1. Energy Efficiency:

This is a type of DSM where we use less power to carry out the same tasks, including a permanent demand reduction by replacing equipment with more efficient ones.

2. Demand response:

This encompasses any preventive or reactive strategies to decrease or shift the demand. Demand response (DR) programs not only focus on reducing the peak consumption to defer high supply cost but also aid in altering the net load structure -which is wind and solar power production subtracted from the total load- while integrating all variations of renewable energy. DR includes all purposeful variations applied on the electricity consumption trends of the utility consumer that are intended to change the timing, the total power consumption, or the intensity of spontaneous demand. DR strategies include a range of actions carried out on the client's end of the electric meter during high charges or congestion of peak period network.

3. Dynamic demand:

Dynamic demand is the delaying of operating cycles of equipment by a few seconds to induce diversification of load sets. The idea of dynamic demand is to monitor the power factor of the electric grid in addition to their parameters, loads administered individually at intermittently during peak periods to stabilize the total system load with production, decreasing serious power disorder. The end user, i.e., the client, has negligible effects as the delay in the operating cycle is only by a few seconds.

4. Distributed Energy Resources (DER):

the on-site generation (OSG), distributed energy and generation, and decentralized/district energy is electrical production and conservation achieved by various small devices that are linked to the grid known as DER. Unlike large renewable power stations, DER is more decentralized, flexible, and within close proximity of the load. However, they tend to carry a capacity of not more than 10 MW. The DER can be controlled and coordinated using an interface within a smart electric grid. The dispersed storage and generation allow accumulation of power from various sources that could decrease the environmental changes and improve the safety of production.

Furthermore, DSM can be categorized into scales of implementation:

National Scale: Improving energy efficiency is as significant as DSM strategies. The legislation and standards in various areas, including machinery, housing, transport, building, and appliances can improve efficiency nationally.

Utility-scale: When the demand is at its peak, utilities can control the storage water heaters, air conditioners, and pool pumps in large regions to stabilize the energy demand with supply.

Community-scale: This is also known as district/precinct/ neighborhood scale. In regions of extreme winter or summer, central heating/cooling systems have been used to manage the peak load. Another way to implement DSM on a communal scale is accomplishing Net Zero Building or community.

Individual household/Personal Business scale: PV systems installed by Magnifier Engineering & Trading Company (METCO) experts are one way to apply DSM on an individual level. The utility of solar energy allows the reduction of energy consumption from the electric grid. Systematic DSM approaches such as energy efficiency measures, storage water heaters, PV operations, air conditioner, building performance, and energy storage systems are practical household/business level strategies.

HOW IS ENERGY DEMAND MANAGED?

Demand side management is a crucial process to reduce electricity consumption, especially when the usage is at its peak. A high requirement of electricity does not only increase the electricity cost but also causes power outages by putting pressure on the electricity grid. By load reduction during peak hours, the grid is stabilized, and usage of costly fossil fuels is minimized that could result in damage to the environment. The objective of DSM programs include investing energy efficiently and time-variant costing (e.g., time-of-use rates). Three strategies of demand side are:

1. Contractual Demand Response:

This is a type of response that compensates for electricity consumption reduction of big power consumers during peak consumption periods. During peak usage of electricity, contractual demand response alters the amount of power consumed by a client to complement the demand with the supply. Previously, this was done by reducing production rate and turning generators on/off or outsourcing power. Failure to keep a balance between the electricity consumption and supply can cause the electric grid to incur sharp voltage fluctuations and instability resulting in crashes in the grid. Hence, the overall production capacity is calculated to correspond to the overall peak demand allowing a margin for some error and contingencies e.g., shutting off plants during the maximum demand period. METCO's core demand response strategy focuses on using the least expensive production capacity (concerning marginal cost) at any given time while opting for additional capacity from more costly plants during peak demand. The primary purpose of demand response is to reduce the high energy demand to decrease the potential risk of disturbances, overcome any requirement for the extra capital cost for more plants and avoid utilizing less efficient or more expensive operating plants. The clients will have to pay more if the generation capacity is fueled by a pricier source of power production.
In most cases, increasing supply to meet the demands can result in higher costs because some units can take longer to function at full capacity and others can be expensive to operate. METCO applies demand response to adjust the client's power demands with the supply. Signaling of demand requests to customers by the utilities is done in a variety of ways such as smart metering or off-peak metering. Smart metering encompasses the requests communicated by utilities to the customers, whereas in off-peak metering the power cost varies at a specific time throughout the day. The customers have the option to either postpone projects requiring high power or provide higher electricity cost. The client also has the opportunity to use alternate sources like diesel generators on-site.

2. Smart Grid Application:

These applications increase the ability of electric utility producers and their consumers to coordinate better with one another to make more informed and effective decisions on efficient electrical power production and consumption (supply and demand) strategies. METCO achieves this by allowing the client to actively shift to a 24/7-based approach to demand

response instead of event-based. This means that rather than the utilities controlling load shedding, the client can control the load all the time. This accelerated two-way communication allows higher demand response opportunities.
A benefit of using this application is the time-based pricing system. Our clients can decide their threshold and set their consumption rate to make the most of the fluctuating cost. By using smart grid application, clients can monitor, switch, and stabilize the load to retain the peak load. The intelligent grid application provides real-time information to the client and producers. However, the main driving factors are environmental and economic incentives.

3. Managing Total Demand:

behavioral alterations for energy consumption can have a significant effect on the client's utility bill. Incorporating slightest changes in the production process can result in higher efficiency and savings. Curbing non-critical energy consumption e.g., HVAC or constant performance maintenance of your equipment could encourage substantial cuts on electricity cost. METCO's professionals make sure to sync with your utility to comprehend your monthly demand cost.

BENEFITS OF DEMAND SIDE MANAGEMENT

METCO's energy savings programs have allowed efficient solutions that have provided an optimum result, including DSM. The benefits of using our DSM services include:

SUSTAINABLE ENERGY CONSERVATION

Demand side management enables the client to maintain and curtail their energy requirements and consumption in a more efficient and eco-friendly manner.

UTILITY COST SAVINGS

Demand side management allows our clients to save considerable sums of their capital on utility bills without having to cut back on their production output or routine operations. It is beneficial for the company owners and the community by cutting down operating costs and reducing carbon footprint by decreasing the need for power plants, respectively.

REDUCTION OF FOSSIL FUEL CONSUMPTION

By making operations and production processes more efficient, demand-side management programs reduce fossil fuel combustion and the need to build expensive power plants.

PROVIDES AUTONOMY TO CONSUMER

Distributed Generation units harness otherwise wasted energy to produce electricity. The line loss is eliminated as DG is an onsite plant that does not require transmission wires.

Need of Energy efficient Motors & Drives

An increase in efficiency in motor will result in large energy savings and reduction in CO_2 emission.

Electric motors impact almost every aspect of modern living. Refrigerators, vacuum cleaners, air conditioners, fans, computer hard drives, automatic car windows, and multitudes of other domestic appliances and devices all use electric motors to convert electrical energy into useful mechanical energy. In addition to running the commonplace appliances, electric motors are also responsible for a very large portion of industrial processes. Electric motors are used at some point in the manufacturing process of nearly every conceivable product that is produced in modern factories. Because of the nearly unlimited number of applications for electric motors, it is not hard to imagine that there are million motors of various sizes in operation across the world. This enormous number of motors and motor drives has a significant impact on the world because of the amount of power they consume.

The systems that controlled electric motors in the past suffered from very poor performance and were very inefficient and expensive. In recent decades, the demand for greater performance and precision in electric motors, combined with the development of better solid-state electronics and cheap microprocessors has led to the creation of modern adjustable speed drive. An adjustable speed drive is a system that includes an electric motor as well as the system that drives and controls it. Any adjustable speed drive can be viewed as five separate parts: the power supply, the power electronic converter, the electric motor, the controller, and the mechanical load.

The power supply can provide electric energy in the form of AC or DC at any voltage level. The power electronic converter provides the interface between the power supply and the motor. Because of this interface, nearly any type of power supply can be used with nearly any type of electric motor. The controller is the circuit responsible for controlling the motor output. This is accomplished by manipulating the operation of the power electronic converter to adjust the frequency, voltage, or current sent to the motor. The controller can be relatively simple or as complex as a microprocessor. The mechanical load is the mechanical system that requires the energy from the motor drive. The mechanical load can be the blades of a fan, the compressor of an air conditioner, the rollers in a conveyor belt, or nearly anything that can be driven by the cyclical motion of a rotating shaft.

Electrical Motor Drives

Today, with advancements in power electronics, control electronics, microprocessors, microcontrollers, and digital signal processors (DSPs), electric drive systems have improved drastically. Power electronic drives are more reliable, more efficient, and less expensive. In fact, a power electronic drive on average consumes 25 per cent less energy than a classic motor drive system. The advancements in solid-state technologies are making it possible to build the necessary power electronic converters for electric drive systems. The power electronic devices allow motors to be used in more precise applications. Such systems may include highly precise speed or position control. Systems that used to be controlled pneumatically and hydraulically can now be controlled electrically as well.

More advanced electric motor drives are now replacing older motor drives to gain better performance, efficiency, and precision. Advanced electric motor drives are capable of better precision because they use more sophisticated microprocessor or DSP controllers to monitor and regulate motor output. They also offer better efficiency by using more efficient converter topologies and more efficient electric motors. The more advanced drives of today also offer a performance boost by utilizing superior switching schemes to provide more output power while using lighter motors and more compact electronics.

Electrical Motor Losses

Motor efficiency may be increased by reducing losses. Motor energy losses can be divided into various categories, each of which is influenced by design and construction of the motor. One design consideration is the size of air gap between the rotor and the stator. Large air gaps tend to maximize efficiency at the expense of power factor, while small air gaps slightly compromise efficiency while significantly improving power factor. The efficiency of a motor is determined by intrinsic losses that can be reduced only by changes in motor design. Intrinsic losses are of two types: fixed losses – independent of motor load, and variable losses – dependent on load. Fixed losses consist of magnetic core losses and friction and windage losses. Magnetic core losses (sometimes called iron losses) consist of eddy current and hysteresis losses in the stator. They vary with the core material and geometry and with input voltage. Friction and windage losses are caused by friction in the bearings of the motor and aerodynamic losses associated with the ventilation fan and other rotating parts.

Variable losses consist of resistance losses in the stator and in the rotor and miscellaneous stray losses. Variable losses depend upon motor load. Resistance to current flow in the stator and rotor result in heat generation that is proportional to the resistance of the material and the square of the current (I2R). Where R is the stator winding resistance for stator resistance loss and for rotor resistance loss it can be used as rotor winding resistance.

Stray losses arise from a variety of sources and are difficult to either measure directly or to calculate, but are generally proportional to the square of the rotor current. No load losses such as core losses and friction and windage losses both are about 15% of the total losses that occur in the motor while under loaded condition. Part-load performance characteristics of a motor also depend on its design. Both η and PF fall to very low levels at low loads.

Energy Efficient Motors

Electric motors are of utmost importance in industrial as well as agriculture sector. These motors found their application as constant speed drives with very low rating as well as variable speed drives with very high rating. Energy efficiency and energy conservation are very closely related to each other. With increase in demand of energy and due to uncertainties in oil supply and fluctuating price of conventional fuels, efficiency and conservation of energy has become an important aspect of industrial as well as rural development. A large amount of electrical energy is consumed by induction motor used for irrigation in rural sector and industrial purpose in urban sector. In country like India agriculture and industrial sector is developing rapidly, in same way electrical energy consumption is increasing. A study indicated that a 5 per cent improvement in overall efficiency of induction motor would save enough energy that would be comparable to energy produced by a new power plant of few hundred megawatts.

Energy-efficient motors are the ones in which, design improvements are incorporated specifically to increase operating efficiency over motors of standard design. Design improvements focus on reducing intrinsic motor losses. Improvements include the use of lower-loss silicon steel, a longer core (to increase active material), thicker wires (to reduce resistance), thinner laminations, smaller air gap between stator and rotor, copper instead of aluminum bars in the rotor, superior bearings and a smaller fan, etc. Energy-efficient motors now available in India operate with efficiencies that are typically 3 to 4 percentage higher than standard motors.

The suitable selection of copper conductor size will reduce the resistance. Reducing the motor current is the most readily accomplished by decreasing the magnetising component of current. This involves lowering the operating flux density and possible shortening of air gap. Rotor I2 R losses are a function of the rotor conductors (usually aluminium) and the rotor slip. Utilisation of copper conductors will reduce the winding resistance. Motor operation closer to synchronous speed will also reduce rotor I2 R losses. Core losses are those found in the stator-rotor magnetic steel and are due to hysterisis effect and eddy current effect during 50 Hz magnetisation of the core material. These losses are independent of load and account for 20 – 25 per cent of the total losses. The hysterisis losses which are a function of flux density, are to be reduced by utilising low loss grade of silicon steel laminations. The reduction of flux density is achieved by suitable increase in the core length of stator and rotor. Eddy current losses are generated by circulating current within the core steel laminations. These are reduced by using thinner laminations.

Friction and windage losses result from bearing friction, windage and circulating air through the motor and account for 8 – 12 per cent of total losses. These losses are independent of load. The windage losses also reduce with the diameter of fan leading to reduction in windage losses. Stray load losses vary according to square of the load current and are caused by leakage flux induced by load currents in the laminations and account for 4 to 5 per cent of total losses. These losses are reduced by careful selection of slot numbers, tooth/slot geometry and air gap.

Energy efficient motors cover a wide range of ratings and the full load efficiencies are higher by 3 to 7 per cent. The mounting dimensions are also maintained to enable easy replacement. As a result of the modifications to improve performance, the costs of energy-efficient motors are higher than those of standard motors. The higher cost will often be paid back rapidly in saved operating costs, particularly, in new applications or end-of-life motor replacements.

Factors affecting the Motor Efficiency Load Variation

Most electric motors are designed to run at 50 per cent to 100 per cent of rated load, the maximum efficiency is achieved usually near 75 per cent of rated load. Thus, a 10-hp motor has an acceptable load range of 5 to 10 hp with maximum efficiency is at 7.5 hp. A motor's efficiency tends to decrease dramatically below about 50 per cent of the rated load. However, the range of efficiency varies with individual motors and tends to extend over a broader range for larger motors. A motor is considered under loaded when it is in the range where efficiency drops significantly with decreasing load.

Overloading of motors can decrease efficiency. Many motors are designed with a service factor that allows short time overloading.

Power Factor

Power factor is an important attribute relating to efficiency of AC induction motors. As the load on the motor comes down, the magnitude of the active current reduces. However, there is no corresponding reduction in the magnetising current, which is proportional to supply voltage with the result that the motor power factor reduces, with a reduction in applied load. Induction motors, especially those operating below their rated capacity, are the main reason for low power factor in electric systems. Motors, like other inductive loads, are characterized by power factors less than one. As a result, the total current draw needed to deliver the same real power is higher than for a load characterised by a higher PF. An important effect of operating with a PF less than one is that resistance losses in wiring upstream of the motor will be higher, since these are proportional to the square of the current. Thus, both a high value of PF close to unity are desired for efficient overall operation in a plant.

Effect of Harmonics

Harmonics are ac voltages and currents with frequency that are integer multiples of the fundamental frequency. In earlier years, harmonics were not prevalent in most of the industries due to balance linear loads using three phase induction motors along with incandescent lighting, resistivity etc., but the rapid advancement of power electronics in industrial application makes industrial loads non-linear type. These non-linear loads draw non-sinusoidal current from the sinusoidal voltage waveform. The distortions thus produced in the voltage and current waveforms from the sinusoidal waveforms are called harmonic disorders.

Harmonics are generated due to increasing number of non-linear loads occurred when the system voltage is linear but the load is non-linear, the current will be distorted and become non-sinusoidal. The actual current will become higher than the current measured by an ammeter or any other measuring instrument at the fundamental frequency. It also occurred when the supply system itself contains harmonics and the voltage is already distorted, the linear loads will also respond to such voltage harmonics and draw harmonic currents against each harmonic present in the system and generate the same order of current harmonics. When the system voltage and loads are both non-linear (a condition which is more common) the voltage harmonics will magnify and additional harmonics will be generated, corresponding to the non-linearity of the load and hence will further distort an already distorted voltage waveform.

Energy Efficiency and Environment

It is well known that environment and efficiency are closely interlinked with each other. Electric drive systems are largely responsible for the largest part of the electricity consumption. Therefore, an increase in efficiency in motor will result in large energy savings and reduction in CO2 emission into our environment. Machine designers over many years have tried their best to respond to the need for improved efficiency of induction motors. Real driver for the evolution of higher efficiency motor is to save the environment through reduction of energy consumption. An improvement in energy efficiency will lead to reduction of CO2 emissions. Today, in India millions of the induction motors are manufactured every year and they combined to consume about 50 per cent of the total energy generated. By improving the efficiency, considerable amount of energy can be saved and it also leads to save environment because to meet the load of these machines power generating stations are releasing millions of tons of greenhouse gases into the atmosphere every year. There is requirement of sustaining the constantly increasing demand of energy and at the same time reducing environmental pollution, then automatic increase in the efficiency of energy conversion will have to substantially improve in order to produce more power from the same or less material.

Summary
The optimum design gives a motor having uniformly high efficiency over a wide range of load and supply voltage. It is seen that, within the same frame size, the full load efficiency of the new motor is about 2.5 per cent more than that of the standard. The active material cost of the energy efficient motor is slightly more than that of the standard motor, but the extra cost is paid back within a reasonable period.

Question Bank

Short

1. What are the precautions to be taken in the case of energy-efficient motor applications?
2. Discuss about adjustable speed drives.
3. Write the principle of fuel cell.
4. What are the two types of hydrogen fuel cells?
5. What are the typical characteristics of Savonius rotor system?
6. What is power factor improvement?
7. What is comfort air-conditioning?
8. Define productivity.
9. Define conversion efficiency of fuel cell.
10. Application of vegetable based cutting fluids
11. Define what is maximum comfort?
12. What are the advantages and disadvantages of a fuel cell?
13. Write short notes on the applications of fuel cell
14. Discuss about alternate casting techniques.
15. How fuel cells are the future option for our energy needs? Justify your answer.
16. Write short notes on the types of electrodes for a fuel cell
17. Discuss in detail about alternate joining techniques
18. Discuss about adjustable speed drives.

Long

1. What is the role of energy-efficient compressors and pumps in energy-efficient systems? Explain.
2. Explain why centrifugal machines offer the greatest savings when used with variable speed drives?
3. Discuss about energy efficient motors.
4. Explain the working of fuel cells and write their advantages.
5. Explain the energy efficient lightning control methods.
6. Explain why variable torque loads offer great energy savings?
7. Explain the classification of fuel cells based on the type of electrolyte.
8. Briefly discuss the selection criteria of luminaries for an industry.
9. Explain with a simple sketch, construction and working of molten carbonate fuel cell.
10. Briefly discuss factors influencing industrial growth on environment
11. Explain why vegetable based cutting fluids are replacing conventional cutting fluids?
12. Explain briefly how variable frequency drives are more energy efficient than conventional motor drives.
13. Briefly discuss classification of fuel cells.
14. What are the relative advantages of advanced joining techniques over conventional techniques?
15. Explain why efficient lighting systems are gaining importance in industries and commercial sectors.

16. Briefly explain the basic design and working of a fuel cell.
17. Explain Why efficient HVAC systems are gaining importance in industries and commercial sectors.
18. Briefly discuss how energy efficient pumps can contribute towards conservation of energy
19. What are the benefits of green manufacturing systems? Explain them in detail.
20. What are the relative advantages of alternate casting over conventional casting techniques?
21. Describe the principle of working of a fuel cell with reference to H2-O2 cell.
22. Discuss the relevance of energy efficient technologies in HVAC systems.
23. Explain in detail, the environmental impact of current manufacturing practices and systems.
24. What is the principle of fuel cell? Discuss problems associated with operation of fuel cell.
25. Give an account of different lighting technologies.
26. Discuss the design and implementation of efficient and sustainable green production system with an example.
27. Write short notes on compressed air storage.
28. What are variable frequency devices? Mention their benefits over other devices.
29. Write short notes on pumped hydro electric storage.
30. Discuss the aims and scopes of demand site management.
31. Discuss the advantages and disadvantages of green manufacturing systems over other systems?
32. What is zero work manufacturing? Explain in detail.
33. Discuss about energy efficient lighting and control.
34. Discuss about energy efficient compressors and pumps.
35. Discuss about the environmental impact of current manufacturing systems.
36. Explain the concept of zero waste manufacturing. What are the challenges in implementing this concept