CHAPTER 2

UNIT II

Energy Conservation in Electrical Machines

Syllabus :

2.1	Need of energy conservation in induction motor and transformer.
2.2	Energy conservation techniques in induction motor by : (a) Improving Power Quality, (b) Motor survey, (c) Matching motor with loading, (d) Minimizing the idle and redundant running of motor, (e) Operating in star mode, (f) Rewinding of motor,(g) Replacement by energy efficient motor, (i) Periodic maintenance
2.3	Energy conservation techniques in Transformer. (a) Loading sharing, (b) Parallel operation, (c) Isolating techniques, (d) Replacement by energy efficient transformers, (e) Periodic maintenance
2.4	Energy conservation Equipment : Soft starters, Automatic star delta convertor, Variable Frequency Drives, Automatic p.f. controller (APFC), Intelligent p.f. controller (IPFC), Active Harmonic filters (AHF)
2.5	Energy efficient motor; significant features, advantages, applications and limitations.
2.6	Energy efficient transformers, amorphous transformers; epoxy Resin cast transformer/Dry type of transformer.

Introduction

- Significant amount of electrical energy in Industrial and commercial sectors of the world is consumed by the electrical motors.
- Three phase squirrel cage induction motor offers simplicity and robustness which has made it the prime mover of the modern industrial era.
- Energy conservation in induction motor is gaining attention due their increased penetration in the use.
- This unit focuses on some methods to bring optimization in motor performance keeping an aim of energy conservation in induction motor.
- Energy efficient motors are discussed compared with standard design of motors being a better option to improve the efficiency.
- Transformer is called as a heart of electrical power system being a device that performs an important function of energy transform and transfer from one circuit to other.
- It achieves this by magnetic coupling of primary and secondary winding.
- Transformers like distribution transformer can supply power to loads and remain energized for all day i.e. 24 hrs.
- Though it does not consume any power, losses are inherent in the process of transformation especially in the core.
- In the past, losses reductions programs for transformer were very less because it was assumed to be very efficient when compared to other electrical devices such as motors.
- However, increasing concern of energy conservation has made to turn head towards transformer.
- Low loss designs, advanced technologies in core quality e.g. amorphous material encourage energy conservation in transformer.
- This unit gives a brief overview of energy conservation techniques in transformer.

2.1 Necessity of Energy Conservation in Electrical Motor and Transformer

2.1.1 Necessity of Energy Conservation in Electrical Motor

(MSBTE – W-14, W-16, W-17, S-18, W-18)

Q.	State need of energy conservation in electrical motors.	W-14, S-18
Q.	Describe the need of energy conservation in induction motor.	W-16
Q.	Explain the necessity of energy conservation in Electrical motors.	W-17
Q.	Describe the need of energy conservation in Induction motor.	W-18

- Energy costs continues to increase due to ever increasing global demand for energy
- Industrial sector is awakening in order to reduce cost of production after the markets has been opened up in early nineties. Decreased production cost makes their product competitive in market.
- Conservation in energy is the most important area which is focused in order to reduce production cost.
- Industrial and commercial consumer identifies their most energy consuming culprit which is found to be motors so that energy conservation measures can be applied.
- 43 % to 46 % of the world energy consumption and near about 70 % of total energy consumption of the industry is due to motor and motor drives.
- Inefficient motors not only causes wastage of electrical energy but also more operational costs.
- Most of the electricity to run these motors is generated from non-renewable energy plants which also has an incremental effect on greenhouse gases.
- So economic as well as environmental aspects necessitates the conservation in Electrical Motors.
- Near about shares of electrical energy use by motors in various sectors of are as follows :

Table 2.1.1

Sector	Share (in %)	Applications
Industrial	70	Processes and Material Handling Equipments
Commercial	38	Mainly HVAC
Agricultural	25	Agriculture Pumps and Fans
Residential	22	Refrigerators/HVAC
Transport	60	Railways

- Penetration of motors in various sectors of energy use as given in above table brings in notice the scope for Energy Conservation in motors.

2.1.2 Need of Energy Conservation in Transformer

(MSBTE – S-12, W-12, W-14, S-16, W-16, S-17, S-18, W-18)

Q.	State the opportunities for energy conservation techniques in transformers.	S-12
Q.	Explain opportunities for energy conservation in transformer.	W-12
Q.	Write opportunities for energy conservation in transformer.	W-14

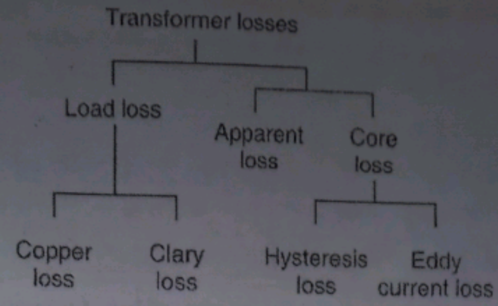
> **Q.** State the need of energy conservation in transformer. Explain the use of Epoxy Resin Cast/Encapsulated dry type transformer from energy conservation point of view. **S-18, W-16**
>
> **Q.** State atleast eight energy conservation opportunities in Transformer.
>
> **Q.** Why energy conservation techniques should be adopted in transformers even though its efficiency is 90% ? **S-17**
>
> **Q.** State the need of energy conservation in transformer. **S-19**
>
> **Q.** State the need of energy conservation in transformer and material used to improve the design & performance of transformer. **W-18**

- Energy conservation in transformer obviously will be step forward when attempts to reduce energy losses related with transformer operation in electrical power system are made.
- Transformers especially in distribution network actually make up near about 40% of energy loss.
- All the electrical power which consumer receives at his end passes through transformer.
- In some cases it may have to undergo numerous stages of transformations (hence numerous transformers) when passes through generator to the consumer.
- Then minimum two of these stages of transformer will belong to distribution (distribution transformer)
- At each transformer power and hence energy losses are obvious.
- If these losses are given attention, it will considerably reduce greenhouse emission.
- A modern distribution transformer operates at high efficiency in the range of 98.99%.
- However, the total number of transformers used in transmission and distribution system, supplying power to all class of consumer industrial, commercial domestic and rural is very large.
- Even small amount of losses in every transformer aggregately contributes a significant energy loss as well as global warming and climate change.
- Thus, even small positive change in transformer efficiency will lead to remarkable reduction in generation capacity requirement and hence greenhouse gases emission.
- Following Table 2.1.2 shows the scenario and potential in this regard.

Table 2.1.2 : Distribution transformer loss, energy saving potential and GHG reduction potential

Country Region	Annual loss in Distributor transformers(JWh)	Annual energy saving potential (JWh)	Annual reduce potential in CO_2 (Millions of tonnes)
Western Europe	55	22	9
USA	141	84	60
Australia	6	3	3
India	6	3	3
China	33	18	13
Japan	44	31	12
Total	285	161	100

Energy saving opportunities lies in various losses occurring in transformers.



2.2 Energy Conservation Techniques in Induction Motor

(MSBTE – S-12, W-13, W-15, S-17)

Q. State various methods/techniques for energy conservation in 3 phase inductor motor in industries. Explain any one in detail. **S-12**

Q. State any four energy conservation techniques in electrical motors. **W-13**

Q. List energy conservation techniques in electrical motors. **W-15**

Q. List out the energy conservation techniques to be adopted to reduce losses in the induction motor. **S-17**

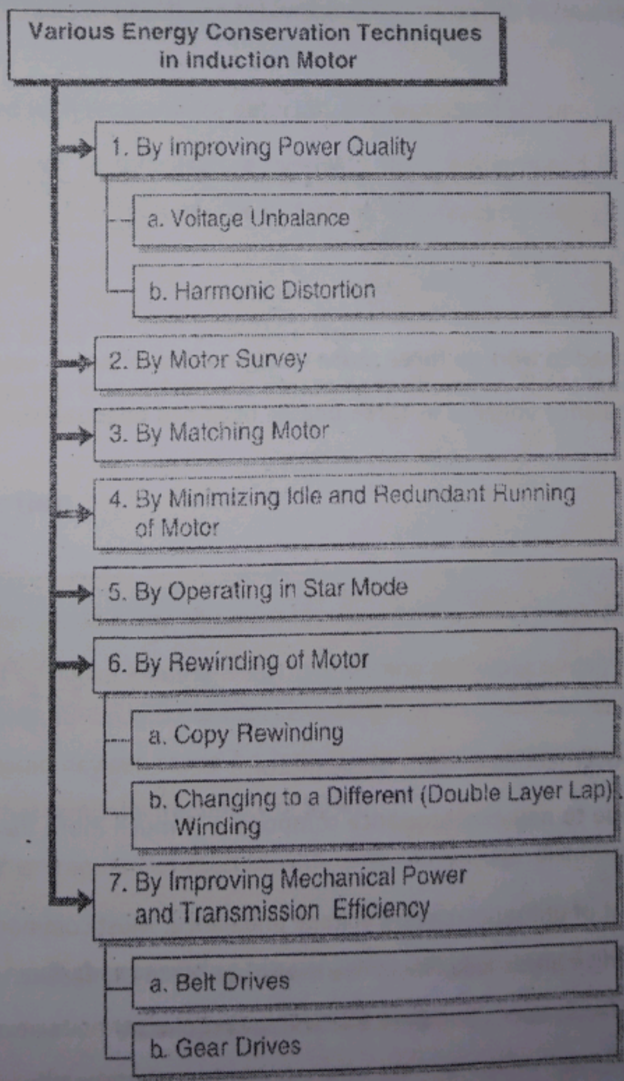


Fig. C2.1 : Energy Conservation Techniques in Induction Motor

2.2.1 By Improving Power Quality

(MSBTE - S-15, S-16, W-16, W-17, S-...)

> Q. Explain how energy can be conserved in induction motor by improving power quality.
> Q. Explain energy conservation technique in induction motor by improving power quality method.
> Q. Describe the following energy conservation methods of electrical motor : (ii) Improving power quality.
> Q. Explain energy conservation method in induction motor by improving power quality.
> Q. Explain the energy conservation technique "By improving power quality" for induction motor.

- Induction motor performance is notably affected by poor quality of input power.
- There are many aspects of the term power quality such as voltage unbalance, frequency and harmonic distortion.
- Motors in India are bind to follow the standards set by the BIS for tolerance of power quality aspects.

Parameter	Permissible Variation (in %)
Voltage	± 5 to ± 10
Frequency	± 3
Combined	± 6

- According to BIS motor is expected to deliver its rated output for a voltage variation of +/ - 6% and frequency variation of +/ – 3%.

2.2.1.1 Voltage Unbalance

(MSBTE – W-14, W-...)

> Q. Explain the effect of voltage unbalance parameter on three phase induction motor.
> Q. Describe the effect of following on Induction Motor :
> (i) Voltage Unbalance

- Three phase motors are designed to work on three phase voltages equal or nearly equal.
- In a condition of voltage unbalance voltages in three phases becomes unequal which may lead motor to significant problems such as :
  - Excess heating
  - Vibration
- Due to three phase unbalanced voltage, unbalanced current drawn by three phase motors are very obvious.
- Unbalanced current means negative sequence component which creates magnetic field in the direction opposite to the normal direction of rotation.
- Most of the times this causes overheating of rotor of the motor.
- Moreover temperature rise due to negative sequence component is much more than thermal rise due to the motor current alone.
- An unequal voltage at the point of utilization causes voltage unbalance. Most common causes of this include,
  - Uneven distribution of single phase loads from one of the phases in the facility.
  - Mal-operation of power factor correction device or voltage regulator.
  - Unbalanced transformer bank
  - Use of cables of different sizes in the distribution system.

- To ensure long life of the motor which is in operation during a voltage unbalance it's derating is required.
- National Electrical Manufacturers Association (NEMA) has suggested standards for derating of motors in case of voltage unbalance in the range of 1% to 5% as given in following table :

Table 2.2.1

Voltage Unbalance (in %)	Suggested Derating (in %)
1	-
2	95
3	88
4	82
5	75

- For motors having rating more than 500 HP derating factor is suggested to calculate by consulting with supplier.
- If motor is provided with protection scheme against excessive unbalancing of currents, nuisance tripping may occur.
- This problem arises mostly when configured tripping is on the basis of percentage of unbalancing of currents rather than temperature rise.
- To minimize the adverse effects of unbalanced currents on the induction motor, monitoring of temperature rise is the best solution.
- Large motors are equipped with temperature detectors and protection scheme is given one input from these.
- Motor is taken offline as soon as temperature overtakes the predetermined limit. This is much better than taking motor offline on excess unbalanced current.

Voltage unbalance can be minimized by

- Equal distribution of single phase loads on all three phases.
- Identifying and taking aside the loads which are disturbing the balance. These loads can be feed from separate line or transformer.

2.2.1.2 Harmonic Distortion

(MSBTE – W-14, W-15)

> **Q.** Explain the effect of harmonic distortion parameter on three phase induction motor. **W-14**
>
> **Q.** Describe the effect of following on Induction Motor :
> (ii) Harmonic Distortion **W-15**

- Widespread power electronic devices cause an increase in voltage distortion. Due to this, presence of unwanted frequencies in addition to fundamental frequency of 50 Hz.
- Undesirable effects of higher frequencies related with harmonic voltage distortion causes increased iron and copper losses.
- This ultimately leads motor to higher operating temperatures due to increased motor heating.
- 5^{th} and 7^{th} harmonics in association with voltage unbalance badly overheats the rotor.
- Effect of Harmonic voltage distortion in induction motor can be compensated again by derating as suggested by NEMA.

2.2.2 By Motor Survey

(MSBTE – S-17, S-1

> Q. Suggest the energy conservation techniques in following cases :
>
> (i) Motor is running with 70% loaded condition.
>
> (ii) Motor is continuously loaded at 50%.
>
> (iii) Motor runs with 30% loaded condition but sometimes rises to 50% loading condition.
>
> (iv) Motor runs continuously under no-load condition.
>
> Q. Describe the following energy conservation methods of electrical motor.
>
> (i) By motor survey

- In large industrial plants, the population of inductions motors is too large that needs attention.
- To make these motors perform optimally over the time, it is necessary to develop and maintain a motor manageme plan.
- This demands the surveying of motor with respect to load by applying some methodology.
- Under this scope for improvement in the motors used in plant is identified.
- General methodology includes :

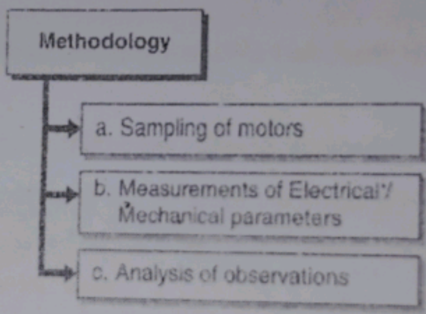


Fig. C2.2 : Methodology

a. Sampling of Motors

Motors are categorized by applying various sampling criteria. This helps to fulfilling objectives of selection representative motor drive of each type for analysis.

(i) Hours of Operation

Motors are categorized on the basis of their utilization factor. In this motor drives which are continuously operat are given preference.

(ii) On the basis of illustrative sample

One motor out of a typical group of application is analyzed and used as an illustrative sample for that class of moto For e.g. Fans used in cooling tower. In this case only a fan or two will be taken as an indicative sample for all the mot used in the fan of all the cooling towers.

(iii) On the basis of probable conservation

In this, motor drives having scope for the conservation are identified and taken care of especially. Some criteria may be

- Machines with inefficient capacity control
- Drives having fluctuating loads, etc.

b. Measurement of Electrical / Mechanical Parameters

- Electrical load parameters as well as machine side mechanical parameters are measured for the purpose of motor study.
- Measurement on selected motors are carried out to for electrical parameters such as :
  - Voltages
  - Load currents
  - Power factor
  - Power Drawn (kW, kVA)
- Measurement of mechanical parameters on the machine side includes :
  - Speed measurement
  - Pressure measurement
  - Mechanical load
  - Temperature measurement, etc. relevant parameters.
- For each case some of the important instruments which are looked into are :
  - Online instruments which are used for routine measurements
  - Power factor correction capacitors
  - Energy meters used for monitoring

c. Analysis of Observations

- Analysis of the observations obtained from measurements on representative motors is done in order to :
  - Find out the expected probable energy consumption and motor load in kW.
  - Identify the areas in the monitoring system which can be improved in order to facilitate energy audit on the regular basis.
  - Search the aspects which can lead to energy conservation.
  - Calculate the benefits associated with identified conservation in terms of money and details of source information.

Observations in the motor surveying

- The observations in the motor surveying indicates
  - Percentage loading in terms of kW.
  - Percentage voltage unbalance in case.
  - And obvious electrical parameters like voltage and currents and also power factor as well as frequency.
  - Load or unload condition of motor.
  - Idle operations.
  - Metering provisions which observe pressure, temperature, flow, etc.
- The outcome of this motor surveying may include some findings or recommendations such as :
- Segregated motors according to loading as :
  - Motors loaded less than 50%
  - Motors loaded between 50 to 75%
  - Motors loaded between 75 to 100%

- Loading over 100%

– Identified motors demanding improvement measures due to suffering from :
  - Low voltage
  - Low power factor
  - Voltage unbalance
  - Pinpointed motors which are subjected to inefficiencies or losses at machine side such as,
  - Idle operations
  - Throttling operations in the path of automatic controls, variable speed drives, etc.

– In this way, motor surveying fulfils the objectives of :
  - Identification of efficiency areas in motor
  - Checking the efficiency of motor, driven machine and controller together in a combined manner.

– Motor load surveying can lead to energy saving in the range of 30 to 40% in driven machine or associated system.

2.2.3 By Matching Motor

(MSBTE – S-12, W-14, W-15, S-16, W-16, S-18, W

Q. Explain the following energy conservation methods of electrical motor : Matching motor rating with required load	**S-12, W-**
Q. Explain following energy conservation methods of electrical motor : (i) Matching motor rating with required load.	**W-15, W-16, S-**
Q. Describe the following energy conservation methods of electrical motor. (ii) By matching loads with motor rating	**S-**
Q. Describe the following energy conservation methods of electrical motors : (i) Matching motor	**W-**

– **Power drawn by motor depends on load and not necessarily with size.**

– A 10 kW fan drawn by 10 kW motor can be said a well match.

– That fan can also be driven by 20 kW motor which will work but not with the desired efficiency.

– Over sizing causes :
  - Lower efficiency
  - Lower power factor
  - Higher initial cost of motor as well as controls associated.

– Several reasons contribute for unmatching of motors with load such as,
  - **Large safely factor** considered by original equipment manufacturers.
  - **Use of large motor** for high starting torque, instead of using specially designed motor.
  - **Under-utilization** of equipments.
  - **Large motor even at low voltages** designing the output to be maintained.
  - **Rounding up** to next size while designing.

– Careful evaluation of load is very important factor to select the matching capacity of the motor.

– Industrial motor undergo varying loads according to process needs.

– Motor is preferred to be selected on highest anticipated load.

- Larger motor features higher rated efficiency as compared to smaller motors. Hence motor having loading 60% to 70% or more are not recommended to replace.
- To form a rule for downsizing is difficult, as motor efficiency curve defers motor to motor.
- In general, motors operating at load 40% less of its rated capacity it should be downsized especially where load variations are rare.
- On the contrary, if some motor is having capacity 100 HP and generally operated at 35 HP but sometimes required to operate at 90 HP, it should not be considered for downsizing.
- Motor which generally takes 50% to 100% of its rated capacity need not to be considered for replacement as its working at its highest efficiency.
- Oversized motor works at lower efficiency level so replacing an oversized motor should be preferred to be replaced it is not failed because energy consumed and cost of new motor.
- However, suitable oversized margin offers the advantages of :
  - Spare capacity in case of future expansion.
  - Accommodation of unexpected additional load.
- In some cases of variable loads, to optimize the size of motor according to the load duration curve of that particular application is referred and approach is
  - Motor of rating little than the peak estimated or expected load is selected. This will sustain overloading for that particular small time period and case for thermal loading is taken.
  - If motor of higher rating is chosen, it would be fully loaded for short duration of peak loading (hence higher efficiency for small time) and it will remain oversized for rest of the operation (hence lesser efficiency for all that time).
- Motors having loads less than 40% offers poor efficiency and no or less energy savings. Therefore, for motors that are often loaded below 40 % of rated capacity an effective method to optimize the matching is the operation of under loaded delta connected motors in star connection.

2.2.4 Minimizing the Idle and Redundant Running of Motor

(MSBTE – S-12, W-14, W-15, S-16, S-18)

Q. Explain the following energy conservation methods of electrical motor : Minimizing idle and redundant running of motor. **S-12**

Q. Explain energy conservation technique in induction motor by minimizing the idle and redundant running of motor. **W-14, S-18**

Q. Explain following energy conservation methods of electrical motor :
(ii) Minimizing idle & redundant running of load. **W-15, S-16**

- Motor is said to undergoing idle operation when it continues to run even though it is not supplying useful work.
- Typical examples of idle operation are :
  - Continuation of unloaded conveyor belts.
  - Running exhaust fans though shop floor is not in operation
- In industries, prolonged idling of machine tools such as conveyor belts and exhaust fans are commonly observed.
- 100% saving of the power consumed by motors in these conditions can be achieved by simply stopping the motor in idle condition.

- Though auxiliaries such as cooling towers, air compressors, etc. demands care to stop idle running during stoppage of production machine for a long time.
- Redundant operation means equipment operates without any significant effect on production neither in quality nor quantity.
- Some exemplifying cases are,
  - Running of cooling tower fans though ambient conditions are favourable.
  - Operation of an air conditioning unit even when desired temperature is achieved.
  - Air conditioning runs also as good as redundant if window is open.
- Stopping these motors is a simple way to large savings of energy as well as money.
- Manually or automatically switching off the idle or redundantly operating motor is the ultimate solution to avoid energy loss in the same.
- Some illustrative energy conservation measures which proves to be effective over idle or redundant conditions may be,
  - Agitator motor in washing machine is provided with time switch. This terms switch stops the operation of rotating back and forth after the set time instead of continuation redundantly.
  - In chemical industries, agitator motor in process vessel may not need in every batch for some duration if boiling is providing enough turbulence. Under this condition, it can be turned off.
  - A fan motor used in cooling tower is given thermostat control so that fan operation can be avoided during favourable ambient conditions.
- In industrial plant having large rolling mills drives, some motors are used to provide cooling. It's observed that the main drive remains idle for 2 to 3 hour every day. The cooling fan motors can be turned off for this duration.

2.2.5 By Operating in Star Mode

(MSBTE - S-15, S-16, W-17, W-18)

Q. Explain when induction motors are run in star connection under 30% load condition, how energy is conserved. **S-15**

Q. Explain energy conservation technique in induction motor by operating I.M. in star mode. **S-16**

Q. Explain the following energy conservation methods of electrical motor : (b) Operating in star mode **W-17, W-18**

- In delta connection, each motor phase winding is supplied with line voltage.
- Whereas, in star connection this line voltage is reduced by a factor of $\sqrt{3}$ and supplied to each phase winding.
- Motor becomes electrically downsized when operated in star and performance characteristic remains same with respect to load.
- Motor operation at full load gives better efficiency as well as power factor in star mode as compared to partial loaded motor in delta mode.
- Three phase wiring of input power is reconfigured at the terminal box while changing from delta operation to star mode.
- Motor can be permanently connected in star if it is found oversized and consistently loaded less than 30% of its rated capacity.
- For the motors which require high starting torque and normally loaded below 30% of rating suitable starters can be used for starting. As soon as it overcomes the starting inertia automatic delta star switching can be done by sensing the current or time control.

- In the cases where normally loading is less than 30% but may exceed to 50% sometimes automatic star delta changeover switch is recommended which works on the basis of current or load sensing. However frequent changeover results in wearing of contactors hence replacement costs.
- Star delta changeover does not prove economical for motors which normally operates above 30% load and only sometimes below 30%.

2.2.6 Rewinding of Motor

(MSBTE – W-14, S-15, W-17)

Q.	Explain the following energy conservation methods of electrical motor : Rewinding of motors.	W-14
Q.	Explain why frequent rewinding of induction motors reduces its efficiency.	S-15
Q.	Explain the following energy conservation methods of electrical motor : (a) Rewinding of motor	W-17

- Rewound motors count more than half of total number of motors in the industry.
- In most of the cases, efficiency level is lowered after rewinding as compared to that before rewinding.
- Many factors contribute in lowering the efficiency such as :
  - Damaged Laminations
  - High Temperature
  - Smaller Conductor Size
  - Improper cooling
- However, with some improvement measures practiced in the procedure of rewinding previous efficiency can be maintained and may be increased in some cases.
- Generally, it is expected that original design of the motor should be preserved in rewinding but if specific load reasons demand it can be changed.
- Keeping energy conservation in view in this area, following are some important aspects, should be worth noted while rewinding.
  - Original winding data should be followed in rewinding. In case if it's unavailable contact manufacturer for the same.
  - Wires of greater cross section with suitable slot size and shortest possible end turn results in reduced stator losses hence increased efficiency.
  - Old, burnt winding is extracted by heating the stator. The care necessary in this is the stator should not be heated with open flame and at the temperature not more than 350^0 C. This will avoid damage to the inter laminar insulation of steel core (which increases core losses otherwise).
  - Some special solvents are available to remove old winding without heating.
  - At the time of purchase of motor documents of no load losses and no load speed are provided. These should be maintained so that it can be used for the purpose of assessing the impact of rewinding later on. This data also helps to take replacement decisions by comparing motor.
- While rewinding repairer can choose any of two options i.e.
  - Copy the original winding which was earlier provided by manufacturer.
  - Design a different winding which will give results same as or better than the previous one.

2.2.6.1 Copy Rewinding

- If as noted earlier when details of manufacturer's original winding is preserved the core can be made ready for rewinding.
- The points which will remain same as those of original winding are :
  - Coil pitch
  - Turns / Coil
  - Connections
- Changes which can be made in order to increase efficiency of the motor are :
  - Reduction in length of coil extensions.
  - Increase in size (cross sectional area) of wire in each coil.

(a) Reduction in Length of Coil Extensions

- Purpose of coil extension is only to connect active conductors inside the slot and it consists of 'inactive' Copper.

(b) Increase in Size (Cross Sectional Area) of Copper

- Increased size of conductor copper helps for
  - Reducing I^2R losses and
  - Maintain or improve efficiency after rewinding has been done.

2.2.6.2 Changing to a Different (Double Layer Lap) Winding

- In the rewinding with this option, lap winding is often preferred to be used as it includes all the same coils.
- This is quite acceptable if it results the same amount of flux per pole as the original winding.
- Flux distribution through the core is achieved much better in double layer winding as compared to single layer.
- Advantages
- Improvement in efficiency or at least maintained.
- All coils are subjected to equal air flow for better cooling.
- Uniformly placed phase insulation and coil bracing.
- Nature of MMF curve much resemble to sine wave.

2.2.7 Replacement by Energy Efficient Motor

- Conventional motor can be replaced with the Energy Efficient motor.
- Energy Efficient Motors incorporate improved design and high quality material in order to reduce losses therefore it has higher efficiency than conventional one.
- EEM runs cooler, uses less electricity and has longer life as compared to conventional motor.
- Refer section 2.5 for more details of Energy Efficient Motors.

2.2.8 Periodic Maintenance

Q.	State any four periodical maintenance which is necessary in transformer to achieve energy conservation.	(MSBTE – S-18) S-18

- Periodic maintenance program of the Induction motor is given here. It may change depending upon type of machine and its application.

2.2.8.1 Weekly Maintenance

- Weekly maintenance include following examinations and actions if required.
  - Starter switches, fuse and other controls
  - Loose connections
  - Oil in bearings
  - Brushes
  - Whether machine reaches to rated speed in normal time.

2.2.8.2 Half Yearly Maintenance

- Thorough cleaning of motor-
  - Blow dirt from winding
  - Wipe commutator and brushes
  - Clean Brush holders – ensure smooth riding of brushes in it.
- Brushes – check and replace if worn out more than half
- Sleeve bearing – drain, wash out and replace oil
- Ball or roller bearing – check grease
- Covers, belt and gear guards – Ensure that they at place with good order and fastened properly.
- Tighten motor and control connections.

2.2.8.3 Yearly Maintenance

- Air gap check
- Insulation – check by Mega Ohm-meter
- Commutator – Check smoothness and clean undercut slots
- Ensure proper connections between commutator and armature coils.
- Clear out magnetic dust clinging to pole.
- Examine clearance between shaft and journal box of sleeve bearing. This will prevent operation with worn bearings.
- Renew grease in ball or roller bearing housing.

2.3 Energy Conservation Techniques Related in Transformer

(MSBTE – W-12, S-13, S-16, W-17, W-18)

Q.	How efficiency in Energy Efficient Transformer is improved.	W-12
Q.	State the methods of energy conservation in transformer.	S-13
Q.	State the opportunities for energy conservation techniques in transformer.	S-16, W-17
Q.	State any two opportunities for energy conservation techniques in transformer.	W-18

Energy Conservation Techniques Related to Transformer

- 1. Parallel Operation of Transformers
- 2. Load Sharing
- 3. Isolating Transformer

Fig. C2.3 : Energy Conservation Techniques Related to Transformer

2.3.1 Parallel Operation of Transformers

(MSBTE – S-15, S-17, W-

Q.	Explain how energy can be conserved by operating two transformers in parallel.
Q.	State how 'parallel operation of transformers' helps in energy conservation.
Q.	Explain parallel operation of the transformer in context of energy conservation.

- In parallel operation of transformers, a second transformer is connected in parallel to supply the load in excess of t rating of an existing transformer.
- Sometimes in industrial or commercial premises also transformers are paralleled to :
- Make power system more reliable
- Provide better power quality
- Prevent voltage sag
- Meet additional load requirement
- Electrical utilities prefer this aiming reliability and power quality whilst consumer remains online.
- Number of small rated transformers in parallel is recommended than a bigger rated electrical power transform because of following advantages.

Advantages of Small Transformers over Bigger Power Transformers

- 1. Much Improved Reliability
- 2. Maximized Availability of Power
- 3. Maximized Power System Efficiency
- 4. Flexibility

Fig. C2.4 : Advantages of small rated transformer over bigger power transformer

1. Much Improved Reliability

- If fault occurs and a transformer is tripped, other transformers in parallel shares the load and no interruption in pow system.
- If load sharing is not done, transformer gets overloaded.

2. Maximized availability of power

- In case, any one of transformer from a set of transformers operating in parallel, it can be taken out for maintenanc

- Total interruption of power is avoided as other transformer in parallel continues to serve.

3. Maximized power system efficiency

- Electrical power transformers operate at full efficiency when they are fully loaded.
- When number of transformers are run in parallel, it is possible to use only those transformers which can serve the total demand by operating close to its rated capacity.
- With the increase in load remaining transformers can be connected one by one to meet the demand.
- Therefore, system can be run with maximum efficiency.

4. Flexibility

- The possibility of increase or decrease of demand in future can never be ignored in power system.
- Provision of connection of parallel transformer to meet the increased demand keeps the system flexible.
- Installation of single transformer of greater capacity by forecasting future demand proves unnecessary investment, which may be worth mostly may not.
- In case of decrease in demand, capital investment and its return can be balanced by simply removing the transformer.
- Connection of parallel operation as follows,

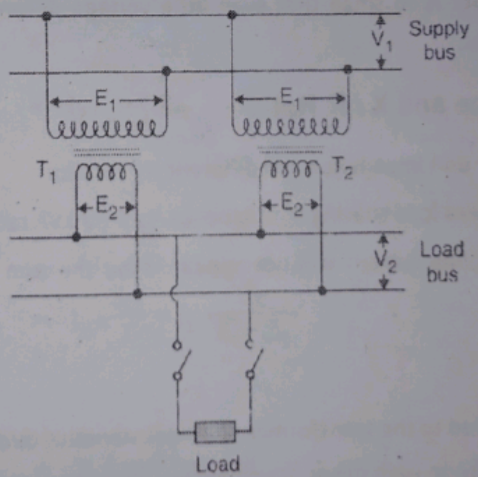


Fig. 2.3.1 : Two single phase transformers in parallel

- Primary windings are connected to supply bus bars and secondary windings are connected to load bus bar.
- Conditions which must be fulfilled for parallel operation of transformer are,
- Same kVA rating
- Same percentage impedance and X / R ratio
- Same voltage ratio and turn ratio
- Same polarity
- Same phase sequence in case of 3ϕ transformers.
- Same phase angle shift.
- Same frequency.

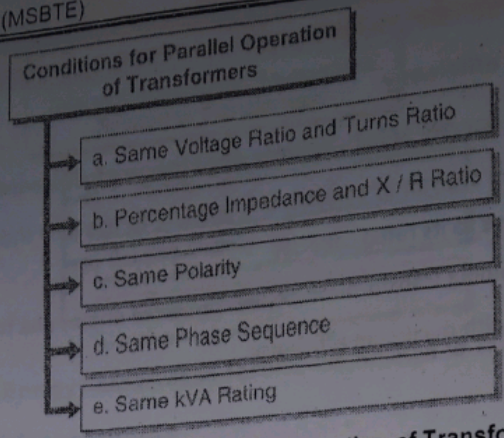


Fig. C2.5 : Conditions for Parallel Operation of Transformers

2.3.1.1 Same Voltage Ratio and Turns Ratio

- If voltage ratio of two transformers connected in parallel with same primary supply is different, a difference in secondary voltage will be caused.
- Now when secondary's are connected to the same load bus, there will be circulating current in not only in the secondary but also in primary due to that.
- Internal impedance of transformer is so small that even little voltage difference circulates high current which also causes highly undesirable IR losses.

2.3.1.2 Percentage Impedance and X / R Ratio

- Transformers may have same per unit impedance and different X / R ratio.
- Same percentage impedance implies load sharing in proportion to their kVA rating.
- If X / R ratios are different total line current will not appear to be the sum of transformer currents which implies reduced combined capacity.

2.3.1.3 Same Polarity

- When same input power is being fed to the transformer and instantaneous direction of e.m.f induced in the secondary of the two transformer are opposite to each other, transformers are in opposite polarity.
- If polarities of parallel connected transformers are not same, large circulating current flows in transformer but no load is fed.

2.3.1.4 Same Phase Sequence

- This condition is mandatory to be followed in parallel connection of three phase transformers.
- Incorrect phase sequence causes short circuit of each pair of phase in every cycle.

2.3.1.5 Same KVA Rating

- Load sharing of parallel connected transformers depends on kVA rating.
- Transformers with same kVA rating share the equal load.
- If transformers with different kVA rating are connected in parallel, load division will be uneven such that each transformer will carry load in proportion to their rating.

2.3.2 Load Sharing

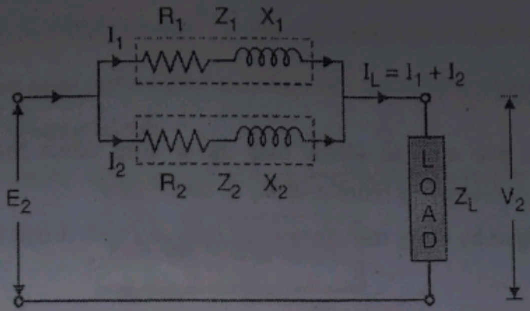


Fig. 2.3.2 : Load Sharing

Assuming no load voltages of both the secondary's same E_2.

Fig. 2.3.2 shows two impedances in parallel let.

Z_1, Z_2 - Transformers impedances

I_1, I_2 - Respective currents

V_2 - Terminal voltage

I_L - Load current

Then,

$$I_1 Z_1 = I_2 Z_2 = I Z_{12} \quad \text{...(i)}$$

Where,

$$Z_{12} = \frac{Z_1 Z_2}{Z_1 + Z_2} \quad \text{...(ii)}$$

$$I_2 = I_L \times \frac{Z_{12}}{Z_2} = I_L \times \frac{Z_1}{Z_1 + Z_2}$$

Multiply both sides by V_2

$$V_2 I_1 = V_2 I_L \frac{Z_2}{Z_1 + Z_2} \text{ and}$$

$$V_2 I_2 = V_2 I_L \frac{Z_1}{Z_1 + Z_2}$$

Where $V_2 I_L \times 10^{-3} = S$ is kVA of combined load

Then load shared by each transformer is given by

$$\left.\begin{aligned} S_1 &= S \frac{Z_2}{Z_1 + Z_2} \\ S_2 &= S \frac{Z_1}{Z_1 + Z_2} \end{aligned}\right\} \quad \text{...(iii)}$$

- For equal load sharing it's important to.
  - o wound the transformers with same turns ratio.
  - o have equal % impedance of transformers
  - o resistance to reactance be equal.
- Parallel operation of transformers achieve the benefits such as,

- Overall demand load is lowered to the directly of loads connected to various transformers.
- Possibility of disconnection of unloaded transformers reduces electricity losses in transformers.

2.3.3 Isolating Transformer

- Usually electrical transformers are used to either step up or step down the voltage. It hardly does anything to minimize the crossing of noise or transients from primary to secondary.
- Circuit impedance can be changed by using transformer to reduce short circuit current (hence associated losses) to insulate between two systems.
- Except autotransformers in any transformers there is no direct connection between primary and secondary winding. Only magnetic flux connects the windings.
- Only a basic separation exists between primary and secondary as shown in Fig. 2.3.3.

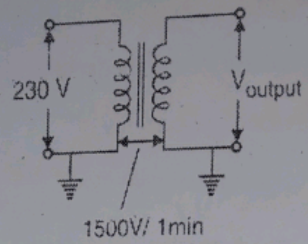


Fig. 2.3.3

- Fig.2.3.4 shows separation transformer having only a physically separated primary and secondary.
- Certain level of protection against electrical shock is provided by insulation between the primary and secondary winding.
- Increasing the insulation between the primary and secondary winding a step ahead, isolation transformer is formed.

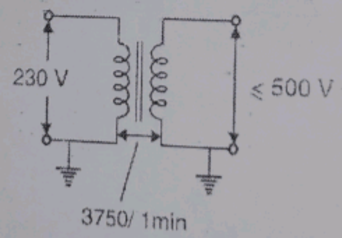


Fig. 2.3.4

- The insulation between the two windings gives a protection level of double insulation against shock.
- In case of contact with the exposed conductive part and the line parts simultaneously this separation minimizes the risk.
- Protection against the dangers of electric shock.
- Transmission of DC signal from one circuit to another can be blocked by isolation transformers.
- Isolation transformers are frequently used to isolate the machine from the remaining installation. This avoids loss of power if first insulation fault occurs.

2.3.4 Periodic Maintenance

Q. State the periodical maintenance is necessary in power transformers, how does it result in energy conservation. (MSBTE - S...)

- The transformer demands less care as compared to other electrical equipments.
- Though periodical inspection and maintenance are necessary.
- The extent of maintenance and periodicity of inspection vary with the capacity of the transforms.

- Information collected through periodical tests on transformer provides an alarm for approaching service issues.
- Also effective interpretation of maintenance records makes the prediction of imminent failure.
- Periodic inspection and remedial methods of maintenance takes care of regions of transformer losses which may lead to efficiency decrease and energy waste.
- Following are the various maintenance activities performed on transformers with their periodicity and methodologies.

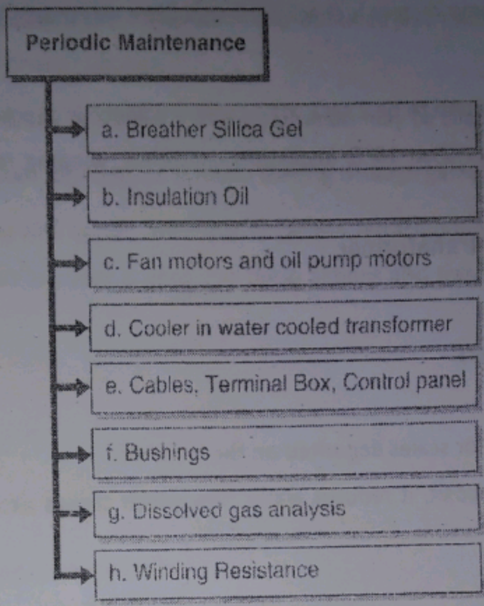


Fig. C2.6 : Periodic Maintenance

a. Breather Silica Gel

Periodicity

Once every half year.

Method

Color of silica get is checked in breather due to moisture in breathed air.

Action

Silica gel is dried out or exchanged it hasturned to ink.

b. Insulation Oil

Periodicity

Every one year.

Method

- Dielectric strength of oil is measured with an oil tester to check it is more than 40 kV/ 2.5 mm gap.
- Moisture content of oil is checked whether satisfactory to criteria or not by automatic volumetric Karl Fischer titration method.
- Acid value of oil is checked and compared with criteria from standard values chart.

Action

- If dielectric strength of oil is not satisfactory filtering and degassing is preferred.

c. Fan motors and oil pump motors

Periodicity

Once in couple of years.

Method

- Insulation resistance of fan motor and oil pump motor is measured by using 500V megger.
- Temperature rise of oil pump motors is checked. It should be less than 10°C.

Actions

- If insulation resistance is found to be 2 MΩ, load current balance is checked and interior of fan motor is dried out.
- If temperature rise is more than 10°C; insulation resistance, winding resistance and three phase balancing of load current is checked.

d. Cooler in water cooled transformer

Periodicity

Once in every couple of years.

Method

- Cooling tubes are checked for scales deposited on the inner side.
- If scales are allowed to deposit, it reduces water flow which causes excess heating of transformer even at normal loads.

Action

- If scales are found accumulated inside cooling tubes, cleaned up.

e. Cables, Terminal Box, Control panel

Periodicity

- Once in every year.

Method

- Insulation resistance of cable is measured with megger and also checked for crack.
- Proper functioning of switches, annunciators, lamps is observed as per schematic diagrams.
- Tightness of control wiring connections.
- Control cabinet and terminal box is checked for water tightness.

Actions

- If cable is found, defective tape is wound or replaced.
- If any part is found functioning improperly, it is replaced with the new one.
- Loose bolts are tightened.
- Worn out rubber gaskets are replaced with new one.

f. Bushings

Periodicity

- Once in every two years.

Method

- Insulation resistance and tanΔ is checked to evaluate deterioration of insulation.

- Terminals are checked, if they are loose; causes excessive heating
- Local damages are checked if any or oil leak in the bushing.
- Also checked for dust, dirt, salt etc. accumulated on busing.

Actions

- Tan Δtesting is done. Though it's a tough job as bushing needs to be taken out from the transformer.
- Evaluation in this regard should not be based solely on values obtained but also values got each year and variation among them. Large discrepancies demands change.
- If terminals are loose, bolts are tightened or clamping of the terminals may be changed.
- Various pieces of bushings are checked for oil leaks. If found leaking through gasket, it is tightened or replaced.
- Dirt, dust on the bushing is clean up with water, ammonia or carbon tetrachloride. In case of more dirt, concentrated HCl acid diluted more than 40 times in water is used. For these actions also transformers has to be taken out of the service.

g. Dissolved gas analysis

Periodicity

- Every six months.

Method

- Analysis of gases dissolved in oil is done periodically.
- Oil is taken from the transformer using an appropriate air tight container.
- Dissolved gases are extracted from the oil and analysis is performed.

Action

- After obtaining the quantities of combustible gases, evaluations of pinpointed location and type of trouble which may occur in a transformer.

h. Winding Resistance

Periodicity

- Once in every year.

Method

- Resistance of winding is measured by bridge method.
- Oil pumps should be operated whilst measuring the winding resistance it provided.
- Simultaneously temperature is also recorded.

Actions

- If winding resistance amended to a particular temperature is found different than the previously obtained data, it is given priority and an investigation is conducted in detail.
- The disciplined analysis of tests inspections and periodic tests will give assurance of optimum transformer performance.

2.4 Energy Conservation Equipments

(MSBTE – S-12, W-15, W-1

Q. State various methods/techniques for energy conservation in 3-phase induction motor in industries.Explain any o detail. S-12

Q. Enlist various energy conservation equipments which can be implemented in lighting system and electric motors. W-15

Q. What is energy conservation equipment and list out energy conservation equipments related to lighting system a induction motor. W-18

Energy Conservation Equipments Related to Electric Motor

- 1. Soft Starters
- 2. Power Factor Controller
- 3. Automatic Star-Delta Starter
- 4. Variable Frequency Drives (VFDs)

Fig. C2.7 : Energy Conservation Equipments Related to Electric Motor

2.4.1 Soft Starters

(MSBTE – W-13, W-14, S-15, S-16, W-17, W-18)

Q. Why soft starter used for motor? W-13

Q. State the working and application of following energy conservation equipment: Soft starter. W-14

Q. Explain how soft structures helps to conserves energy. S-15

Q. Why soft starter used for motor? State its two advantages. S-16

Q. Compare soft starter with conventional starter (any four point). W-17

Q. Describe the working of soft starter and state its advantages over conventional starter. W-18

Definition : ***Soft starter*** *is any device, which controls the acceleration of an electric motor by means of controlling the applied voltage.*

- In technical terms, as of starter is any device that reduces the torque applied to the electric motor.
- It generally consists of solid state devices like thyristors to control the application of supply voltage to the motor.

2.4.1.1 Working Principle

- The starter works on the fact that the torque is proportional to the square of the starting current, which in turn is proportional to the applied voltage.
- Thus, the torque and the current can be adjusted by reducing the voltage at the time of starting the motor.
- Basic principle of soft starter is by controlling the conduction angle of the SCRs the application of supply voltage can be controlled.

2.4.1.2 Main Components of a Basic Soft Starter

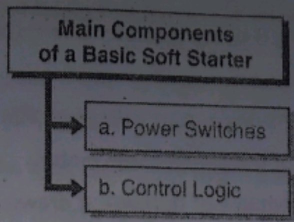


Fig. C2.8 : Main Components of a Basic Soft Starter

a. Power Switches

Definition : *Power switches are Solid-State Switches like SCR sand Triac which need to be phase controlled such that they are applied for each part of the cycle.*

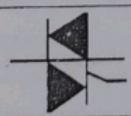
- The average voltage is controlled by varying the conduction angle of the switches.
- Increasing the conduction angle will increase the average output voltage.
- For a 3 phase motor, two SCRs are connected back to back for each phase. The switching devices need to be rated atleast three times more than the line voltage.

b. Control Logic

Control Logic using PID controllers or Microcontrollers or any other logic to control the application of gate voltage to the SCR, i.e. to control the firing angle of SCRs in order to make the SCR conduct at the required part of the supply voltage cycle.

2.4.1.3 Voltage Control

- Voltage control is achieved by means of solid-state A.C. switches in series with one or more phases.
- These switches comprise the following:

	One Triac per phase in a 3-phase system.
	One SCR and one Diode connected reverse parallel per phase in a 3-phase system.
	Two SCRs connected reverse parallel connected per phase in a 3-phase system

- Voltage control can be achieved by control electronics in two ways:

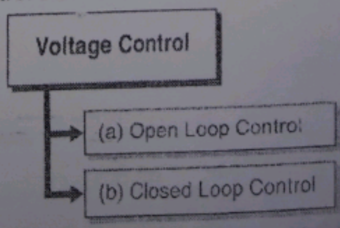


Fig. C2.9: Voltage Control

1. Open loop control-voltage is controlled on at time sequence
2. Closed loop-voltage is controlled based on current and speed feedback

(a) Open Loop Control

- Open Loops of starters are soft starter shaving a start voltage profile
- It is in dependent of the current drawn ,or the speed of the motor.
- A start voltage is applied with time, irrespective of the current drawn or the speed of the motor.
- For each phase, two SCRs are connected back to back and the SCRs are conducted initially at a delay of 180 degree during the respective half wave cycles (for which each SCR conducts).
- This delay is reduced gradually with time until the applied voltage ramps upto the full supply voltage.
- This is also known as Time Voltage Ramp System. This method is not relevant as it doesn't actually control the motor acceleration.

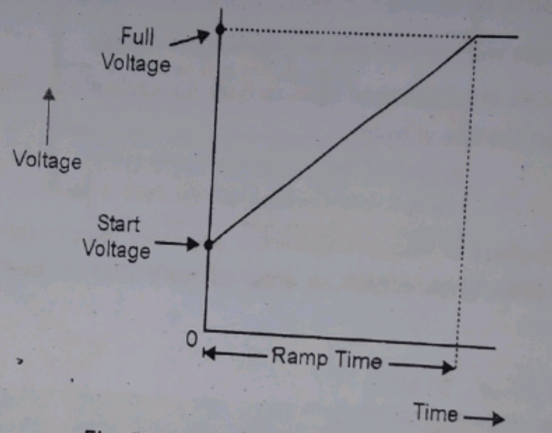


Fig. 2.4.1 : Voltage Ramp Time

(b) Closed Loop Control

- Any of the motor output characteristics like the current drawn or the speed is monitored and the starting voltage is modified accordingly together required response.
- The current in each phase is monitored and if it exceeds a certain set point, the time voltage ramp is halted.
- Constant current starters are idea If or high inertia loads, or loads where the starting torques requirements do not change.
- The current ramp soft starter operates in the same manner as the constant current soft starter except that the current is ramped from an initial start current to a current limit setting over a period of time.
- The initial start current, current limit, and the ramp time are all user adjustable settings and are suitable for the different applications.
- The current ramp soft starter can be used for a number of advantages over constant current in some applications.

Current ramp soft starter can be used for:

1. Conveyers
2. Pumping applications
3. Generator set applications

2.4.1.4 Soft Stop

- Soft starters can have soft stop included for no extra cost.

- Soft stop is the opposite of soft start.
- The voltage is gradually reduced, reducing the torque capacity of the motor.
- The reduction of available torque causes the motor to begin to decelerate when the shaft torque of the motor is less than the torque that is required by the load.
- As the torque is reduced, the speed of the load will reduce to the point where the load torque equals the shaft torque.
- Generally, the soft stop uses an open loop voltage ramp.

2.4.1.5 Advantages of 'Soft Starter'

(MSBTE - S-12, S-13, W-13, W-14, W-15, S-16, S-18)

Q.	State the advantages of 'soft starter' compared to 'DOL' starter.	S-12, W-14
Q.	Compare soft starters with conventional starters.	S-13
Q.	State four advantages of soft starter.	W-13, S-18
Q.	State advantages of soft starters over conventional starters.	W-15
Q.	Why soft starter used for motor? State its two advantages.	S-16

- **Smooth starting** by torque control for gradual acceleration of the drive system thus preventing jerks and extending the life of mechanical components.
- **Reduction in starting current** to achieve break-away, and to hold back the current during acceleration, to prevent mechanical, electrical, thermal weakening of the electrical equipment such as motors, cables, transformers and switchgear.
- **Enhancement of motor starting duty** by reducing the temperature rise in stator windings and supply transformer.
- The microprocessor version of the Soft starter has a software controlled response at full speed which economizes energy, whatever maybe the load.
- **The power factor improvement** is a self-monitoring in built feature. When the motor is running at less than full load, the comparative reactive component of current drawn by the motor is unnecessarily high due to magnetizing and associated losses. Hence the voltage dependent losses are minimized with the load proportional active current component and as a result the power factor also improves simultaneously.

2.4.1.6 Applications of Soft Starter

- Steel industries (Rolling mills and processing lines).
- Cement industries
- Sugar plants
- Paper and pulp
- Rubber and plastic
- Textile industries
- Machine tool applications
- Power sector
- Water supply scheme
- And various process control applications.

2.4.2 Automatic Power Factor Controller

(MSBTE - W-14)

Q. How efficiency of electric motor is improved by using equipment : Power factor controller. **W-14**

- In electrical power systems, power factor control has long been accepted as an important step to energy conservation.
- Capacitors are switched in and out of the system according to need of VAR compensation.
- If properly applied and controlled (possibly automatic) capacitance improve performance of distribution network as it provides reactive current locally and offers the advantage of
  - Lower losses
  - Improved line voltage
  - Reduced utility penalty hence lessened billing charges.
- Automatic power factor control may be achieved using relay / microprocessor / microcontroller.
- Most popular methods of control in automatic power factor controlling are :
  - Voltage control
  - KVAR control
- KVAR sensitive controls are recommended where voltage level is closely regulated and not possible to use as a control variable.

Voltage Control

- Switched capacitors are implemented at the points where voltage reduces as result of circuit load increase.
- At such points only voltage is the parameter which can be used as a source of intelligence.
- Generally they are applied when voltage drop of 4% to 5 % is caused with increasing load.
- Another type of voltage control which is independent of load cycle is at substation.
- At the places like substation, voltage is a factor of prime importance as it needs to be maintained at a particular level.
- So voltage is the most commonly observed parameter over here.
- During conditions like light loads or low supply voltage, these capacitors may give leading power factor.

2.4.2.1 kVAR Controller

- kVAR controllers are used where voltage is not available as a control variable.
- The capacitor is switched as a response to change in power factor due to change in system loading.
- kVAR control can also avoid penalty due to low power factor as it adds capacitors in as soon as p.f. starts to decrease below the desired value.
- kVAR controller needs two inputs viz. current and voltage from the incoming feeder.
- This is fed to p.f. correction mechanism which may be microprocessor or relay.

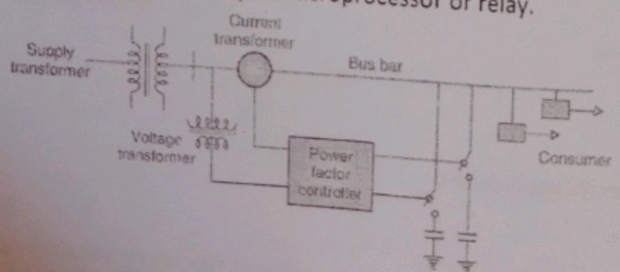


Fig. 2.4.2 : kVAR controller scheme

- As can be seen in above Fig. 2.4.2 reactive power compensation scheme is located at entrance of the facility which offsets the inductive loading (lagging p.f.)
- kVAR controller in general includes :
  - Switched capacitor units
  - Intelligent control unit
  - CT and PT to sense the current and voltage.
- Mostly capacitor banks consist of 3 to 9 capacitors connected in 3ϕ grounded star, ungrounded star or delta.
- Switched capacitor banks are preferred over fixed banks as it switches capacitor units on and off to meet the changing load condition.
- Following Fig. 2.4.3 shows an example kVAR demand over a period of 24 hours.

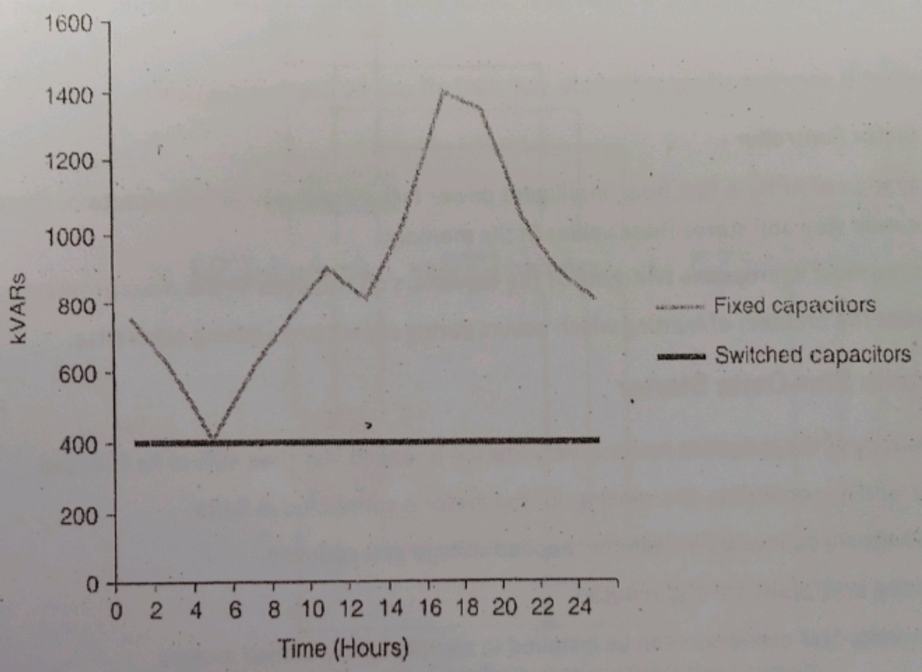


Fig. 2.4.3 : kVAR demand over and 24 hours graph

- This curve can be simply determined by recording kVAR meter or calculated by kW and p.f. measurement.
- The fixed banks satisfy the base kVAR demand and switched capacitors meet the inductive kVAR peak during heavy load slot.

(a) Control

- Controller Senses Voltage and current and uses it either directly or in terms of derived parameters like p.f. to compare against a threshold.
- Generally power factor transducer is employed inside which p.f. is measured and converts it into a DC voltage.
- This voltage is compared with a reference voltage which is calibrated in terms of p.f. and can be set by knob.
- When p.f. falls below the pre-set desired value, the capacitor are sequentially switched.
- The capacitors are controlled by relay.
- This relay is a brain of control circuit as it controls the P.F by sending signals to on or off the capacitors.

(b) Calculation of Required kVAR

- In order to calculate the capacitive kVAR necessary to correct to a new higher power factor, inductive kVAR of the corrected P.F. ($P.F._{new}$) is subtracted from the existing P.F. ($P.F._{old}$).
- The difference is the capacitive kVAR to be added to the system.
- **kVAR = kW × [Tan (Cos^{-1} $P.F._{old}$) – Tan (Cos^{-1} $P.F._{new}$)]**
- Where,
- kW – the system kilowatt load
- kVAR – amount of capacitive kilowatt to be added.
- All capacitor units of same rating and should be ON or OFF in a linear sequences only.
- A dead band range of phase angle is defined over which relay doesn't respond in order to avoid hunting due to over correction.
- When load current is very low all capacitors are switched off one by one in a sequence.

Intelligent Power Factor Controller -

- During the operation of APFC in first hour, intelligent power factor controller (IPFC) ascertains therating of capacitance to be added at each step and stores these values in the memory.
- IPFC performs the most appropriate switching of the capacitors on the basis of this measurement.
- In effect, it avoids the problem of hunting which occurs during capacitor switching otherwise.

2.4.3 Automatic Star-Delta Starter

- Operating efficiency of the induction motor is very low if it is loaded less than 40% of its full load.
- During normal running conditions, the windings of the motor is connected in Delta.
- When the windings are connected in Star, the applied voltage gets reduced.
- The corresponding iron losses are also reduced.
- Automatic Star-Delta-Star converters can be installed to identify lightly loaded motors.
- The converter works by sensing the current.
- ADLS is an Automatic Star Delta Converter.
- ADLS switches the Motor to Star Mode when the load is less than 40%.
- When the load increases beyond 40%, ADLS switches the motor to operate in Delta Mode.
- In the Star Mode, the current consumption drops by 1/3rd, there by Saving Energy.

2.4.3.1 Principles of "ADLS" Operation

> Q. State function of Automatic Star delta convertor. **(MSBTE – W-12, W-14)** **W-12**
>
> Q. Explain working of automatic star delta convertor and state its advantages. **W-14**

- All motors of higher capacity (generally>10hp) are provided with Star/Delta windings.
- During the initial startup the motor is connected in Star Mode to reduce the initial in rush of current.
- Once the motor achieves the required speed, it switches to the Delta Mode, after which the motor can be loaded.
- ADLS makes use of the fact that whenever the Load on the Motor is less (<40%),it switches the Motor to Star Mode and as soon as the load increases (>40%) it switches the Motor to Delta Mode.

- When the motor operates in the Star Mode its current consumption drops by 1/3rd, there by saving energy.
- In short, ADLS cuts off unnecessary wastage of electricity as drawn by the motor when it is not required.
- The savings are near about 10-40% depending on the Motor Load and the Load changes.
- The more the in loaded time, the more are the savings.
- Certain industrial applications have observed more than 50% of the savings.

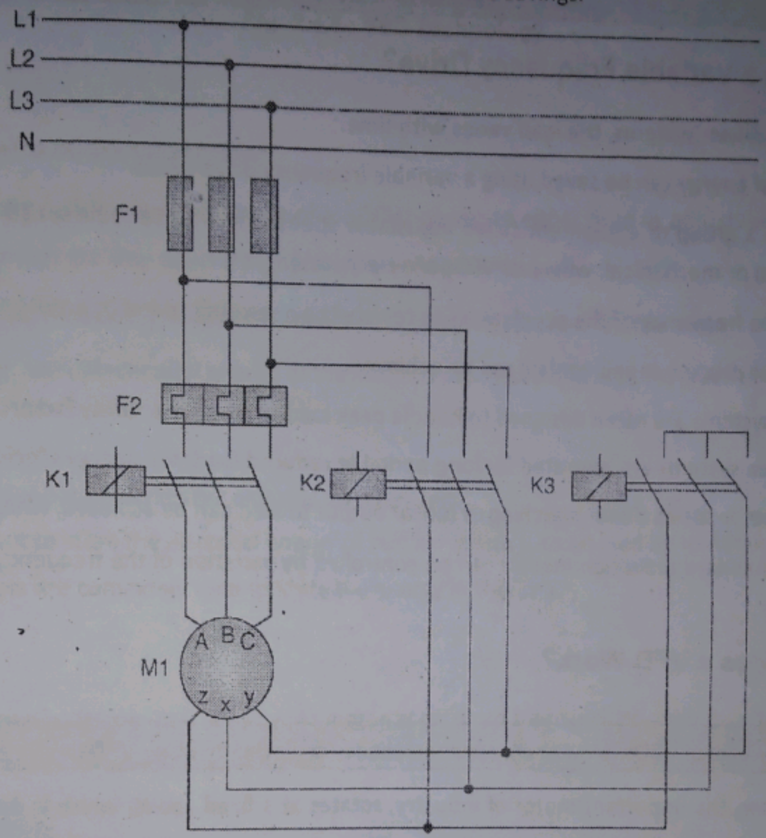


Fig. 2.4.4 : Automatic Star-Delta connection (main circuit)

- L1, L2, L3- external conductor
- N-neutral conductor
- F1-Fuses
- F2-Thermal cut-out
- K1-Main contactor
- K2-Delta contactor
- K3-Star contactor
- M1-Three-phase motor

2.4.3.2 Advantages of ASD Starter

- Star-Delta starters are widely used due to the irrelatively low price.
- There are no limits to the number of times they can be operated.
- The components require very little space.
- The starting current is reduced to approximately one-third.

2.4.4 Variable Frequency Drives (VFDs)

(MSBTE – S-13, W-13, S-15, S-...)

Q.	What is VFD?	S-1...
Q.	How efficiency of electric motor is improved by using : Variable frequency drives?	W-1...
Q.	Explain how Variable Frequency Drive (VFD) can helps to conserve electrical energy.	S-1...
Q.	State the use of "Variable Frequency Drive". State its advantages.	S-1...

2.4.4.1 What is a Variable Frequency Drive?

- In some motor driven systems, the load varies with time.
- Large amount of energy can be saved using a variable frequency drive (VFD).
- VFDs belong to a group of equipment called adjustable speed drives or variable speed drives. (Variable speed dri... can be electrical or mechanical, where as VFDs are electrical.)
- VFD changes the frequency of the supply voltage to vary the operating speed of a motor.
- Thus continuous process speed control can be achieved.
- Motor-driven systems are often designed to handle peak loads that have a safety factor.
- Therefore, when systems are operated for long period at reduced load, the energy efficiency decreases.
- By adjusting motor speed closer matching of motor output to load can be achieved, which results in energy savings.
- The speed of standard induction motors can be controlled by variation of the frequency of the voltage applied to t... motor.

2.4.4.2 How does a VFD Work?

(MSBTE – W-1...)

Q.	State the benefits of VFDs. How energy conservation is achieved by using VFDs.	W-1...

- Induction motor, the important motor of industry, rotates at a fixed speed, which is determined by the frequency ... the supply voltage.
- Alternating current applied to the stator windings produces a rotating magnetic field having synchronous speed.

$$N_s = 120f/P$$

- For a 4-pole motor, with 50Hz frequency supply

$$N_s = 120*50/4 = 1500 \text{ rpm}$$

- The rotor of an induction motor is always trying to follow this rotating magnetic field.
- Under load, the rotor speed "slips" slightly behind the rotating field.
- Slip speed generates an induced current, and the resulting magnetic field in the rotor, which will produce torque.
- By changing the frequency of the applied voltage the most effective and energy-efficient way to change the mot... speed can be achieved.
- VFDs convert the fixed-frequency supply voltage to a continuously variable frequency.
- Therefore we will get adjustable motors peed.
- AVFD converts power frequency (50Hz) to any new frequency between 0 to 300 Hz and sometimes even more.
- The technology includes following units.

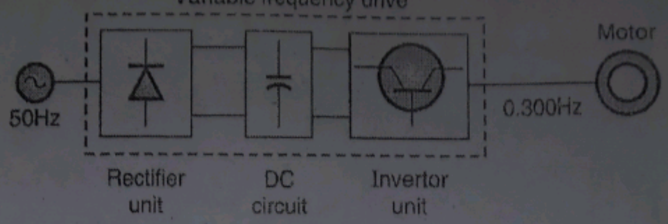


Fig. 2.4.5 : VFD Technology

(1) Rectifier Unit

- Electrical network feeds AC drive via rectifier.
- A full-wave, solid-state rectifier converts three-phase 50Hz power to either fixed or adjustable DC voltage. The system may include transformers for step down if higher supply voltages are used.
- Unidirectional Rectifier Unit-Energy is taken from network to accelerate and run the motor.
- Bidirectional Rectifier Unit-Mechanical energy of the motor is processed and supplied back to the electrical network.

(2) DC Circuit

- DC circuit is a mediator between rectifier unit and inverter unit.
- it's as to rage element to store the electrical energy of rectifier which is to be used by inverter.
- High power capacitors are commonly used to store the energy in this unit.

(3) Inverter Unit

- Electrical energy stored at DC circuit is supplied to motor at required frequency through inverter unit.
- It consist of,
  - Electronic Switches
  - Power Transistors or Thyristors
- These produce current and voltage waveform of desired frequency by ON and OFF switching.
- Properly designed inverters and filters minimize distortion to a large extent.
- Converting DC to variable frequency AC is accomplished using an inverter.
- Most currently available inverters use pulse width modulation (PWM) because the output current wave form is closer to a sine wave.
- Power semiconductors switch DC voltage at high speed, producing a series of short-duration pulses of constant amplitude.
- Output voltage is varied by changing the width and polarity of the switched pulses.

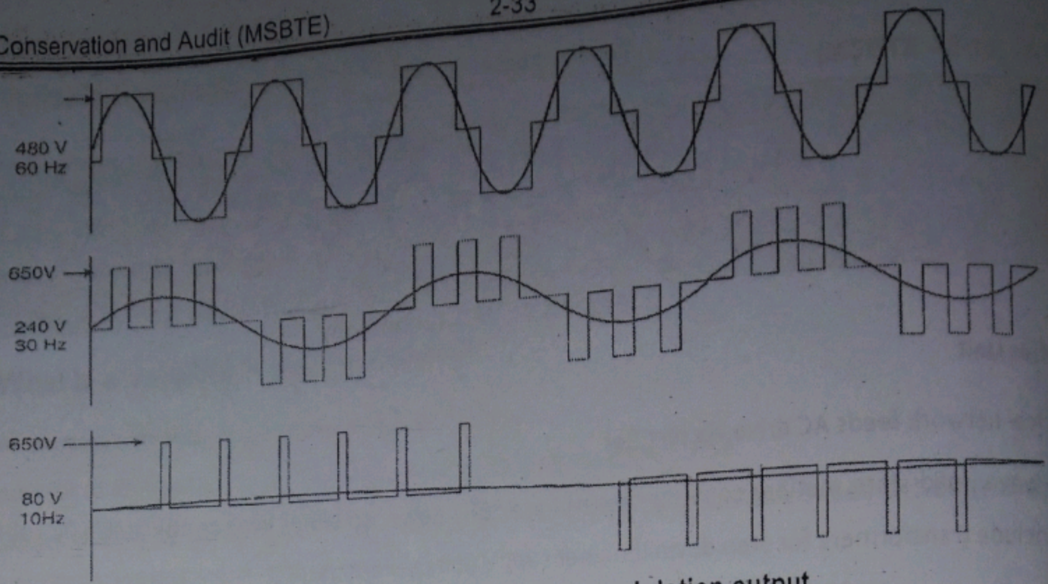


Fig. 2.4.6 : Inverter's pulse width modulation output

- Output frequency is adjusted by changing the switching cycle time.
- Point should be noted that output waveform of the VFD is square wave. Though this wave shape is not that suitable for general distribution system it is more than sufficient for a motor.
- Reduction in motor frequency can be achieved by slower switching of inverter output transistors.
- Reduction in voltage is must with reduction in frequency so as to maintain V/Z ratio.
- The high-speed switching of a PWM inverter results in less wave form distortion and, therefore, lowers harmonic losses.
- PWM inverter is the best solution because of it slow cost, high speed switching etc.

(4) Control system

- An electronic circuit receives feedback information from the driven motor and adjusts the output voltage or frequency to the selected values.
- Usually the output voltage is regulated to produce a constant ratio of voltage to frequency (V/Hz).
- Controllers may have many complex control functions.

2.4.4.3 Applications

(MSBTE – S-13, S-16, W-17, W-19)

Q.	State two applications of variable frequency drives.	S-13
Q.	State two applications of variable frequency drives.	S-16, W-17
Q.	State the use of variable frequency drive with its advantages.	W-19

Variable speed drives are used for two main reasons :

- Complex and difficult environments such as water and wastewater processing.
- Tunnel boring, Oil drilling platform, mining.
- Motor-driven centrifugal pumps, fans and blowers.
- Conveyers, machine tools and other production-line equipment.

2.4.4.4 Benefits of VFDs

(MSBTE – S-12, S-13, W-12, W-14, W-15, S-16, W-16, W-17)

Q.	State the benefits of variable frequency drive (VFDs).	S-12
Q.	How VFD is useful in energy conservation.	W-12
Q.	State two benefits of variable frequency drives.	S-13
Q.	State four benefits of Variable Frequency Drives (VFDs).	W-14
Q.	State the benefits of variable frequency drives.	W-15
Q.	State two benefits variable frequency drives.	S-16, W-17
Q.	State the benefits of VFDs. How energy conservation is achieved by using VFDs.	W-16

- Energy savings
- Better process control
- Cost saving
- Increased productivity
- Improved product quality
- It can be used for control of process temperature, pressure or flow without the use of a separate controller.
- Less maintenance costs.
- Longer life for be a rings and motors.
- A soft starter for the motor is not required.
- VFD to limits torque to a user-selected level. Therefore, it protects the equipment when there is excessive torque.

2.4.5 Active Harmonic Filter (AHF)

- In Power System, harmonics are defined as sinusoidal voltage and current at the frequencies that are integer multiples of fundamental frequency.
- And these create major distortion in mains voltage and load current.
- There are two types of harmonics:
  - Current Harmonics
  - Voltage Harmonics
- The **current harmonics** induced by the non-linear load such as VSDs (variable speed drives). The nonlinear loads draw current from the power line that is not in a perfect sinusoidal waveform.
- Most of the times, the current harmonics cause **voltage harmonics**. The non-sinusoidal current drawn by non-linear loads causes a non-sinusoidal voltage drop at the source impedance which then results as the distorted voltage produced at load terminals.
- Harmonics have numerous adverse effects on the power system:
  - Increase in current leading to heating of conductors and equipments
  - Misfiring of VSDs
  - Malfunctioning of equipments
  - Mis-operation of relays
  - Torque pulsation in motor and many such.

- Harmonic filters are used to protect costly electrical equipments from distorted power supply caused due to harmonics. These are of two types:
  - Passive Filters
  - Active Filters
- Passive Filters – mainly consist of simple passive components such as resistor, inductor and capacitors.
- Active Filters – it incorporates active (mainly power electronic) components such as BJTs, IGBTs, MOSFETs and ICs, etc.
- Active Harmonic Filters (AHF) work on the principle of Superposition.
- AHF senses the voltage and current waveform that is drawn by the non-linear load and induces a current waveform of opposite phase such that it cancels the effect of the harmonic as a result.

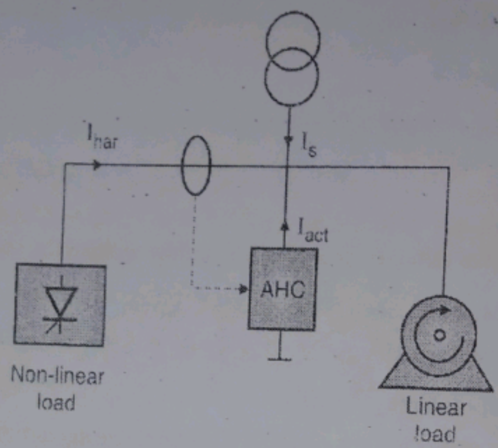


Fig. 2.4.7 Operation of AHF

- Above figure shows a parallel connected active harmonic filter (AHF) which is alternately known as Active Harmonic Conditioner (AHC).
- In this figure,

  I_s – Source Current

  I_H – Harmonic Current

  I_{ACT} – Active harmonic filter current
- AHF injects the current I_{ACT} in the phase opposite to the harmonic current I_H drawn by the non-linear load such that Line current I_s remains sinusoidal in effect.
- Distorted waveform of the current drawn by the non-linear load miss out some portion and this portion is replaced by active filter. Following is the illustrative diagram.

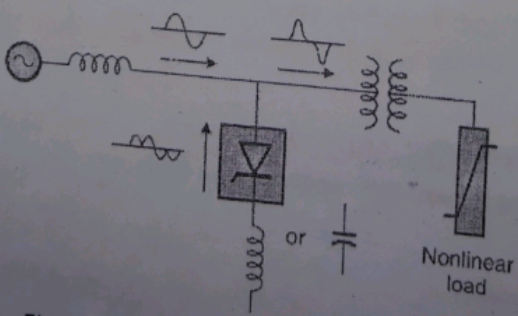


Fig. 2.4.8 : Active filter at the load terminals

- An electronic control continuously observes the line voltage and current and accordingly switches the Power Electronics circuitry to follow the line voltage and current to force it to be sinusoidal.
- Therefore, though the nonlinear load draws the distorted current, the system observes a sinusoidal one.
- In the figure shown, an inductor (which stores the current) is used to inject the current. Similarly another approach is using the capacitor in place of inductor.
- Active filters can be installed in series or shunt with the non-linear load to compensate the harmonic current or voltage drawn by the load.

2.5 Energy Efficient Motors

(MSBTE – S-15, S-17)

Q.	Write any six techniques that are to be adapted while designing energy efficient motors as compared to conventional induction motors.	S-15
Q.	State the significant features of Energy Efficient Motor.	S-17

- Energy efficient motors are motors in which improvements in the design are assimilated so as to increase the efficiency more than the standard motor.
- Design improvements in Energy Efficient Motors mainly target reduction in inherent motor losses.
- Each loss is addressed specifically by adopting some measures as follows

Stator Cu loss

- Selection of a proper size of the copper conductor so as to reduce its resistance.
- Mostly the copper cross section of winding wires are preferred to increase which decreases resistance and hence I^2R losses.

Rotor Cu losses

- Increasing the section of rotor bars and end rings, rotor copper losses can be reduced though weight increase.
- Use of copper conductors (instead of usually used Aluminium) in rotor causes less winding resistance comparatively.
- Synchronous speed operation of motor also reduces I^2R loss.

Core losses

- To reduce Hysteresis loss use of low loss grade silicon steel, modest increase in stator and rotor core length.
- To reduce eddy current use of thinner laminations.

Friction and Windage losses

- Better fan design is adopted (Proper Diameter)
- Use of improved and proper bearings.
- Improvement in aerodynamic design of rotor and facilitation of airflow.

Stray load losses

- These can reduce by better electromagnetic design of slots and windings by careful selection of
  - All gap length
  - Number of slots
  - Tooth per slot geometry

– These modifications incorporated in order to improve efficiency uses more and better material, makes energy efficient motors expensive as compared to standard motors.

2.5.1 Comparison with Conventional Induction Motors

(MSBTE – W-15, S-16, W-16, W-17, S-18, W-18)

Q. State advantages of Energy Efficient motors as compared to conventional motors. W-15

Q. Write any four comparison between energy efficient motor with conventional induction motor. S-16

Q. State atleast eight positive features of energy efficient induction motor (I.M.) as compared to conventional induction motor. W-16

Q. Compare energy efficient motor with standard motor on the basis of

(a) Starting torque (b) Construction

(c) Energy conservation (d) Efficiency W-17

Q. Compare conventional induction motor with energy efficient motor on the basis of following points :

(i) Noise,

(ii) Cost,

(iii) Effect of voltage fluctuations,

(iv) Efficiency S-18

Q. State the features of energy efficient motors as compared to conventional induction motors. W-18

– Energy efficient motors offer wider ranges of capacities.

– Full load efficiencies are found higher than the conventional one by 3% to 7%.

– Above Graph shows comparison of efficiencies between convention three phase induction motor and energy efficient motor.

– High efficiency motors run cooler due to lower operating temperature hence ventilation fan can be downsized.

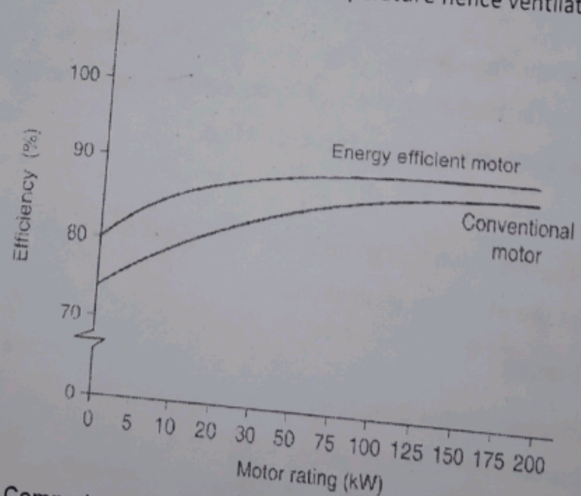


Fig. 2.5.1 : Comparison of Conventional motor and Energy Efficient Motor

– Voltage fluctuation in input supply has less effect on energy efficient motor.

– Less noise while operation

– Acceleration to loads with high inertia is better than conventional.

– Cost of energy efficient motor tends to be higher than the standard design.

– Though higher costs are retrieved in the saved operating costs.

- Applications of high intermittent duties are still to be supported by these motors so conventional can be used here.
- Energy efficient motors can't be installed for special applications which demands flame proof operations e.g. fire pumps where conventional motors can.
- Applications of a very low speed are not suitable to use with these motors.
- Another limitation compared to conventional motor is most of the energy efficient motors are suitable for operators of continuous duty cycle.

2.5.2 Caution

- Lower slip of energy efficient motors makes it run at slightly higher speeds.
- These speeds may cause higher flows in applications like centrifugal pumps thus can cause increased power.
- In such cases care is necessary to avoid neutralization of reduced motor losses by increased power.

2.5.3 Energy Saving

- Energy saving can be estimated by an example such as,

  Replacement of conventional 10kW motor with an energy efficient motor.

$$\text{Standard efficiency} = 83\%$$

$$\text{Efficiency of energy efficient motor} = 89\%$$

$$\text{Power saving} = 10 \times \left(\frac{1}{0.83} - \frac{1}{0.89}\right)$$

For operation of 5000 hours/annum

$$\text{Energy saved} = 0.81 \times 5000$$

$$= 4050 \text{ kWh/annual}$$

It tariff is considered Rs. 4/kWh

$$\text{Cost saving} = \text{Rs. } 16{,}200/\text{- per annum}$$

2.6 Energy Efficient Transformers

(MSBTE – W-12, S-13, W-15, S-17)

Q. How efficiency in Energy Efficient Transformer is improved.	**W-12**
Q. State the methods of energy conservation in transformer.	**S-13**
Q. Describe energy conservation techniques for transformer related to change in material and design.	**W-15**
Q. Explain, how technical losses can be reduced by use of energy efficient transformer in Transmission and Distribution system.	**S-17**

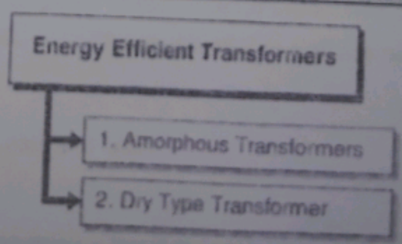


Fig. C2.10 : Energy Efficient Transformers

2.6.1 Amorphous Transformers

(MSBTE – S-12, W-12, S-13, W-13, W-14, S-15, W-16, W-17, W-...

Q.	Explain the importance of amorphous core transformers from the energy conservation point of view.	S-12, W-1...
Q.	Explain working of amorphous core transformer.	W-1...
Q.	Explain the use of amorphous metal.	S-1...
Q.	How efficiency of transformer can be improved by amorphous core? State the reason?	W-1...
Q.	Compare conventional core transformer with amorphous core transformer on the basis of (i) initial cost of installation (ii) construction used (iii) material required (iv) losses.	W-1...
Q.	Explain how Amorphous transformers are efficient as compared to conventional transformers.	S-1...
Q.	Describe the importance of amorphous core transformers from the energy conservation point of view.	W-1...
Q.	State and explain the features of amorphous core transformers which results into energy conservation.	W-1...
Q.	Explain amorphous core transformer w.r.t. energy conservation.	W-1...

- Conventional transformer use the core of silicon steel laminations with an almost uniform crystalline structure CRGO.
- Amorphous transformers employ core of amorphous steel which has lower hysteresis losses.

Amorphous alloy

- Metal have crystalline structure with a neat arrangement of atoms.
- When a metal in a liquid form at high temperature is rapidly cooled it retains its liquid structure on solidification.
- It results in a non-crystalline alloy which contains randomly arranged crystals, termed as amorphous alloy
- Amorphous alloys have superior strength and better electrical characteristics but needs advanced machin... techniques.
- Amorphous transformer consists of a magnetic core of ferromagnetic amorphous metal.
- Quintessentially used material in met glass.
- Met glass alloy = Iron + Boron + Silicon + Phosphorous.
- It's used in the form sheets of near about 25μm as shown in Fig. 2.6.1
- These material offers the advantages
  - High magnetiz ability
  - Less affected by external magnetic field or better coercivity.
  - Greater electrical resistance.

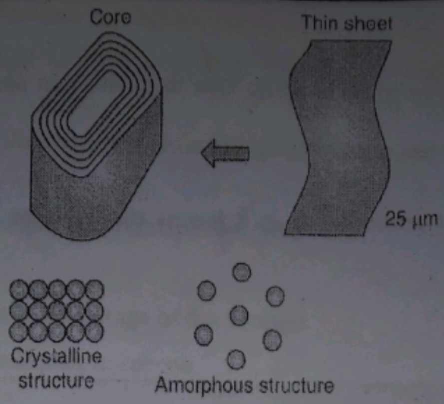


Fig. 2.6.1

- Fig. 2.6.1 shows a typical core made up of layers of thin ribbons or sheets of amorphous metal.
- Due to this foiled structure, less induction of eddy currents when exposes to alternating magnetic field.
- In the manufacturing itself amorphous metal gives metal as a very thin ribbon like continuous strip having thickness much lesser to that of standard silicon steel sheets.
- This causes near about 40% less eddy current loss to that caused by silicon steel lamination.

2.6.1.1 Advantages

(MSBTE – S-13, W-15)

Q.	Explain advantage of amorphous metal in transformers.	S-13
Q.	List the advantages and disadvantages of amorphous core in transformer	W-15

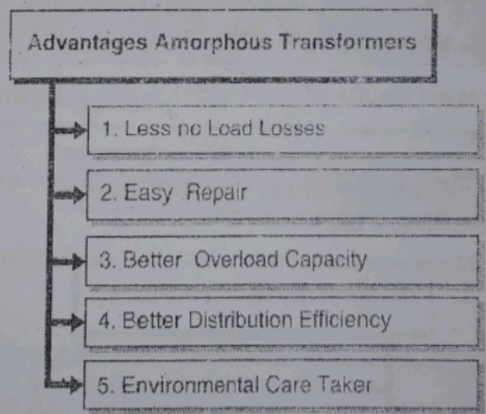


Fig. C2.11 : Advantages of Amorphous Transformer

- Easier to magnetize and demagnetize.

1. **Less no load losses**

   No load losses are 20 to 30% less as compared to conventional silicon steel sheet transformer which keeps occurring for lifetime despite of transformer load.

2. **Easy repair**

   Its modular construction makes repair easy and fast.

3. **Better overload capacity**

   Over load capacity is better as heat generation is less due to less loss and obviously less effect on aging of insulation.

4. Better distribution efficiency

Distribution efficiency increases due to reduced no load loss. This can save monetary investments in generati capacity concern.

5. Environmental care taker

Also contributes to protection of environment as it lowers the emission of CO_2 and SO_2as a result of reduc generation need.

2.6.1.2 Disadvantages

(MSBTE – W-1

> Q. List the advantages and disadvantages of amorphous core in transformer **W-15**

- The final product in the ribbon form is brittle and narrow continuous. To cut this into section is a tough job. Hen preferred to be manufactured as a hollow cylindrical wound core of single continuous strip.
- Larger cross section of core is required for same power and rating of silicon steel lamination. This is due to le useable peak magnetic field intensity in amorphous core. Also causes added weight and size.
- With large size of core longer winding conductors are obvious which causes increased load losses.

2.6.2 Dry Type Transformer

(MSBTE – W-12, W-13, W-15, W-1

> Q. Differentiate between Epoxy resin cast / The encapsulated dry type transformer. **W-12**
> Q. How efficiency of transformer is improved by Epoxy Resin cast material? **W-13**
> Q. Describe constructional features of dry type transformer to improve efficiency. **W-15**
> Q. Explain epoxy resin cast (dry type transformer) w.r.t. energy conservation. **W-18**

- As its name dry type means it does not require oil or any other liquid to cool the electrical core and coils. The purpo is served by normal air ventilation.
- In India, Dry type transformers in the range upto 11 kV and capacity 2.5 MVA are manufactured.
- The popular design in Dry type construction are :

Design in Dry type construction
- a. Epoxy Resin Impregnated
- b. Cast Resin

Fig. C2.12 : Design in Dry type construction

2.6.2.1 Epoxy Resin Impregnated

(MSBTE – S-16, W-16, S-1

> Q. State the need of energy conservation in transformer. Explain the use of Epoxy Resin Cast/Encapsulated dry typ transformer from energy conservation point of view. **S-16**
> Q. Describe the use of Epoxy Resin cast/Encapsulated Dry type transformer from energy conservation point of view. **W-16**
> Q. Epoxy resin transformers are more suitable in hazardous areas. Give reason. **S-17**

- This is also termed as Vacuum Pressure Impregnated (VIP).
- VIP transformers are constructed with the insulation which sustain high temperatures and exceeds the rating of cellulose.
- Polyesters sealant is applied to the winding in interchanging pressure and vacuum cycles, termed as vacuum pressure impregnators.
- Polyester sealant is high temperature and moisture resistant.
- Then coils are treated in oven.
- Better penetration of warmish is an advantage of this process.
- These units propound greater resistance to corona.

2.6.2.2 Cast Resin

- In these units, coils are enveloped in resins by process of moulding.
- The transformer coils are solidly cast in resin under a vacuum in a mould.
- The manufacturing process is such that winding is locked in strong epoxy resin.
- Epoxy resin as high dielectric strength which makes the transformer sustain extreme operating conditions.
- In the actual environments like chemical process plant, constructional material factories, outdcor installations coil needs additional strength and protection. Cost resin type is suitable for this.
- In such environments salts, moisture caustic gases and metal particles ruins other types of dry transformers.
- Electrical surges and overloads of repeated short duration are handled by this type.
- Advanced electronic controls the winding process. This achieve uniformly distributed winding and. high level of accuracies.
- Basic insulation level of cost resin type may be as high as liquid filled types.

2.7 MSBTE Question and Answers

Summummer 15 – Total Marks 34

Q. 1 Explain how Variable Frequency Drive (VFD) can helps to conserve electrical energy. **(Refer Section 2.4.4)** **4 Marks**

Q. 2 Explain why frequent rewinding of induction motors reduces its efficiency. **(Refer Section 2.2.6)** **4 Marks**

Q. 3 Write any six techniques that are to be adapted while designing energy efficient motors as compared to conventional induction motors. **(Refer Section 2.5)** **6 Marks**

Q. 4 Explain how energy can be conserved in induction motor by improving power quality. **(Refer Section 2.2.1)** **4 Marks**

Q. 5 Explain how energy can be conserved by operating two transformers in parallel. **(Refer Section 2.3.1)** **4 Marks**

Q. 6 Explain when induction motors are run in star connection under 30% load condition, how energy is conserved. **(Refer Section 2.2.5)** **4 Marks**

Q. 7 Explain how Amorphous transformers are efficient as compared to conventional transformers. **(Refer Section 2.6.1)** **4 Marks**

Q. 8 Explain how soft structures helps to conserves energy. **(Refer Section 2.4.1)** **4 Marks**

Winter 15 - Total Marks 45

Q. 1 List energy conservation techniques in electrical motors. **(Refer Section 2.2)** **4 Marks**

Q. 2 State advantages of Energy Efficient motors as compared to conventional motors. **(Refer Section 2.5.1)** **4 Marks**

Q. 3 Describe the effect of following on Induction Motor : (i) Voltage Unbalance **(Refer Section 2.2.1.1)** **3 Marks**

(ii) Harmonic Distortion **(Refer Section 2.2.1.2)** **6 Marks**

Q. 4 Describe constructional features of dry type transformer to improve efficiency. **(Refer Section 2.6.2)** **4 Marks**

Q. 5 List the advantages and disadvantages of amorphous core in transformer. **(Refer Section 2.6.1.1)** **4 Marks**

Q. 6 Explain following energy conservation methods of electrical motor :

(i) Matching motor rating with required load. **(Refer Section 2.2.3)**

(ii) Minimizing idle and redendent. **(Refer Section 2.2.3)** **4 Marks**

Q. 7 Describe energy conservation techniques for transformer related to change in material and design. **(Refer Section 2.6)** **4 Marks**

Q. 8 Enlist various energy conservation equipments which can be implemented in lighting system and electric motors **(Refer Section 2.4)** **4 Marks**

Q. 9 State the benefits of variable frequency drives. **(Refer Section 2.4.4.4)** **4 Marks**

Q. 10 State advantages of soft starters over conventional starters. **(Refer Section 2.4.1.5)** **4 Marks**

Summer 16 – Total Marks 44

Q. 1 Explain following energy conservation methods of electrical motor :

(ii) Minimizing idle & redundant running of load. **(Refer Section 2.2.4)**

(i) Matching motor rating with required load. **(Refer Section 2.2.3)** **4 Marks**

Q. 2 State the need of energy conservation in transformer. Explain the use of Epoxy Resin Cast/Encapsulated dry type transformer from energy conservation point of view. **(Refer Section 2.1.2, 2.6.2.1)** **6 Marks**

Q. 3 Write any four comparison between energy efficient motor with conventional induction motor. **(Refer Section 2.5.1)** **4 Marks**

Q. 4 State the opportunities for energy conservation techniques in transformer. **(Refer Section 2.3)** **4 Marks**

Q. 5 Explain energy conservation technique in induction motor by operating I.M. in star mode. **(Refer Section 2.2.5)** **4 Marks**

Q. 6 Why soft starter used for motor? State its two advantages. **(Refer Section 2.4.1, 2.4.1.5)** **4 Marks**

Q. 7 Explain energy conservation technique in induction motor by improving power quality method. **(Refer Section 2.2.1)** **4 Marks**

Q. 8 State two benefits and two applications of variable frequency drives. **(Refer Section 2.4.4.3, 2.4.4.4)** **4 Marks**

Q. 9 State two benefits and two applications of variable frequency drives. **(Refer Section 2.4.4.4)** **4 Marks**

Q. 10 State the need of energy conservation in transformer. Explain the use of Epoxy Resin Cast/Encapsulated dry type transformer from energy conservation point of view. **(Refer Section 2.6.2.1)** **6 Marks**

Winter 16 – Total Marks 30

Q. 1 Describe the need of energy conservation in induction motor. **(Refer Section 2.1.1)** **4 Marks**

Q. 2 State atleast eight positive features of energy efficient induction motor (I.M.) as compared to conventional induction motor. **(Refer Section 2.5.1)** **4 Marks**

Q. 3 Explain following energy conservation methods of electrical motor :

(i) Matching motor rating with required load. **(Refer Section 2.2.3)** **3 Marks**

(ii) Improving power quality. **(Refer Section 2.2.1)** **3 Marks**

Q. 4 Describe the use of Epoxy Resin cast/Encapsulated Dry type transformer from energy conservation point of view. **(Refer Section 2.6.2.1)** **4 Marks**

Q. 5 State atleast eight energy conservation opportunities in Transformer. **(Refer Section 2.1.2)** **4 Marks**

Q. 6 Describe the importance of amorphous core transformers from the energy conservation point of view. **(Refer Section 2.6.1)** **4 Marks**

Q. 7 State the benefits of VFDs. How energy conservation is achieved by using VFDs. **(Refer Section 2.4.4.4 and 2.4.4.2)** **4 Marks**

Summer 17 – Total Marks 32

Q. 1 List out the energy conservation techniques to be adopted to reduce losses in the induction motor. **(Refer Section 2.2)** **4 Marks**

Q. 2 Why energy conservation techniques should be adopted in transformers even though its efficiency is 90% ? **(Refer Section 2.1.2)** **4 Marks**

Q. 3 Epoxy resin transformers are more suitable in hazardous areas. Give reason. **(Refer Section 2.6.2.1)** **4 Marks**

Q. 4 State the significant features of Energy Efficient Motor. **(Refer Section 2.5)** **4 Marks**

Q. 5 Suggest the energy conservation techniques in following cases :

(i) Motor is running with 70% loaded condition.

(ii) Motor is continuously loaded at 50%.

(iii) Motor runs with 30% loaded condition but sometimes rises to 50% loading condition.

(iv) Motor runs continuously under no-load condition. **(Refer Section 2.2.2)** **4 Marks**

Q. 6 State how 'parallel operation of transformers' helps in energy conservation. **(Refer Section 2.3.1)** **4 Marks**

Q. 7 Explain, how technical losses can be reduced by use of energy efficient transformer in Transmission and Distribution system. **(Refer Section 2.6)** **4 Marks**

Q. 8 State the use of "Variable Frequency Drive". State its advantages. **(Refer Section 2.4.4)** **4 Marks**

Winter 17 – Total Marks 35

Q. 1 Explain the necessity of energy conservation in Electrical motors. **(Refer Section 2.1.1)** **3 Marks**

Q. 2 Explain energy conservation method in induction motor by improving power quality. **(Refer Section 2.2.1)** **4 Marks**

Q. 3 Explain the following energy conservation methods of electrical motor :

(a) Rewinding of motor. **(Refer Section 2.2.6)**

(b) Operating in star mode. **(Refer Section 2.2.5)**

Q. 4 State the opportunities for energy conservation techniques in transformer. **(Refer Section 2.3)**

Q. 5 Explain parallel operation of the transformer in context of energy conservation. **(Refer Section 2.3.1)**

Q. 6 Compare soft starter with conventional starter (any four point). **(Refer Section 2.4.1)**

Q. 7 State two benefits and two applications of variable frequency drives. **(Refer Sections 2.4.4.3 and 2.4.4.4)**

Q. 8 Compare energy efficient motor with standard motor on the basis of

(a) Starting torque (b) Construction

(c) Energy conservation (d) Efficiency **(Refer Section 2.5.1)**

Q. 9 State and explain the features of amorphous core transformers which results into energy conservation. **(Refer Section 2.6.1)**

Summer 18 – Total Marks 36

Q. 1 State the need of energy conservation in electrical motor. **(Refer Section 2.1.1)**

Q. 2 State the need of energy conservation in transformer. **(Refer Section 2.1.2)**

Q. 3 Explain the energy conservation technique "By improving power quality" for induction motor. **(Refer Section 2.2.1)**

Q. 4 Describe the following energy conservation methods of electrical motor.

(i) By motor survey **(Refer Section 2.2.2)**

Q. 5 Describe the following energy conservation methods of electrical motor.

(ii) By matching loads with motor rating

(Refer Section 2.2.3)

Q. 6 Explain energy conservation technique in induction motor by minimizing the idle and redundant running of motor. **(Refer Section 2.2.4)**

Q. 7 State any four periodical maintenance which is necessary in transformer to achieve energy conservation. **(Refer Section 2.2.8)**

Q. 8 State four advantages of soft starter. **(Refer Section 2.4.1.5)**

Q. 9 Compare conventional induction motor with energy efficient motor on the basis of following points :

(i) Noise, (ii) Cost,

(iii) Effect of voltage fluctuations, (iv) Efficiency **(Refer Section 2.5.1)**

Winter 18 – Total Marks 36

Q. 1 Describe the need of energy conservation in Induction motor. **(Refer Section 2.1.1)**

Q. 2 State the need of energy conservation in transformer and material used to improve the design & performance of transformer. **(Refer Section 2.1.2)**

Q. 3 Describe the following energy conservation methods of electrical motors : (i) Matching motor (Refer Section 2.2.3) **3 Marks**

Q. 4 Explain the following energy conservation methods of electrical motor : (b) Operating in star mode (Refer Section 2.2.5) **3 Marks**

Q. 5 State any two opportunities for energy conservation techniques in transformer. (Refer Section 2.3) **4 Marks**

Q. 6 What is energy conservation equipment and list out energy conservation equipments related to lighting system and induction motor. **(Refer Section 2.4)** **2 Marks**

Q. 7 Describe the working of soft starter and state its advantages over conventional starter. **(Refer Section 2.4.1)** **4 Marks**

Q. 8 State the use of variable frequency drive with its advantages. **(Refer Section 2.4.1)** **4 Marks**

Q. 9 State the features of energy efficient motors as compared to conventional induction motors. **(Refer Section 2.5.1)** **4 Marks**

Q. 10 Explain amorphous core transformer and epoxy resin cast (dry type transformer) w.r.t. energy conservation. **(Refer Sections 2.6.1 and 2.6.2)** **4 Marks**

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