1

General Background

1.1 INTRODUCTION

Modern civilization depends heavily on the consumption of electrical energy for industrial, commercial, agricultural, domestic and social purposes. Electrical power is generated in large thermal, hydro, nuclear power stations. The energy is transferred from these generating systems to distant distribution networks *via* the transmission systems. The modern electrical power system is in the form of a large interconnected 3 phase AC network. The generating stations, transmission and distribution systems are interconnected to form a 3 phase AC system operating synchronously at the common single frequency of 50 Hz (60 Hz in USA). The total Network covers a vast geographical area.

The electrical power supply undertaking aims at the following :

— Supply of required amount of power to all the consumers over the entire geographical area at all times continuously.

— Maximum possible coverage of geographical area.

— Maximum security of supply and minimum fault duration.

— Supply of electrical power within targetted limits of frequency (49 Hz – 51 Hz).

— Supply of electrical power within specified limits of voltage (*e.g.* variation within ± 5%), with specified waveform.

— Supply of energy at lowest cost.

Three Phase, 50 Hz, AC System is used universally for electrical power system.

The Electrical Power System has two closely inter-linked sides

(1) The Supply Side and (2) Demand Side (Load Side).

Power flows from Supply Side to Load Side in accordance with the Demand. Demand and Load are similar Terms. Users and Consumers are also similar terms. Users have a demand on the Supply Company (Utility) by virtue of the Loads.

Unit of electrical Power is Watt. Practical Unit is kW and MW.
Unit of electrical Energy is Watt-hour (Wh). Practical unit of energy is kWhr and MWhr.

Load has certain kW rating. When the load of 1 kW rating is operated for one hour, the energy consumption is 1 kWhr. The consumer pays for the energy consumed in accordance with the Tariff 9 say, 4 Rs. per kWhr).

Power Flow : Supply Side $\longrightarrow$ Demand Side
Money Flow : Demand Side $\longrightarrow$ Supply Side

1.2 THREE TECHNOLOGY-REVOLUTIONS

Human Civilization changed its course from manual labor to machine labor during the First Industrial Revolution during Middle of 19th Century. This Industrial revolution has been followed by the three Rapid technological Revolutions during the span of past 100 years of the 20th Century. Amazing !

Electricity has changed the life style of people, industry and civilization during the 20th century. This fact has been generally overlooked as we are so much used to electricity and we take it for granted as if it is all the while available for use. Infact electricity is a precious and high quality energy to be used judiciously ! Computers brought about the facility intelligence of calculating, data processing, data storing. Computers and Microprocessors are now used in every field and every automation device. *Likewise Information Technology* is changing, changed the life style of people, industry and business during the present (21st century). The growth of Information Technology has been fastest, since around 1985. These technology-revolutions.

TECHNOLOGY REVOLUTIONS

1880s	1950s	1980s
Electrical Power Systems	**Computers Micro-processors** Digital Electronics**** High Power Electronics**	**Information Technology*****
— Generation — HV Transmission — Sub-transmission — Distribution — Power Control	— Hardware — Software — Digital Controls* — Communication Systems*	— Data, Information and Knowledge — Telephone, FAX, e-mail, WWW — Power line carrier

*Used in almost all high tech fields of human activities.

— Utilization*	—Fiber Optic Cable *****	—Local Area Networks
— UPS		—Wide Area Networks
	—Robotic, Expert Systems	—Control, Instrumentation
	— Data Base Management	— Industrial Automation
	— Data Transmission*****	— Power line carrier

* Used in almost all high tech fields of human activities.

**Microprocessors correspond to Central Processor in Digital Computer μP is a single integrated Circuit (on Silicon Chip) Microprocessor with associated hardware and software become Personal Computer (PC), Micro Computer (or micro for short) or a micro processor based device for control, protection, monitoring etc.

***SCADA Supervisory Control and Data Acquisition Systems are per se Information Technology Applied to Power Systems, Utilization Systems, Factory Automation, Process Automation, Computers and Microprocessors at Management level are linked with Computers at Remote Terminal Units (RTUs) for Remote Control, Monitoring, Optimizing.

**** These are Off-Shoots of Electrical Technology.

***** *Fiber Optics.* Data and electrical signals are converted into Digital Light Pulses and then transmitted through Optical Silica Fiber. Glass fiber can be connected to high voltage point. Digital signals through optical fiber do not suffer from electromagnetic disturbances.

Fiber Optics are for Digital Data Communication only. Not for Analog Data Communication.

A/D conversion is necessary at interface between Analog System and Digital System.

D/A conversion is necessary at interface between Digital System and Analog System.

Hard copper wires are used for electrical signals carrying Intelligence (coded information .

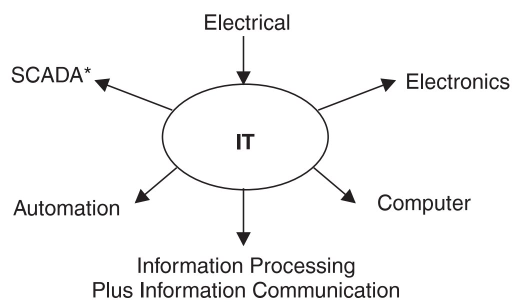
Hard Insulated Wires are also used for Power Flow.

Only the principal technologies are mentioned below. Each principal Technology results from merger of innumerable other Technologies. There is complex interrelationship.

— Electrical technology has revolutionized the style of Energy Utilization at low, medium, high power. Automation has been introduced in Plants and Equipment for various applications.

— Computers brought about change in Calculation, Data Processing, Data Management, Digital Entertainment, Automation, Robotics, Expert Systems, etc.

— Information Technology is bring about change in every sphere of commercial, industrial, personal activity related with communication and information, We can now communicate and exchange information with distant friend/organization, do transaction from our home computer. It has made the World has become small and fast ! It has broken the National barriers. The Technologies are Closely Interwoven. It integrates inputs from several other technologies, and contributes to them immensely.



1.3 UTILIZATION OF ELECTRICAL ENERGY

We use electricity everywhere. Electricity is essential in every field of modern human life.

Imagine what would happen in the world, if electricity were not used for one day.

Let us list down a short list of applications.

Domestic Applications

Lighting, Heating, Pumping, Kitchen & Garden, Appliances, Entertainment, Information–Processing ; Communication, Computers, Vacuum cleaner, Refrigerators, Air conditioning, Safety Devices, Transport Vehicles, Energy Storage, etc.

Commercial Applications

Lighting, Communication, Information processing, Air-conditioning, Security Systems, Automatic Safety Devices, Transport vehicles, Community centres : All above plus Public-Address Systems (Loudspeakers), Flood Lighting, Transport Vehicles.

Agriculture, Farming, Food Processing, Food Preservation

Farms are irrigated by pumping sets driven by electric motors.

Water Supply, Irrigation

Electricity is used for pumping and purifying water.

Transportation, Lifting and Shifting

- Electricity drives traction vehicles ; battery powered vehicles and road transport, Ships and water-transport. Transportation of people and consignments [Industrial, Commercial, Agricultural etc.]
- Electricity is used in Air-crafts and air-transport.
- Space Crafts use Electricity, Control, Lighting, and communication.

Humanitarian Applications

Agriculture and Forests Development, Space Travel, Environment and Disaster Management, Water Supply, Irrigation, Education, Medical, Research and Development.

Industrial Applications

Heating, Melting, Heating, Ventilation Refrigeration Air Conditioning (HV-AC),

Illumination, Motor Drives, Electroplating, Electro-metallurgy, Electrochemical processes, Handling, Transport, Communication, Pumping, Computation, Information Management.

Safety, Defense and Security.

Automation, Supervision, Remote Control.

Electronic Data Processing.

Entertainment, Communication and Information Technology.

Computers, Telephones, e-mail, e-commerce, e-business, Radio, TV, Cinema.

Imagine life without entertainment and communication means!

Printing, Press, Media, Word processing Desk top Printing.

Satellites

Electricity generated in Solar PV Panels provides energy to satellites.

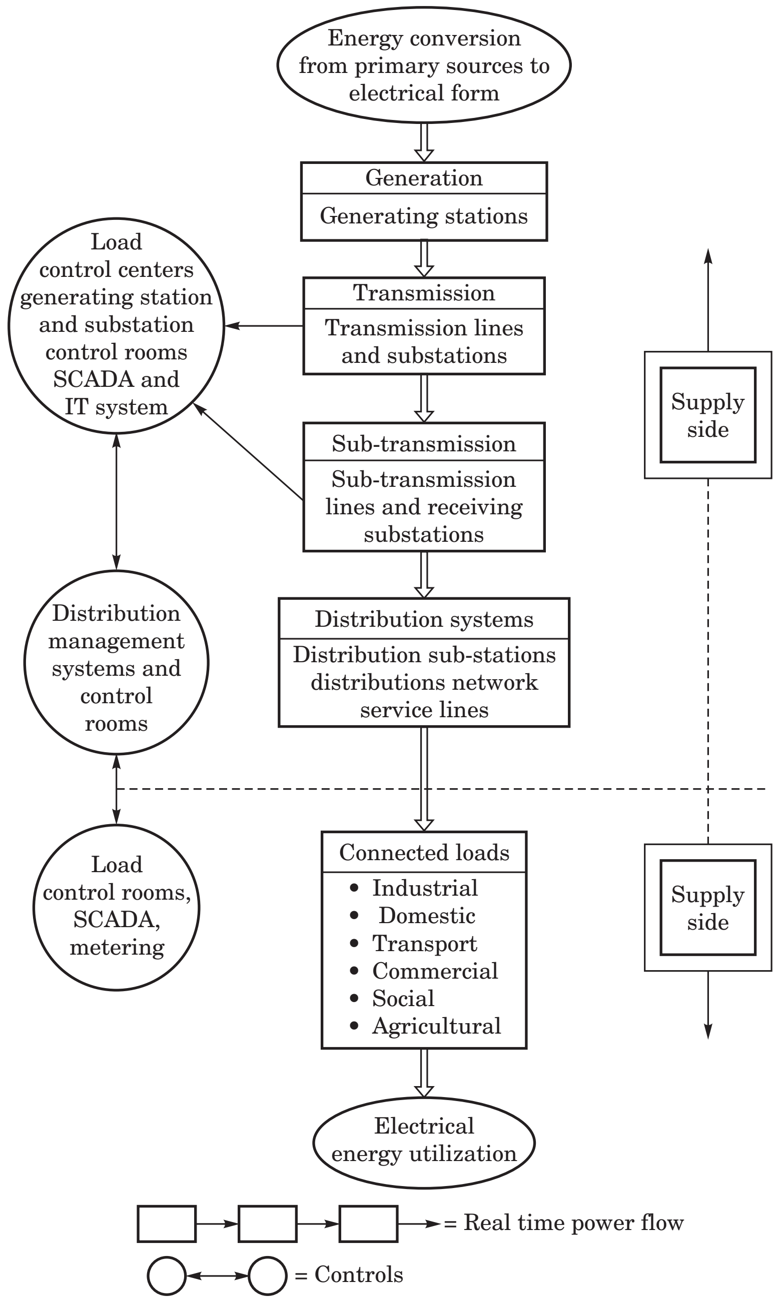


Fig. 1.1. Components of electrical energy system [Supply side + Demand Side].

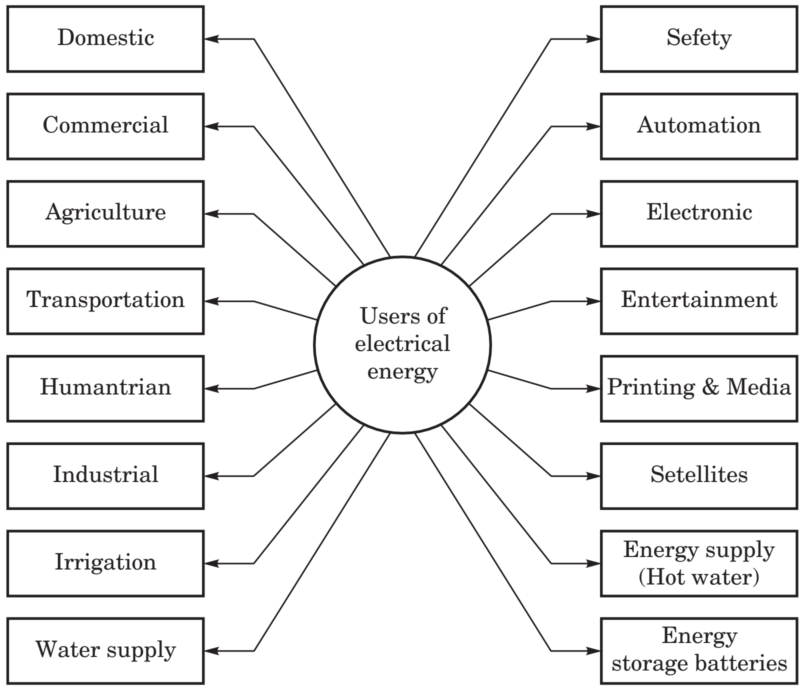


Fig. 1.2. Applications of Electrical energy in modern high tech civilization.

Commercial Energy Supply

Electricity is a vehicle for energy. The energy is converted to electrical form in power plants, transmitted and distributed and final utilized by consumers. 50% energy is consumed in electrical forms and other 50% as fuels. Electricity is supplied in regions in which there is no other primary energy source.

Energy Storage (in kWh range only)

Electrical energy is stored in batteries and the energy storage is movable (portable).

Unfortunately, electricity cannot be stored in large quantity (Mower range).

Uninterrupted Power Supply is based on Stored electrical energy.

1.4 ENERGY ROUTES FOR CONVENTIONAL ENERGY RESOURCES

Various primary energy resources are :

(1) Explored

(2) Extracted

(3) Processed

(4) *Transported* by road/rail/ocean-tankers/river-ships/pipe-lines in liquid or gaseous form *alternatively* converted into electrical power and then *transmitted* and distributed in electrical form.

(5) Supplied as fuel, chemicals or electrical power.

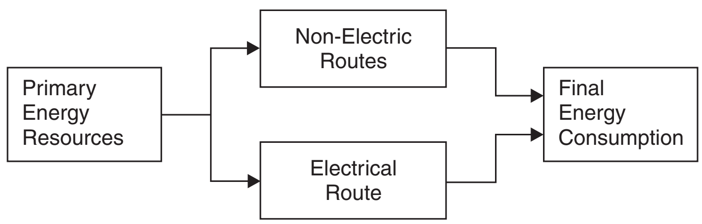


Fig. 1.3. Two alternative routes of energy supply.

The choice of particular energy route depends upon

— Type of primary energy source, recoverable energy

— Process for conversion to intermediate form

— Distance between extraction site and consumer centre

— Techno-economic choice of transportation/transmission

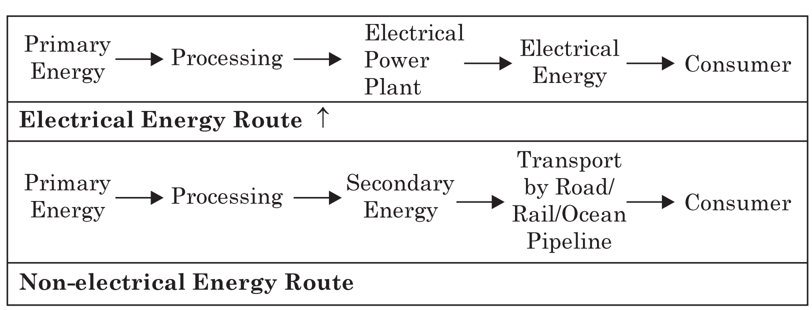
— End use as secondary energy, electrical or non-electrical

— Technology for control and utilization.

Presently about 40% of world's energy supply is through the Electrical Energy Route, about 48% is through Non-electrical energy route and about 12% is by direct non-commercial route.

With *fossil fuels*, both the energy routes (electrical and non-electrical) are being used.

Wing *renewables,* electrical energy route is more acceptable.



Energy Utilization in Industry

In Industry we use energy in form of

1. **Liquid Fuels : Furnace oils**
2. **Liquefied Petroleum Gas (LPG)**
3. **Petrol (Liquid) or Diesel** for two wheeler or four wheeler road vehicles, heavy transport vehicles.
4. **Electricity.** For Lighting, Pumping, Drives, Transport, Refrigeration and Air Conditioning, Electroplating, Electrorefining, Automatic Processing, Electrometallurgy, Automation, Computer and Information Systems, IT friendly and energy efficient user-friendly electrical devices.

Industrial Factories has Motor Drives, Electrical Heating and Melting Furnaces, Electroplating shops. Some industries are energy-intensive and electrical energy is the major cost factor in them [For example : Foundries using electrical melting furnaces, aluminium extraction pot lines.]

Energy Utilization in Transportation World

Railways, Road Trams, Road Trolleys, Aircrafts, Satellite, Ships depend on electricity and fuels.

Even if Fuels are used as an intermediate source, the drives and controls are mostly electrical.

Five categories of Transport Sector are :

Rail Transport	Road Transport	Ocean or River Transport	Air Transport	Space Transport

The applications of Electrical Energy in various sectors of economy.

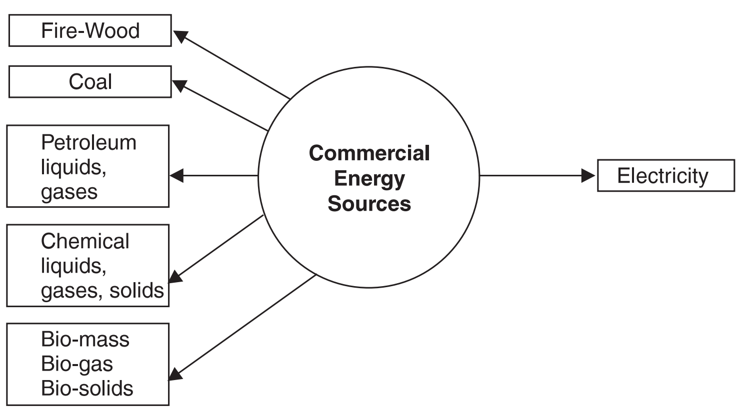


Fig. 1.4. Application of Electrical Energy in various sectors.

1.5 ELECTRICAL ENERGY AND OTHER FORMS OF USABLE ENERGY [FUELS]

Energy gets transformed from one form to another while doing the work.

Work is possible only with energy. While performing work some part of the energy goes into the surroundings in the form of heat, waste or/and pollutants. The substances or media containing concentrated usable energy are called energy sources or forms of energy (the word source is not mentioned in usage).

Primary energy sources are those which are available in nature in raw form [*e.g.* Coal, Fire-wood, Biomass, Crude Petroleum oil/gas, Hydro-reservoir, Soil containing nuclear elements, flowing river, ocean waves.

Secondary energy sources are those, which can be directly supplied and used by consumer for Utilization of energy. Secondary energy sources, are *Usable energy sources* (called energy for short). Secondary energy sources. (*e.g.*, Electrical Energy ; Fuels).

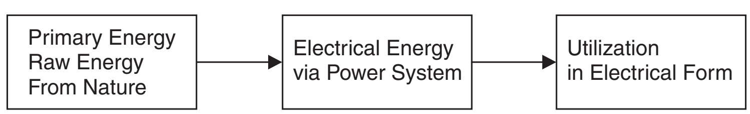
Primary energy sources are raw forms energy sources available in nature. These sources are processed and converted to secondary energy for use by the consumers for various activities.

Electricity is a vehicle for energy. The energy is converted to electrical form in power plants, transmitted and distributed and final utilized by consumers. 50% energy is consumed in electrical forms and other 50% as fuels. Electricity is supplied in regions in which there is no other primary energy source.

Electricity is used in two broad application-categories : High Power and Low Power.

Two Faces of Electricity

Main Power Chain :



Low Power Applications

Measurement, Control, Protection, Communication, Entertainment, other low current electronics.

Low power controls high power.

1.6 ENERGY AND POWER

Power is the time rate of energy conversion or energy flow. If 'E' is energy, 'P' is power, t is time,

$$P = \frac{dE}{dt} \quad \text{and} \quad E = \int P\, dt$$

In electrical power systems, power P is generated and consumed simultaneously. Hence the electrical energy supply system is called electrical power system.

From the law of conservation of energy,

Energy Generated = Energy Utilized + Energy Losses

[MWh-generated] = [MWhr-utilized] + [MWh-Losses]

Likewise, for steady frequency, 50 Hz

Power-generated = Power utilized + Power Losses

[MW-generated] = [MW-utilized + MW-loss]

1.7 ELECTRICAL ENERGY

Electrical Generators produce *electrical energy* from *mechanical energy*. Magnetohydrodynamic Generators produce *electrical energy* from thermal energy. Fuel cells produce electrical energy from chemical energy.

Units of electrical energy are :

Watt. second = joule

1 watt × 1 second = 1 joule

1 watt. second is a very tiny unit.

In practice we use :

1 kWh = 1000 (Watt × hour)

1 MWh = 10^6 (Watt × hour)

1 GWh = 10^9 (Watt × hour)

1 EWh = 10^{18} (Watt × hour)

Electrical Energy, has several effects such as :

— *Electro-mechanical effect.*

Two current carrying conductors have mechanical attraction or repulsion due to magnetic fields.

Electrical energy can be converted into mechanical energy and *vice-versa* (motor, generator).

— *Electro-Thermal Effect*

Current passing through a conductor produces heat due to I^2Rt losses. This is also called Joule effect. (electrical ovens, furnaces) I^2Rt losses are converted to heat.

— *Electro Chemical Effect*

Current passing through electrolyte produces electrolysis. (electroplating)

— *Biological Effect*

Electrical energy has effect on biological cells. Electric current through a human body or a bio-plant produces biological reactions. (*e.g.* electric shocks, electro-therapy).

1.8 ELECTRICAL ENERGY IS SUPERIOR AND COSTLY

Electrical energy is used universally as a vehicle for energy. Energy is transmitted, distributed, supplied in the form of electrical energy. The main advantages of electrical energy are :

— Easily obtained from various primary energy resources.
— Easily and quickly transmitted.
— Easily distributed.
— Easily measured, controlled, monitored, accounted for.
— Easily converted to other forms for final energy consumption.
— Safe, pollution free, reliable source for energy.
— Versatile and uses-friendly.
— Superior, high efficiency.
— In many applications, electricity is the only option. You cannot operate a computer by heat or chemical energy.
— Electricity can be supplied to smallest loads of a fraction of watt to large loads of a few MW, by suitable choice of voltage and current combination.
— Electricity can be used for a variety of applications.
— Electrical energy consumption is pollution free.

1.9 DC LOADS AND DC SUPPLY

Various forms of supply systems and connected loads are shown in Fig. 1.5 (*a*).

DC supply is necessary for electro-plating, electro-refining, DC traction systems, DC trolley-bus, DC motor drives, Super-conducting magnet coils, Excitation field of Alternators, Storage battery systems, UPS, Automatic control and protection systems etc.

DC supply is not provided by supply companies. Supply companies provide 3 phase, 50 Hz, AC supply.

DC supply is obtained by rectification of AC supply in rectifiers.

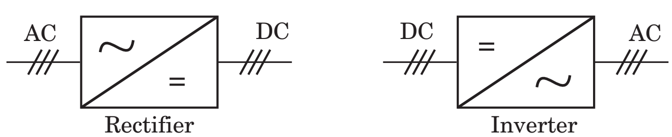


Fig. 1.5 (*a*)

1.10 SINGLE PHASE AC AND 3 PHASE AC LOADS

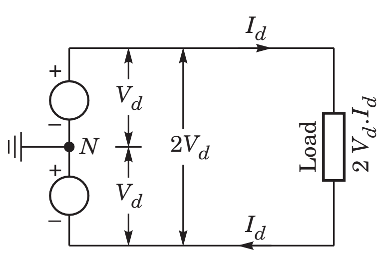
Supply companies provide 3 phase, 50 Hz, AC supply or 1 phase, 50 Hz AC supply to the consumers at 'service connection'. The consumers may be LT consumers (Low tension) or HT consumers (High Tension) AC system is universally popular because

- — AC supply voltage can be easily stepped-up or stepped down by using Power Transformer.
- — AC supply can be directly used for driving induction motors.
- — We can easily get DC supply from AC supply.
- — Single phase AC loads (small) and three phase AC loads (> 1.5 kW) can be connected to three phase 4 wire AC supply as shown in Fig. 1.
- — 3 phase AC system has provision of Neutral grounding fault detection is easy.

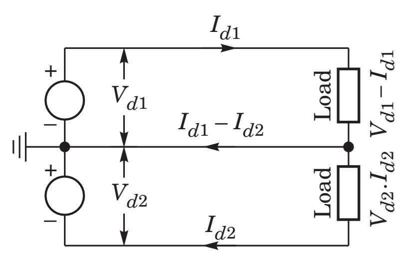
Three phase 4 wire supply system is economical, flexible and provides neutral earthing facility along the distribution line multiple neutral earthing is possible.

Three phase motors, transformers and other loads are more economical than corresponding single phase loads.

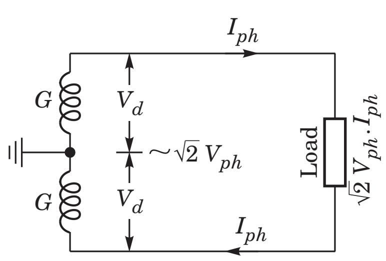
Three phase systems can have 3 phase Single Transformer or 3 single phase transformers to form a 3 phase bank.



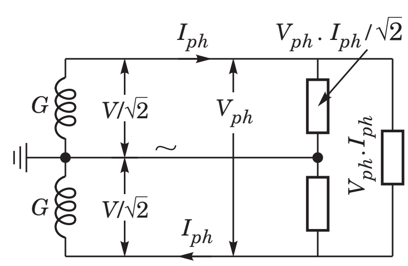
(1) DC-2 Wire



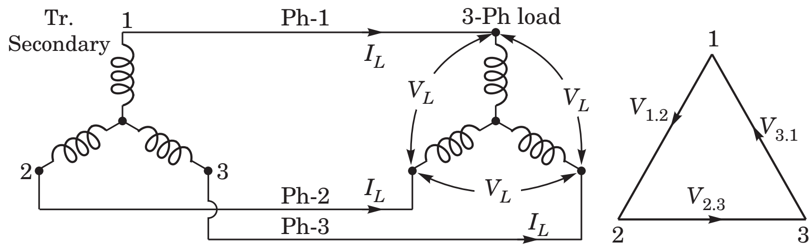
(2) DC-3 Wire



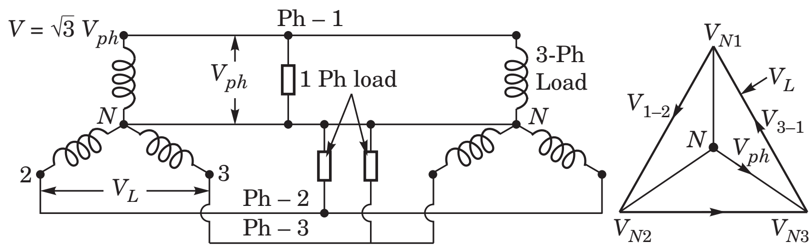
(3) 1 PH AC-2 Wire



(4) 1 PH AC-3 Wire



(5) 3 Ph 3 Wire AC



(6) 3 Ph 4 Wire AC

1. DC-2 Wire System (obsolete)	2. DC-3 Wire (obsolete)
3. 1 Ph AC-2 Wire (not used)	4. 1 Ph AC-3 Wire (not used)
5. 3 Ph. 3 Wire AC (used)	6. 3 Ph. 4-Wire, AC (used)

Fig. 1.6. Types of supply circuits for secondary distribution.

1.11 TYPES OF LOADS AND DEMAND

The distribution system collects power from the bulk power system and supplies it to various types of consumers as per their prevailing demands. Demand refers to steady state MVA drawn by the consumer at particular power factor, MVA, MW, I, are interrelated. The power supply requirement of *each consumer* in terms of load characteristics (steady/transient), demand (KW and KVA) characteristic, peak demand/its time, demand factor, requirement of power quality/continuity/reliability, etc. *are different.* The switching control of power consuming devices at load end may be manual or automatic.

Load on electrical distribution system (kW or kVA) is the electric power used by the power-utilizing devices connected to the distribution system. *Load is the most important aspect in the functioning of distribution system.*

The total system load on a *distribution substation* at a prevailing time is the *sum of the loads* drawn by various consumers plus the system losses at that time.

Some of the power consuming devices are manually controlled, some are automatically controlled and some have controlled both manual/automatic control.

The amount of load (kW or kVA) at any instant of clock time is determined by the *consumers* requirement called *the demand. The demand may be measured either in kW or in kVA or in both. The term demand may apply to a single service conductor, or a secondary feeder, or a distribution transformer, or a primary feeder, or a distribution substation, or a subtransmission line*. The distributions systems Demand Management can dictate some influence on the demand by means of load shedding, load staggering, two part tariff, penalty for excess demand etc. However, these controls of demand management by distribution system result from lapse in generating/transmission/ distribution planning and expansion. The distribution system expansion falls behind load growth resulting in above mentioned measures for curtailing the demand.

The types of loads supplied by the distribution system are many and varied. However they are usually classified in the order of magnitude of demand as

(1) Industrial
(2) Commercial
(3) Transport
(4) Residential : Urban, Suburban
(5) Rural and Agricultural.

The service requirements of each type of load (1 to 4) differ from other with respect to quality of power and magnitude of demand (MW, MVA) and the load cycle. The facilities, equipment and control to be provided in the distribution system for the type of load (1 to 4) need careful analysis while planning designing and expanding the distribution systems.

Table 1.1

Types of loads, Load Characteristics and Requirements or Power Supply from Distribution System

Description	*Type of load*			
	Industrial	*Commercial & Municipal*	*Residential Urban, Sub-urban*	*Rural and Agricultural*
1. Connected loads	— Small, Medium Large Industrial units	— Lighting — Fans — Airconditioners	— Listing — Radio, TV — Heating — Air Coolers,	— Lighting — Pump set — Cottage industry

(*Table Contd...*)

Description	*Type of load*			
	Industrial	*Commercial & Municipal*	*Residential Urban, Sub-urban*	*Rural and Agricultural*
	— Heating Melting — Chemical — Machines & Drives — Computers — Food Industry — Various Industrial processes	— Elevators — Communication — Computers — Water pumps — Transport — Small industry — Illumination — Street lighting — Showrooms	AC — Airconditioner — Refrigerators — PCs — Water pumps — Street lighting — Kitchen machines — Hotels	— Small shops — Floor mills — Rice mills — Brick-ovens — Food processing industry — Street lighting
2. Maximum demand of individual consumer	— Hundreds of KW to few MW	— upto 1000 KW	— upto 5 KW	— upto 5 KW
3. Frequently Switched loads	— Motors, Drivers — Refrigeration and AC equipment — Furnaces — Welding sets Transportation vehicles — Boilers	— Elevators — Air Conditioners — Water heaters — Computers	— TV — Water heater — Kitchen machine — Water pumps	— Agricultural pumps sets — T.V. sets
4. Load Density (MW/km^2)	— Highest	— Next highest	— Urban : High Suburban : Moderate	— Low
5. Starting Currents and number of switchings per day	— Very high 10 to 200 times	— Moderate	— Moderate	— Low

(*Table Contd...*)

6. Power quality requirement				
— Reliability service continuity	— Highest	— Highest	— Moderate	— Moderate
	— Highest	— Highest	— Moderate	— Low
	— HIghest	— Highest	— Moderate	— Low
— Voltage regulation	(for process) control	(for computers)		
— Wavefarm accuracy				
— Flicker voltage				

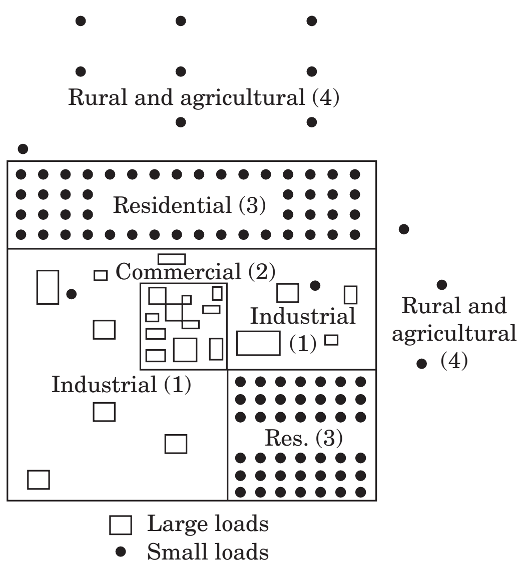


Fig. 1.7. Classification of loads in the area served by a distribution system. (1) Industrial (2) Commercial (3) Residential : Urban, Suburban (4) Rural and Agricultural.

1.12 kW, kVA AND POWER FACTOR

The variables voltage, current, apparent power, real power, reactive power, power factor are mutually related. In AC systems, the magnitudes of sinusoidal voltage and current are in terms of rms values. Phase angle between current and voltage phasers is denoted by power factor angle ϕ.

Real and reactive power. Real power is converted from electrical power to other form of power such as mechanical/thermal etc. and its units are Watts/kW/MW. Normally it is expressed by symbol P, with V in phase to neutral,

$$P = VI \cos \phi \qquad \text{...for single phase loads.}$$

Reactive power (Q) is utilised in inductive or capacitance circuits but does not produce real work. It is expressed as Q, with V in phase to neutral.

$$Q = VI \sin \phi \qquad \text{...for single phase loads.}$$

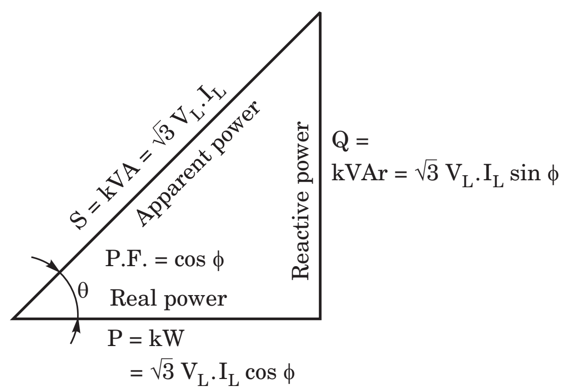


Fig. 1.8. Relationship between *kVA, kW, kVA.*

$$\text{Apparent power} = \sqrt{(\text{Real power})^2 + (\text{Reactive power})^2}$$

$$kVA^2 = \sqrt{kW^2 + kVAr^2}$$

$$S = \sqrt{P^2 + Q^2}$$

$S = kVA$ = Apparent power

$P = kW$ = Real power

$Q = kVAr$ = Reactive power.

For 3 phase Loads

Real Power P is given by

$$P = \sqrt{3}\, V_L I_L \cos \phi \qquad \text{...for 3 phase load}$$

Reactive Power Q

$$Q = \sqrt{3}\, V_L I_L \sin \phi \qquad \text{...for 3 phase load}$$

Consumer makes certain demand of power P and Reactive Power Q at certain voltage V. This demand is met by the distribution system.

1.13 SINGLE PHASE LOADS AND 3 PHASE LOADS

Distribution system gives service to single phase loads and three phase loads. *Single phase AC loads* are usually small AC loads for domestic, commercial and industrial consumers. They are served through phase wire and neutral wire of 3 phase 4 wire AC secondary distribution system. Connected loads above about 2 kW are served through 3 phase 4 wire system with 3 phase wires and are neutral wire.

Table 1.2

Secondary Service Supply to Single Phase Consumers and 3 Phase Consumers

1. Single-phase (Fig. 1.6)	One phase conductor and one neutral conductor $400/\sqrt{3}$ -V, 1 ph.	Lighting load, Small load. Rural consumers.
2. 3 Phase 4 wire. Most widely used system for distribution. For residential load of 2 kW and above this type of supply is now compulsory (Fig. 1.6)	— 3 Ph. conductors and 1 neutral conductor. — 400 V, 3 Ph. — 400 V ph to ph — $400/\sqrt{3}$ -V Ph to neutral — Range 3.3 kV, 6.6 kV, 11 kV 22 kV ; 33 kV ph to ph	3 phase conductors and one neutral conductor taken from star connected secondary of transformer. — 3 Ph. loads connected to 3 phase conductors — 1 ph load connected between phase and neutral on LV side. Neutral at supply end is grounded
3.3-phase, 3 wire (Fig. 1.6)	— 3 Nos. phase conductors	Used in primary distribution feeding delta connected primaries of distribution transformers.

1.14 LOAD CURVES AND PEAK LOAD PROBLEM

Load Curves are very useful for planning, operation and for Supply Side Management (SSM) and Demand Side Management (DSM). SSM aims at generation transmission and distribution of energy according to the load curves to fulfil the expectations of consumers. DSM aims at reshaping the load curves by various available methods to suit the power supply capability of the supply system and economic operation.

The greatest problem for a power supply company is varying load. The generation should be matched with the load constantly.

Chronological time is plotted on X-axis and load in MW on a particular plant or a group of plants is plotted on Y-axis. A *load curve* is drawn for (*i*) 24 hours of a day (Daily Load Curve), (*ii*) 7 days of a week (weekly load curve) or (*iii*) 12 months of an year (Yearly Load Curves).

Fig. 1.9(*a*) shows a daily load curve. The daily load variation has a certain repetitive cyclic curve depending upon life-style, business hours, industrial hours etc. The load line touching the highest peak gives *Peak Load.* The total installed capacity of a plant (or a group of plants) should be more than the peak load with adequate surplus margin for steady state stability limits of generators, planned outages, single or twin contingencies due to forced outages etc.

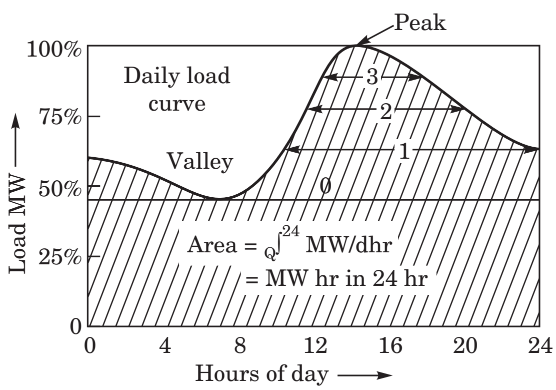


Fig. 1.9 (a). Typical Daily Load-Curve.

— Instead of increasing installed capacity for peak load ; the region may *import power* through *interconnected line* as per scheduled exchange. Peak loads in two regions are generally displaced in time.

— Another alternative is *Energy storage* during off-peak valley periods and Release of the stored energy during peak loads.

Daily load curve shape depends upon consumers routine schedules. Load curves can be reshaped by bringing about change in routine. Peak load in Paris occurs at mid-night whereas peak load in London occurs at 9 P.M. Power is exchanged via interconnection by HVDC submarine cable between England and France.

Weekly load curves can be reshaped by staggering office/factory/ cinema timings and weekly-offs of factories and commercial localities.

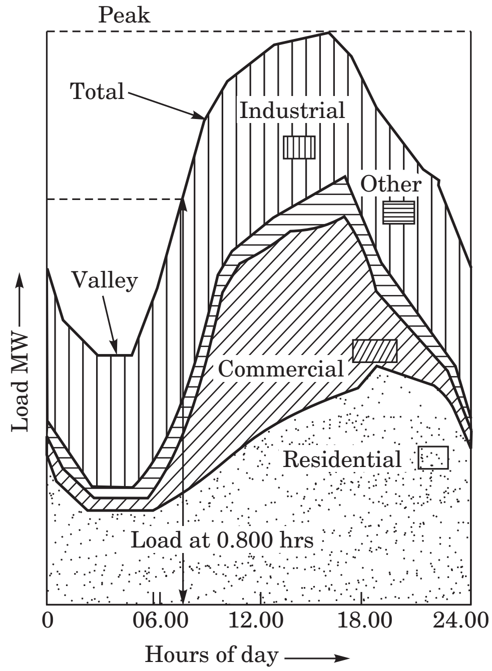


Fig. 1.9 (b). Composition of Daily Load Curve.

Area under the curve gives MWhr supplied.

Area under the daily load curve and corresponding daily load duration curve is given by

$$\text{Area} = \int_0^{24} \text{MW} \ . \ \text{dhr} = \text{MWhr}$$

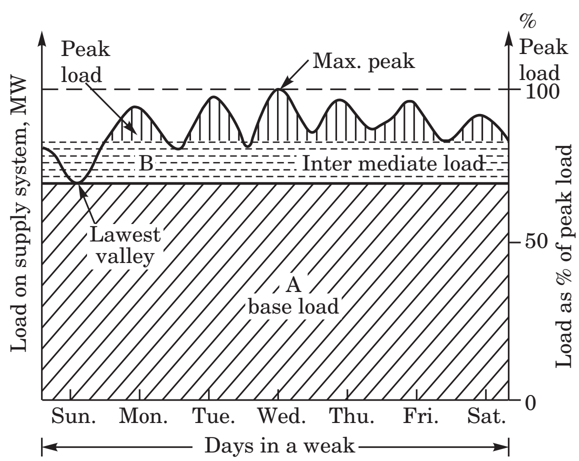


Fig. 1.9 (c). Typical Weekly Load Curve.
A. Box load, **B.** Intermediate load, **C.** Peak load.

Thus area under these curves represents *electrical energy* supplied during 24 hours.

From the well known law of conservation of energy

Total MWhr Energy Generated

= Total MWhr Energy Consumed + Total MWhr Losses

Also, Total MW being Generated

= Total MW Load Prevailing + Total MW Losses.

1.15 BASE LOAD, INTERMEDIATE LOAD AND PEAK LOAD

The **base load** (A) prevails during entire week. Base load power is supplied by power plants running continuously. The **Intermediate load** (B) prevails for some part of the day. The peak load (C) prevails only for a few hours of the day.

Load Management aims at reducing the maximum peak load and peak load duration by various demand side load changes to reshape the load curve. The **valley** depth is reduced by valley filling. The **base** load upper line is raised and intermediate load upper line is lowered to eliminate the valley.

Methods of Energy Storage and Release

Pumped Hydro

Valley Hours. The set is taken in (rectifier storage) mode, the Hydro machine is operated in pumping mode and Electrical Machine in Motoring mode.

Peak Hours. The set is operated in release mode, the Hydro machine operated in turbine mode and Electrical Machine in Generating mode and energy is released in the supply circuit.

Battery Storage

Valley Hours. The set is taken in rectifier (storage) mode, the batteries are charged from supply power.

Peak Hours. The set is operated in inverter (release) mode, and the energy is released by the charged batteries in the supply system.

Compressed Air Storage Energy Scheme (CAES)s

Storage Mode. During off-peak (valley) hours, the plant is operated in storage mode. The electrical machine drives the air compressors and the air is stored at high pressure in tanks/caverns.

Release Mode. During peak load hours the compressed air drives the air-pumps and the electrical machine is operated as generates to supply electrical energy to the supply system.

Dispersed Generation (Stand Alone Generating)

After 1980s the energy policy shifted its focus on energy conservation and use of renewable energy sources for power generation. The renewables include (1) Wind (2) Solar heat (3) Oceon heat (4) Oceon waves (5) Geothermal heat (6) Bio mass from waste (7) Chemicals (8) Small hydro, etc.

Dispersed generating plants are installed where renewable energy is available during most part of the year with sufficient energy density. The plants are either stand alone or grid connected. The plants are generally with energy storage facility (storage battery and rectifier/ inverter power conditioning set).

Dispersed generation relieves the supply system of equivalent energy burden. Power is available to remote consumers.

SUMMARY

Load Management includes simultaneous Supply Side and Load Side Management. The objective is to optimize the energy supply to consumers be shaping the loads and improving the load curves, improving the supply by energy storage, dispersed generation, etc. to achieve economic generation, transmission and distribution of electrical energy.