LECTURE NOTES

ON

ENERGY AUDITING AND DEMAND SIDE MANAGEMENT

IV B. Tech I Semester (JNTUA-R15)

Dr.D.CHANDRA SEKHKAR, M.Tech, P.hD, MISTE
Professor & HOD

Department of Electrical and Electronics Engineering

VEMU INSTITUTE OF TECHNOLOGY::P.KOTHAKOTA
NEAR PAKALA, CHITTOOR-517112
(Approved by AICTE, New Delhi & Affiliated to JNTUA, Anantapuramu)

SYLLABUS

UNI –I: INTRODUCTION TO ENERGY AUDITING

Energy Situation – World and India, Energy Consumption, Conservation, Codes, Standards and Legislation. Energy Audit- Definitions, Concept, Types of Audit, Energy Index, Cost Index, Pie Charts, Sankey Diagrams, Load Profiles, Energy Conservation Schemes. Measurements in Energy Audits, Presentation of Energy Audit Results.

UNIT -II: ENERGY EFFICIENT MOTORS AND POWER FACTOR IMPROVEMENT

Energy Efficient Motors , Factors Affecting Efficiency, Loss Distribution , Constructional Details , Characteristics - Variable Speed , Variable Duty Cycle Systems, RMS Hp- Voltage Variation-Voltage Unbalance- Over Motoring- Motor Energy Audit.Power Factor – Methods of Improvement, Power factor With Non Linear Loads

UNIT –III: LIGHTING AND ENERGY INSTRUMENTS FOR AUDIT

Good Lighting System Design and Practice, Lighting Control, Lighting Energy Audit - Energy Instruments- Watt Meter, Data Loggers, Thermocouples, Pyrometers, Lux Meters, Tong Testers, Application of PLC's

UNIT –IV*:* INTRODUCTION TO DEMAND SIDE MANAGEMENT

Introduction to DSM, Concept of DSM, Benefits of DSM, Different Techniques of DSM – Time of Day Pricing, Multi-Utility Power Exchange Model, Time of Day Models for Planning. Load Management, Load Priority Technique, Peak Clipping, Peak Shifting, Valley Filling, Strategic Conservation, Energy Efficient Equipment. Management and Organization of Energy Conservation Awareness Programs.

UNIT –V: ECONOMICS AND COST EFFECTIVENESS TESTS OF DSM PROGRAMS

Basic payback calculations, Depreciation, Net present value calculations. Taxes and Tax Credit – Numerical Problems. Importance of evaluation, measurement and verification of demand side management programs. Cost effectiveness test for demand side management programs - Ratepayer Impact Measure Test, Total Resource Cost, Participant Cost Test, Program Administrator Cost Test Numerical problems: Participant cost test, Total Resource Cost test and Ratepayer impact measure test.

TEXT BOOKS:

1. **Industrial Energy Management Systems,** Arry C. White, Philip S. Schmidt, David R. Brown, Hemisphere Publishing Corporation, New York, 1994.
2. **Fundamentals of Energy Engineering -** Albert Thumann, Prentice Hall Inc, Englewood Cliffs, New Jersey, 1984.

REFERENCES:

1. Economic Analysis of Demand Side Programs and Projects - California Standard Practice Manual, June 2002 – Free download available online http://www.calmac.org/events/spm_9_20_02.pdf
2. Energy management by W.R. Murphy & G. Mckay Butter worth, Heinemann publications, 2007.
3. Energy management by Paul o' Callaghan, Mc-graw Hill Book company-1st edition, 1998
4. Energy efficient electric motors by John .C. Andreas, Marcel Dekker Inc Ltd-2nd edition, 1995.

UNIT - I
INTRODUCTION

Energy Situation – world and India, energy consumption, conservation, codes, standards and Legislation.

Energy Situation – World and India

Energy problems are now being largely ignored, despite their continuing importance. The near-disappearance of energy from the U.S. public agenda is apparent in the scant attention given to energy topics by the media and by public figures. Some suggestions for governmental action were stimulated by the rise in gasoline prices in the Spring of 1996, but the matter was treated as a short-term anomaly -- not as a harbinger of more severe difficulties to come.

This lack of long term concern is perhaps natural, because fuel supplies are generally ample and prices are still relatively low; with the real cost of gasoline in 1994 only one half the costs in 1981. However, we believe that neglect of potential future difficulties is highly imprudent. We summarize belo w the considerations that lead us to this conclusion. (This Background Paper was prepared by members of the Panel on Public Af fairs of the American Phys ical Society.

It is meant to reflect the considerations that underlie the Statement on "Energy: the Forgotten Crisis" issued by the American Physical Society. This paper has not been revie wed by the Society.)

I. Energy: An Essential for Society

1. **Adequate energy supplies are crucial to our pattern of life.**
   - Without adequate energy supplies our society cannot function. The transportation sector is particularly vulnerable to energy disruptions and uncertainties. Economic gro wth, as well as projected population growth of 1 %/year for the U.S. and and 1.7%/year for the world will create increased energy demands.
2. **Coupling between energy and the economy has been reduced, but it is still a reality.**
   - Because of the increased efficiency of energy use and because of modal shifts in our economy, the ratio of U.S. energy use to GDP has decreased by 32 % from 19,000 BTU/$ in 1973 to 12,900 BTU/$ in 1995 (1992 dollars).
   - The rate of improvement in this ratio has fallen sharply since 1986. In the first period since the oil embargo (1973-86), the GDP (in constant dollars) rose by 41%, while energy consumption rose by less than 0.1 %. However, in the the next period (1986-1995), the GDP rose by 23 % while energy consumption rose by 17%. On the other hand, energy use on a per capita basis has been relatively constant, dropping by about 14 % in the decade following the oil embargo, but by 1995 rising most of the way back to ward the 1973 value.
   - Since 1975, electricity use has increased almost in lock-step with GDP, rising 72% from 1975 to 1995, while the GDP rose 74% (in constant dollars).

3. **The rest of the world has justifiable aspirations that will entail greater energy use.**
    - Energy consumption is growing much more rapidly in the still developing countries than in the industrialized countries of the Organization for Economic Cooperation and Development (OECD). For example, during 1970-1990 energy consumption increased 178 % for non- OECD As ia (5.3 % per year) compared to 36% for the OECD (1.6 % per year). Within several decades, these and other developing countries are likely to outstrip the OEC D countries in total energy consumption.

II. Fossil Fuels, the Main Source of Energy.

4. **Fossil fuels continue to be the mainstay of our energy economy.**
    - Fossil fuels (petroleum, natural gas, and coal) provided 84 % of primary energy used in the U.S. in 1995; petroleum contributed about 40 % of total primary energy.

5. **U.S. dome stic petroleum supplies are limited.**
    - U.S. proven reserves of crude oil have declined for 7 consecutive years. Low oil prices and a lack of good petroleum prospects are major factors in the downturn in domestic drilling and the success rates. U.S. proven oil reserves dropped from 32 billion barrels (Bb) to 22.5 Bb bet ween 1977 and 1994. Although the total amount of remaining recoverable oil in the U.S., both discovered and anticipated, is estimated to be significantly greater than the proved reserves alone -- perhaps in the rough neighborhood of 100 Bb -- this total is considerably less than the amount of oil already produced.

    - In spite of new Alaskan production, U.S. oil production dropped from 9.6 million barrels per day (Mb/d) in 1970 to 6.5 Mb/d in 1995. Alaskan production dropped from 2.0 Mb/d in 1988 to 1.5 Mb/d in 1995. Production from the lower-48 states dropped from 9.4 Mb/d in 1970 to 5.0 Mb/d in 1995.

    - The number of discoveries of large fields in the U.S. has greatly decreased and it seems unlikely that many ne w large fields of oil and gas will be found in the U.S. Since 1980 no discovered field has more resources (estimated ultimate recovery) than the top 100 previously discovered oil or gas fields.

6. **Reliance on oil imports creates proble ms for the U.S. and other nations.**
    - The U.S. trade deficit on net petroleum inputs was $48 billion in 1995, which was about 30 % of the total trade deficit and 7 % of total imports.

    - U.S. net petroleum imports have risen 31 % since the oil embargo (6.0 Mb/d in 1973 to 7.9 Mb/d in 1995). The fraction of U.S. oil from imports (in quad/y) was about 50 % in 1995, and is projected to rise to about 60 % in 2010.

    - The OPEC fraction of the world oil market is projected to rise from 40 % in 1990 to 57 % in 2015, as a result of the fact that OPEC countries have a large fraction of remaining oil resources.

7. **World dependence on oil from the Middle East entails military and economic risks.**
   - The Middle East continues to be a region of potential political instability. The U.S. fought the 1991 Persian Gulf War in part to defend the unimpeded flow of oil to OEC D nations.
   - Dependence on Persian Gulf oil has motivated U.S. arms shipments to that region and increased military involvement.
   - Europe and Japan have partially prepared themselves for future petroleum shortages by using cons iderably higher gasoline prices ($4/gallon) to raise revenue and moderate demand.
8. **Natural gas and coal are considered by some to be the "bridging fuels" of the future.**
   - U.S. proven natural gas reserves dropped from 200 trillion cubic feet (TCF) to 164 TCF from 1983 to 1994. (1 TCF is about one quad.) The present rate of consumption is 21 TCF/y. Resources may be as high as 1000 TCF, but it is not clear how much of this can be converted to proven reserves. There are very large resources of coal, but their mining and use entails major environmental problems.

III. Environmental Aspects of Energy.

9. **Combustion of fossil fuels is harmful to air quality in many cities.**
   - 40 urban areas violate at least one of the U.S. ambient air quality standards, adversely affecting human health. Many foreign cities have considerably worse air quality problems. Automobiles contribute about one-half of the cities' air pollution.
10. **Energy production and use can adversely affect the environment.**
    - Energy use and production generally entail adverse environmental impacts. These can arise from both routine and accidental releases of pollutants, the preemption of land (and rivers), and the accumulation of waste products. A more efficient use of energy can contribute to reducing these effects.
11. **Combustion of fossil fuels and climate change.**
    - The atmospheric concentration of greenhouse gases has risen 30 % since pre-industrial times, resulting in an increased radiative forcing of the climate system. If current trends in fossil fuel use continue, carbon dioxide concentrations will double in the next century.
    - According to the Intergovernmental Panel on Climate Change (I PCC, 1995), changes in weather and temperature patterns, particularly the spatial pattern of temperature changes, all point to "a discernible human influence on global climate".
    - IPCC and others estimate that the global average temperature will change by the end of the next century by 2 oC (4 oF) -- although the actual change could easily be twice or half this value. The aggregate impacts of changes in temperature, precipitation, and sea-level, while uncertain, are likely to be harmful to both human and natural systems.

IV. U.S. Energy Demand and the Needs of the Future.

12. **Buildings and appliances consume about 40% of U.S. energy; there are great opportunities to reduce these energy requirements.**
    - New building diagnostic computer codes allow architects opportunities to use new energy-management techniques. For example, from 1973-1985, the average ceiling insulation in new U.S. single-family houses increased from R14.4 to R26.7 and wall insulation increased from R10 to R12.5. The need for space heating in new large buildings and houses can be decreased by more than 50% on a cost-effective basis. Because of the long lifetime of buildings and the incomplete application of energy standards for buildings, the national transition to more energy efficient buildings will be slow. However, an EIA study found that houses built after 1988 consume only 59 % as much natural gas as those built before 1980.
    - From 1972 to 1990, new refrigerator energy usage dropped from 2000 kwh/year to about 800 kwh/year.
    - About one-fourth of U.S. electricity is used for lighting. Long-lived compact fluorescent lamps use only 30 % as much energy as incandescent bulbs. Considerable improvements in lighting efficiency have been accomplished on an economic basis with high frequency ballasts, and advanced control circuits. The cost effectiveness of these lamps improves as the fraction of the time they are operated increases.
13. **Transportation alternatives are an extremely important challenge.**
    - Because transportation uses 2/3 of U.S. petroleum and over 1/4 of U.S. energy, it is a very critical target for energy savings.
    - Since the oil embargo of 1973-74, the number of registered passenger cars has risen from 102 million to 147 million, an increase of 44 %. The DOE's Energy Information Administration projects that vehicle miles traveled by light duty vehicles will increase by 1/3 by 2015. The U.S. is saving huge amounts of fuel and billions of dollars a year because the current standard (average) fuel economy for new automobiles of 27.5 miles/gallon is twice the 1973 fleet average of 13.5 miles/gallon.

V. Non-Fossil Energy Sources.

14. **Alternatives to fossil fuels are nuclear (fission and fusion), solar (photovoltaic, biofuels, wind, hydro, and solar thermal), tidal, and geothermal.**
    - These energy sources are sufficient to sustain the Earth's economy, but in most cases the costs are not now competitive with fossil fuels.
15. **Renewable energy sources are not widely replacing fossil energy sources.**
    - Hydroelectric power has remained relatively constant over the past two decades. Wind energy has grown considerably, but still contributes relatively little. Geothermal (not strictly renewable) has grown considerably, but is showing signs of depletion.

16. **Nuclear fission's role will diminish without new initiatives.**
   - In 1995 nuclear energy's share of the electricity generated by utilities was 22% in the United States, 76 % in France and 33 % in Japan. Nuclear energy has risen from a negligible contributor to U.S. electricity generation in 1970 to the second largest source (after coal, and before natural gas and hydro) in 1995, substantially moderating the need for fossil fuel sources.
   - No new reactors have been ordered in the U.S. for more than 20 years. Several versions of improved reactors are expected to be available for pre-licensing shortly, but there are no immediate prospects for U.S. utility purchases. Two such reactors are being completed in Japan.
   - No decisions have been reached in the U.S. on the location of either interim or permanent nuclear waste repositories, and it is not clear that a coherent, politically acceptable, nuclear waste disposal program can be established in the near future.
   - Little work is continuing toward the design of reactors and fuel cycles that attempt to address simultaneously the problem of long term fuel supply and the danger of the proliferation of nuclear weapons.
   - Replacing the present 100-gigawatt nuclear capacity with combined-cycle gas-fired plants would require about 4.5 trillion cubic feet of natural gas, equal to over 20% of the present total U.S. natural gas consumption.

17. **Fusion energy, at be st, will not be available for several decades.**
   - In research facilities many parameters critical to commercialization of fusion energy have improved dramatically, but the commercialization date for fusion remains uncertain.

VI. Some Energy Policy Issues

18. **Science and technology have had major successe s.**
   - Energy R& D has produced new and improved products and accelerated market penetration, such as: combined-cycle power plants, compact fluorescent bulbs, enhanced nuclear safety, more efficient automobiles, high bypass ratio jet engines for airplanes, improved building designs, catalytic converter muff lers, improved photovoltaic cells, more reliable wind mills, and so forth.
   - R&D is necessary to enhance development of future energy sources and to improve end-use energy efficiency.

19. **U.S.Government Energy R& D**
   - Energy R&D is carried out consistent with the DOE mission, although its relative share of the DOE budget has been in steady decline over the past 18 years. While the overall DOE budget has stayed fairly level since 1978, at about 1% of the total federal budget, DOE's energy R&D budget has currently dropped by about 74 % (in constant dollars) from the 1978 budget. As a percentage of the DOE budget, energy R&D has gone from 45% of the total DOE budget request in 1980 to 18% in 1995. To place these figures in perspective, in 1995 the total federal investment in energy R& D (expenditures for all agencies) was about 0.5 % of total U.S. energy expenditures.

20. The federal government has an essential role in addressing problems with long time horizons?

- When the private sector is not addressing issues that pose threats to the national security and well-being, federal involvement may become necessary. Industry will typically invest in products which have a relatively short payback period. Ho wever, energy problems may require several decades of development and success is not assured. Individual private companies may prefer to wait for others to develop a technology, and then modify aspects of that technology for their purposes. Thus, there is likely to be insufficient industry investment in important long term R& D projects. Federal help is then needed to fill the gap. This should be done with a stability in funding that goes beyond the yearly Congressional budget cycles.

21. National energy policy options.

The AP S statement on "Energy: the Forgotten Crisis" concludes that "Low-cost oil resources...are rapidly being depleted," that pollution is a threat to human health and the environment, and that changing climate patterns may be expected from massive reliance on fossil fuels. These conclusions indicate the need for action by the nation. We present the follo wing illustrative policy options that respond to these conclusions. Their presentation does not necessarily signify endorsement, but it illustrates a range of options that we think worthy of consideration and further analysis.

a. **Means for establishing national energy priorities and policies.**
The long-term decline in general energy research funding, and the severe fluctuations in funding individual energy technologies demonstrate the need for a coherent, long-term, and bi-partisan, U.S. energy policy. One possible step towards this goal could be the establishment of a permanent, bipartisan presidential commiss ion to provide a continuous revie w of energy policy.

b. **Energy education and communications initiatives.**
It is desirable to increase efforts, especially within the education programs of the Department of Energy, to educate the public -- particularly students, teachers, and consumers -- about the vital contribution of energy to our national well-being and the fundamental issues and problems surrounding its production and use.

c. **Measures to promote efficient and prudent use of energy.**
Technological improvements in energy efficiency provide the most readily accepted means for restraining energy consumption. These have had remarkable, although not well-enough noticed, success over the past two decades. Further gains may be achievable through R&D efforts directed to ward cost-effective technological improvements. Consideration also should be given to the implications of possible additional measures, such as: (i) gasoline taxes to reduce the use of oil; (ii) higher fuel economy standards for passenger cars, the extension of fuel standards to additional classes of vehicles (e.g. light trucks, minivans), or a revenue-neutral "feebate" system of sales taxes and rebates designed to encourage the purchase of vehicles with good fuel efficiency; and (iii) increased energy standards on buildings and appliances.

d. **Measures to encourage non-fossil sources for energy production.**

For rene wable energy sources that may be approaching competitiveness in some regional markets, such as solar thermal electricity and wind energy, the maintenance or extension of moderate financial incentives could speed the large-scale introduction of the technology. This would permit the evaluation of its economic and environmental merits. For more expensive technologies, such as photovoltaic power, it may be desirable to spur technological development through more direct assistance in research, development, and test deployment.

	Indicators	India	Per capita
1	Coal consumption	339 million short tons (2001E)	0.32
2	Coal production	358.9 million tonnes	0.34 million tonnes per 1000000
3	Coal production in 1981	130.1 million tonnes	0.12 million tonnes per 1000000
4	Commercial energy use	494.03 (2000)	n.a .
5	Electricity - consumption	509.89 billion kWh (2000)	487.54 kWh
6	Electricity - exports	321 million kWh (2000)	0.31 kWh
7	Electricity - imports	1.385 billion kWh (2000)	1.32 kWh
8	Electricity - production	547.12 billion kWh (FY 2000-01, utilities only) (2000)	523.13 kWh
9	Electricity - production by source (fossil fuel)	83%	N.A.
10	Electricity - production by source (hydro)	14%	N.A.
11	Electricity - production by source (nuclear)	3%	N.A.
12	Electricity - production by source (other)	0%	N.A.
13	Gasoline prices	0.98 (1998-2000 MRYA)	N.A.
14	Hydroelectricity consumption	74.5 terawatt-hours	0.07 terawatt-hours per 1000000

15	Hydroelectricity consumption in 1965	19.2 terawatt-hours	0.02 terawatt-hours per 1000000
16	Natural gas consumption	803 billion cubic feet (2001E)	767.8 cubic feet
17	Natural gas production	803 billion cubic feet (2001E)	767.8 cubic feet
18	Natural gas reserves	26.9 trillion cubic feet (1/1/03E)	25,720.71 cubic feet
19	Nuclear electricity generation	17.8	0.02 per 1000000
20	Nuclear energy consumption	19.4 terawatt-hours	0.02 terawatt-hours per 1000000
21	Nuclear reactors operable	14	0.01 per 1000000
22	Nuclear reactors operable (MWe)	2,550	2.44 per 1000000
23	Nuclear reactors planned	1	0 per 1000000
24	Nuclear reactors planned (MWe)	440	0.42 per 1000000
25	Nuclear reactors under construction	8	0.01 per 1000000
26	Nuclear reactors under construction (MWe)	3,728	3.56 per 1000000
27	Nuclear reactors uranium required	299	0.29 per 1000000
28	Nuclear waste generated	-0.06 (1996)	n.a .
29	Oil consumption	2.0 million barrels per day (2002E)	1.91 barrels per day per 1000
30	Oil imports {net}	1.2 million barrels per day (2002E)	1.15 barrels per day per 1000
31	Oil production	793 thousand barrels per day	0 thousand barrels per day per 1000
32	Oil production in 1972	152 thousand barrels per day	0 thousand barrels per day per 1000
33	Oil production in 1982	412 thousand barrels per day	0 thousand barrels per day per 1000
34	Oil production in 1992	643 thousand barrels per day	0 thousand barrels per day per 1000

35	Oil refining ability	2.1 million bbl/d (1/1/03E)	2.01 barrels per day per 1000
36	Oil reserves	5.4 billion barrels (1/1/03E)	5.16 barrels
37	Traditional fuel consumption	20.7%	N.A.
38	Wall plugs - frequency	"50 HZ, 60 HZ "	N.A.
39	Wall plugs - plug type	UK	N.A.
40	Wall plugs - voltage	230-250 V	N.A.

Energy Codes and Standards

What are energy codes?

Energy codes are a subset of a broader collection of written legal requirements known as building codes, which govern the design and construction of residential and commercial structures. Building codes protect individuals from substandard living and working conditions by setting minimum standards for acceptable practice. Energy codes address increasing the energy efficiency of building systems.

How do they work?

Energy codes reference areas of construction such as wall and ceiling insulation, windo w and door specifications, HVAC equipment efficiency, and lighting fixtures. Usually, there are t wo methods for compliance. The most common method is the prescriptive approach, in which the code stipulates the stringency of the materials and equipment the builder must use. For the performance approach, the code allocates a total allowable energy use for a building, and the builder can choose the materials and equipment that will meet this target.

Where did they come from?

In the United States, national model energy codes were created in response to the energy and economic crises of the 1970s. In 1978, Congress passed legislation requiring states to initiate energy efficiency standards for new buildings. Since then, energy codes have undergone significant improvements. The 1992 Energy Policy Act ("EPAct") mandated that all states must review and consider adopting the national model energy standard. The Energy Policy Act of 2005 specified the most current model energy codes at the time of its passage (2004 IECC supplement, AS HRAE 90.1-2004). Today, AS HRAE Standard 90.1-2007 and the 2009 International Energy Conservation Code (IECC) are the national model energy codes, and each is updated on a three-year cycle.

Int ro du ction

Energy codes provide minimum building requirements that are cost-effective in saving energy. The energy saved is a cost savings to the building owner through lo wer monthly utility bills, and smaller and thus less expensive HVAC equipment. More than 2/3rds of the electricity and 1/3rd of the total energy in the U.S. are used to heat, cool, and operate buildings. This means that implementing and enforcing energy codes will result in fewer power plants and natural resources being used to provide electricity and natural gas. It also means fewer emissions to the atmosphere. Emissions have been linked to smog, acid rain, and global warming. In the U.S. most buildings are constructed to meet minimum energy code requirements; therefore energy codes contribute to sustainability by saving energy and protecting the environment.

Energy codes are effective in reducing per capita energy usage (energy use per person). The per capita energy use in California has remained steady due to its active use and enforcement of energy codes for buildings, while energy use in the rest of the U.S. has increased.

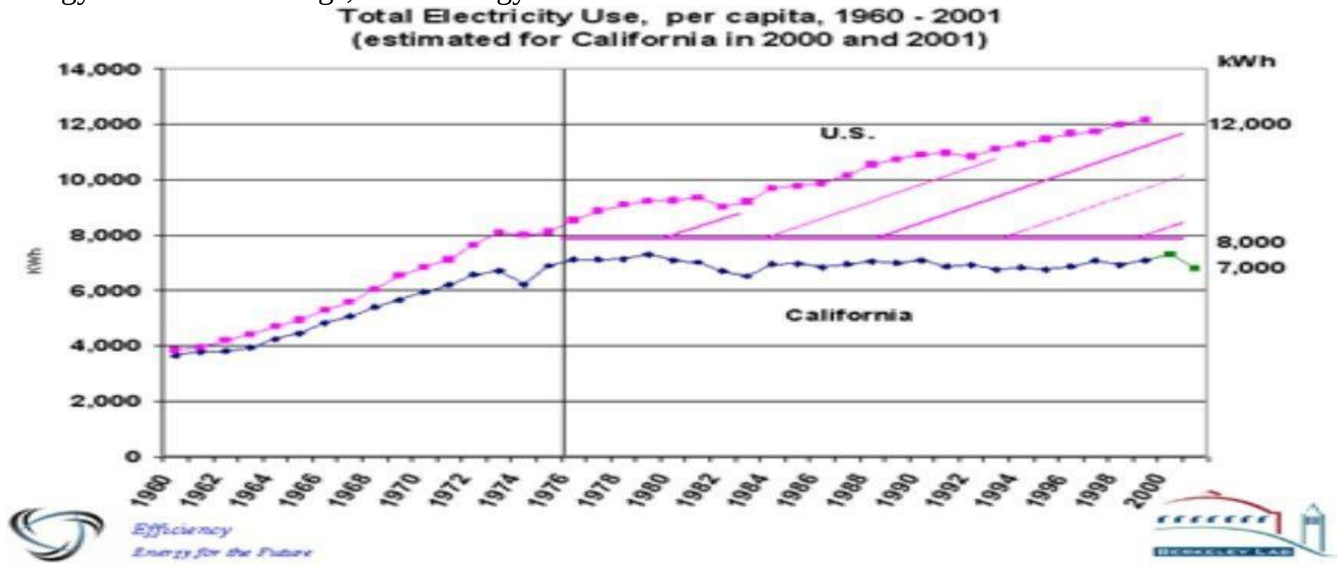


Fig.1. Total Electricity Use, per capita, 1960-2001 (estimated for California for 2000 and 2001)

Description

A. Commonly Used Energy Codes

The U.S. Energy Conservation and Production Act (ECPA) requires that each state certify that it has a commercial building code that meets or exceeds ANSI/ASHRAE/IESNA Standard 90.1-1999. In this sense, "commercial" means all buildings that are not low-rise residential (three stories or less above grade). This includes office, industrial, warehouse, school, religious, dormitories, and high-rise residential buildings. The process is administered by the Department of Energy. ASHRAE 90.1 is the most commonly used energy code for commercial and other non-residential buildings. The Model Energy Code (MEC), now the International Energy Conservation Code (IECC), is the most commonly used residential energy code by states. The IECC also has a commercial section that allows the use of ASHRAE 90.1 for compliance. The International Residential Code (IRC) is also used by some states. The NFPA has commercial and residential energy codes based on ASHRAE Standards 90.1 and 90.2 (low-rise residential). The status of energy codes by states is available from the Building Codes Assistance Project (BCAP). Some states, such as Florida and California, have independently developed and adopted their own energy codes. Some states and jurisdictions do not yet have energy codes despite the federal requirement.

Table 1. Energy Codes in Order of Frequency of Adoption by States

Commercial[1]	Residential
ASHRAE 90.1	IECC (MEC)
IECC[2]	IRC
NFPA 5000[3]	NFPA 5000[3]
	ASHRAE 90.2

[1]Commercial codes often include high-rise residential; see individual codes for definitions.
[2]The IECC allows the use of ASHRAE 90.1.
[3]NFPA 5000 is based on ASHRAE 90.1 and 90.2.

Table 2. Residential Energy Code Adoption – Autumn 2004

MEC Version or Equivalent State Code	States Adopted or Adopting
2003 IECC, IRC	10 States (AR, CT, KS, MD, NE, NM, PA, RI, PA, VT)
2000 IECC, IRC or equivalent state code adopted or under review or in rulemaking for statewide adoption/equivalence	18 States and DC (AL, CA, DC, DE, FL, GA, ID, KY, NC, NH, NY, OH, OR, SC, TX, VA, WA, WI, WV)
1998 IECC	1 State (OK)
95 MEC, Mandatory statewide adoption/equivalence	6 States(AK, HI*, MA, MN, NJ, VT)
95 MEC, Partial adoption/equivalence	1 State (LA)
93 MEC, Mandatory statewide adoption/equivalence	1 State (ND*)
92 MEC, Mandatory statewide adoption/equivalence	3 States (IA, IN, TN)
No statewide residential code or residential code is not EPAct compliant	10 States (AZ*, CO*, IL*, ME, MI, MO, MS*, NV*, SD, WY*)

*Code implementation depends upon the voluntary adoption by local jurisdictions.
(Source: Building Codes Assistance Project(http://bcap-ocean.org/code-status))

Table 3. Commercial Energy Code Adoption – Autumn 2004

ASHRAE/IESNA Standard or Equivalent State Code	States Adopted or Adopting
2003 IECC/ASHRAE 90.1-2001	13 States (AR, CT, FL, GA, KS, ME, MT, NM, NE, SC, UT, PA, RI)
ASHRAE/IESNA 90.1-1999, Statewide or equivalent state code adoption or in adoption process	21 States and DC (CA, DC, DE, ID, IL, KY, LA, MA, MD, MI, NC, NH, NJ, NY, OH, OR, TX, VA, WA, WI, WV)
ASHRAE/IESNA 90.1-1989, Mandatory statewide adoption/equivalence	5 States (HI, IA, MN, ND*, OK)
No commercial code or commercial code is not EPAct compliant	10 States (AK, AL, AZ*, CO*, MO*, MS, NV, SD, TN*, WY*)

*Code implementation depends upon the voluntary adoption of the code by local jurisdictions. (Source: Building Codes Assistance Projects)

Ne w federal commercial and multi-family high-rise residential buildings must meet standards in 10 CFR 434, based on the ANSI/ASHRAE/IESNA Standard 90.1-1989. The U.S. Department of Navy (DON) and Department of Defense (DOD) use ANSI/ASHRAE/IESNA 90.1-1999 rather than 10 CFR 434. Government low-rise residential energy standards generally comply with ENERGY STAR. The U.S. Department of Energy's Federal Energy Management Pr ogram (FEMP) oversees the efforts to reduce energy and impacts to the environment at federal sites.

Modifications to existing buildings often need to meet new building requirements or ANS I/ AS HRAE/IES NA Standard 100-1995 – Energy Conservation in Existing Buildings. A common method of reporting energy performance for existing and new buildings is described in ANSI/ASHRAE Standard 105-1984 (RA 99) –Standard Methods of Measuring and Expressing Building Energy Performance.

B. Scope of Energy Codes

Energy codes generally dictate requirements for the building's envelope, mechanical, and lighting (nonresidential only) requirements. Energy codes must be easy to understand for architects and builders to use and code officials to enforce. For this reason codes cannot incorporate all good design practices and should not be confused with good practice. For instance, significant energy can be saved by considering building orientation, limiting infiltration, planting trees, and using passive solar design strategies. Yet these are not mandated in most energy codes at this time. Also, if durability of building materials were considered, energy could be saved in the manufacturing and installation of replacement materials throughout the life of the building. But durability is not considered in energy codes at this time.

Energy codes strive to provide cost-effective criteria. For example, commercial building criteria in AS HRAE 90.1 generally has a payback period of less than 10 years and residential building criteria in ASHRAE 90.2 generally has a payback period of less than 20 years. See resource page Life-Cycle Cost Analysis.

Building envelope requirements in codes generally include minimum insulation levels for walls, roofs, and floors, as well as window requirements. These generally vary with climate region, since more insulation is cost-effective in cold or extremely hot regions.

Mechanical system requirements include minimum equipment efficiency requirements, insulation requirements for ducts and piping, and controls for off-hours and dead bands (commercial).

Commercial building requirements for lighting include total building wattage requirements for interior and exterior lighting. Controls are generally required to assure lighting is turned off when facilities are unoccupied. This can be achieved through programmable controls or occupancy sensors.

C. Prescriptive versus Performance Criteria

Codes generally have prescriptive and performance paths for compliance. Prescriptive paths are easy-to-use tables that contain required minimum or maximum values. Performance paths are used to trade one energy saving meas ure for another. For instance, if the wall insulation does not meet the prescriptive requirements, but the ceiling insulation exceeds the prescriptive requirements, then using a performance method may show compliance of the whole building with the code. Prescriptive paths are commonly used for typical buildings in states with newly adopted codes. Once designers become familiar with performance software, these become more popular. Some performance methods can be used to show energy savings beyond code, and are used for sustainability programs or state tax credits.

In prescriptive tables, opaque elements such as walls and roofs will have requirements in terms of thermal resistance (R-values) and thermal transmittance (U-factors). The U-factor includes the effects of insulation as well as framing members and interior and exterior finishes. The "overall" R-value is the reciprocal of the U-factor. The "added" R-value is the R-value of the added insulation, which is a simpler way of stating the requirement since insulation materials are labeled for R-value. The effect of framing and building materials other than insulation does not have to be calculated for prescriptive tables with "added" R-value requirements. For fenestration (windo ws and associated frames) the requirements are in terms of U-factor and solar heat gain coefficient (SHGC). Some codes have pre-calculated U-factors for walls, roofs, or windows so that the pre-calculated values can be easily compared to the prescriptive requirements.

For walls with thermal mass (such as concrete, masonry, adobe, or logs) R-values are not a true indicator of energy performance. These materials have a relatively low R-value, yet buildings constructed with these materials perf orm well and are comfortable in many climates. Thermal mass absorbs heat, thereby reducing and delaying the effects of outdoor temperature extremes on the HVAC system, especially when temperatures fluctuate with highs or lo ws bet ween 50 to 75°F (10 to 25°C). In most climates, buildings with insulated mass walls will save energy compared to buildings without mass with the same R-value. In many southern and western climates, mass walls without insulation will perform as well as non-mass walls with insulation. In commercial buildings where cooling demand often peaks in the afternoon due to the loads from people and equipment, walls with thermal mass can absorb and lessen this peak. Since the mass reduces peaks in mechanical system loads, first costs for HVAC equipment may also be reduced in some climates. Most energy codes allow an adjustment for wall thermal mass in the prescriptive portion.

The performance paths in energy codes generally allow the use of an easy-to-use computer trade-off program or a detailed energy budget method. Generally the more complicated the compliance tool, the more flexibility the designer is allo wed. Trade-off tools also allow for innovation in design and materials. COMcheck™ is an easy-to-use program for determining commercial building compliance for AS HRAE 90.1, IECC, and many state codes. REScheck™ (formerly MECcheck) is an easy-to-use program for determining residential building compliance with the MEC, IECC, and many state codes. A detailed computer-based energy analysis program such as DOE2 and Visual DOE4.0 calculate yearly energy consumption on an hourly basis. Such programs are useful when using the energy budget method because other simpler compliance tools do not take into account special features of the building or its components. The energy budget method compares the annual energy use of a building that meets prescriptive requirements with the proposed building to determine compliance. Codes provide rules and guidelines for the energy budget method.

Legislation

The legislation:

- implements the carbon pricing mechanism for Australia to reduce carbon pollution and move to a clean energy future
- sets out how the carbon pricing mechanism will be run, and what businesses will have to do
- links the carbon price to the Carbon Farming Initiative and to credible schemes overseas
- provides for assistance to emissions intensive and trade exposed industries through the Jobs and Competitiveness Program and to electricity generators to ensure energy security
- excludes emissions from agriculture, the land sector, and the combustion of biomass, biofuels and biogas from the mechanism
- sets up a Clean Energy Regulator to administer the carbon pricing mechanism, the National Greenhouse and Energy Reporting scheme, the Renewable Energy Target and the Carbon Farming Initiative
- sets up an independent Climate Change Authority, which will advise the Australian Government on the setting of carbon pollution caps and periodic review of the carbon pricing mechanism and other climate change laws
- applies an effective carbon price to transport fuels used in rail, shipping and aviation (fuels used by motorists and in light commercial vehicles are excluded), to off-road use of transport fuels by businesses (other than in the agricultural, forestry and fishery industries), and to synthetic greenhouse gases
- provides a refundable tax offset for conservation tillage equipment, and
- assists those Australian households that need it most, including pensioners and low- and middle-income earners

The Clean Energy Legislative Package and related legislation

Clean Energy Act 2011 — commenced on 2 April 2012

The Clean Energy Act 2011 is the central Act of the Package. It sets up the carbon pricing mechanism (the mechanism) and deals with assistance for emissions-intensive trade-exposed industries (the Jobs and Competitiveness Program) and the coal-fired electricity generation sector.

It contains rules for who is covered, the Opt-in Scheme as well as what sources of carbon pollution are included, the obligation to surrender emissions units, caps on the amount of carbon pollution from 1 July 2015, international linking, monitoring, enforcement, appeal and review provisions.

Clean Energy Regulator Act 2011 — commenced on 2 April 2012

The Clean Energy Regulator Act 2011 sets up the Clean Energy Regulator as a statutory authority that will administer the carbon pricing mechanism, National Greenhouse and Energy Reporting Scheme, the Renewable Energy Target and the Carbon Farming Initiative.

Climate Change Authority Act 2011 — commences on 1 July 2012

The Climate Change Authority Act 2011 sets up the Climate Change Authority, which will begin on 1 July 2012. The Authority will advise the Australian Government on the setting of carbon pollution caps and periodic review of the carbon pricing mechanism and other climate change laws.

This Climate Change Authority Act 2011 also sets up the Land Sector Carbon and Biodiversity Board, which will advise on the implementation of land sector measures.

Clean Energy (Consequential Amendments) Act 2011

Different parts of the Clean Energy (Consequential Amendments) Act 2011 will start at different times, depending on the element of the mechanism to which they relate or the specific legislation that it amends.

This Act makes amendments to other laws to ensure that the mechanism is integrated with existing la ws, regulatory schemes and processes. It includes changes that ensure:

- the National Greenhouse and Energy Reporting scheme supports the mechanism (the consolidated NGER Acts as of 2 April 2012 and 1 July 2012, are now available on Comlaw)
- the Australian National Registry of Emissions Units covers the mechanism, as well as the Carbon Farming Initiative
- the Regulator covers the mechanism, Carbon Farming Initiative, the Renewable Energy Target and the National Greenhouse and Energy Reporting scheme
- the Regulator and Authority are set up as statutory agencies and regulated by public accountability and financial management rules
- that carbon units and their trading are covered by laws on financial services and regulated by the Australian Securities and Investment Commission
- that activities related to emiss ions trading are covered by la ws on money laundering and fraud
- synthetic greenhouse gases are covered by an effective carbon price by extending existing Regulation of those substances
- the taxation treatment of emissions units for the purposes of GST and income tax is clear, and
- the Regulator can work with other regulatory bodies, including the Australian Securities and Investments Commission, the Australian Competition and Consumer Commiss ion and Austrac.

ENERGY AUDITING

Energy audit- definitions, concept, types of audit, energy index, cost index, pie charts, Sankey diagrams, load profiles, Energy conservation schemes. Measurements in energy audits, presentation of energy audit results.

Energy Audit

An energy audit is an assessment of ho w much energy a home consumes and the development of a plan to make the home more energy efficient. An energy audit cannot only reveal ways to help conserve precious energy; it can also save you significant amounts of money by maximizing energy efficiency in your household. During an audit, an expert examines the building for energy leakages (such as air leaks) as well as ways to maximize energy usage (such as with more efficient lighting and heating/cooling systems).

Definition of Energy Audit

An energy audit is a review of current energy costs so that a company can achieve savings. An audit is conducted by a company's in-house personnel or by a professional energy audit firm. If an audit firm does the audit, they either charge a flat fee or ask that you pay them a percentage of the savings achieved. The three types of energy audit are a preliminary audit, the general audit and an investment grade audit, according to Gard Analytics.

Definition

An **energy audit** is an inspection, survey and analysis of energy flows for energy conservation in a building, process or system to reduce the amount of energy input into the system without negatively affecting the output(s).

History

Energy audits initially became popular in response to the energy cris is of 1973 and later years. Interest in energy audits has recently increased as a result of growing understanding of human impact upon global warming and climate change.

Principle

When the object of study is an occupied building then reducing energy consumption while maintaining or improving human comfort, health and safety are of primary concern. Beyond simply identifying the sources of energy use, an energy audit seeks to prioritize the energy uses according to the greatest to least cost effective opportunities for energy savings.

Home energy audit

A home energy audit is a service where the energy efficiency of a house is evaluated by a person using professional equipment (such as blo wer doors and infrared cameras), with the aim to suggest the best ways to improve energy efficiency in heating and cooling the house.

An energy audit of a home may involve recording various characteristics of the building envelope including the walls, ceilings, floors, doors, windows, and skylights. For each of these components the area and resistance to heat flow (R-value) is measured or estimated. The leakage rate or infiltration of air through the building envelope is of concern, both of which are strongly affected by windo w construction and quality of door seals such as weather stripping. The goal of this exercise is to quantify the building's overall thermal performance. The audit may also assess the efficiency, physical condition, and programming of mechanical systems such as the heating, ventilation, air conditioning equipment, and thermostat.

A home energy audit may include a written report estimating energy use given local climate criteria, thermostat settings, roof overhang, and solar orientation. This could show energy use for a given time period, say a year, and the impact of any suggested improvements per year. The accuracy of energy estimates are greatly improved when the homeowner's billing history is available sho wing the quantities of electricity, natural gas, fuel oil, or other energy sources consumed over a one or two-year period. A home energy audit is often used to identify cost effective ways to improve the comfort and efficiency of buildings. In addition, homes may qualify for energy efficiency grants from central government.

Industrial energy audits

Increasingly in the last several decades, industrial energy audits have exploded as the demand to lo wer increasingly expensive energy costs and move to wards a sustainable future have made energy audits greatly important. Their importance is magnified since energy spending is a major expense to industrial companies (energy spending accounts for ~ 10 % of the average manufacturer's expenses). This growing trend should only continue as energy costs continue to rise.

While the overall concept is similar to a home or residential energy audit, industrial energy audits require a different skill set. Weatherproofing and insulating a house are the main focus of residential energy audits. For industrial applications, weatherproofing and insulating often are minor concerns. In industrial energy audits, it is the HVAC, lighting, and production equipment that use the most energy.

Concept

Energy Concepts specializes in Energy Audits and Energy Star certifications in the East Texas area. We are proud to announce our most recent partnership in the Home Performance with Energy Star program.

If you are considering building a ne w home, Energy Concepts can provide the expertise to help design your new home’s energy efficiency. For existing home purchases, an energy audit can provide you with a detailed analysis sho wing you potential problems with your future home.

Types of Audits and Reviews

The Audit Process

In general, a typical audit includes the following sequential steps:

- Scheduling an opening conference to discuss the audit objectives, timing, and report format and distribution.

- Assessing the soundness of the internal controls or business systems and operations.

- Testing the internal controls to ensure proper operation.
- Discussing with management all preliminary observations.
- Discussing with management the draft audit report and their responses, if available, prior to release of the final audit report.
- Following up on critical issues raised in audit reports to determine if they have been successfully resolved.

Audits

Types of Audits and Reviews:

1. Financial Audits or Reviews
2. Operational Audits
3. Department Reviews
4. Information Systems Audits
5. Integrated Audits
6. Investigative Audits or Reviews
7. Follow-up Audits

Financial Audit

A historically oriented, independent evaluation performed for the purpose of attesting to the fairness, accuracy, and reliability of financial data. CS ULB's external auditors, KPMG, perform this type of review. CS ULB's Director of Financial Reporting coordinates the work of these auditors on our campus.

Operational Audit

A future-oriented, systematic, and independent evaluation of organizational activities. Financial data may be used, but the primary sources of evidence are the operational policies and achievements related to organizational objectives. Internal controls and efficiencies may be evaluated during this type of review.

Department Review

A current period analysis of administrative functions, to evaluate the adequacy of controls, safeguarding of assets, efficient use of resources, compliance with related laws, regulations and University policy and integrity of financial information.

Information Systems (IS) Audit

There are three basic kinds of IS Audits that may be performed:

1. General Controls Review

A revie w of the controls which govern the development, operation, maintenance, and security of application systems in a particular environment. This type of audit might involve reviewing a data center, an operating system, a security software tool, or processes and procedures (such as the procedure for controlling production program changes), etc.

2. **Application Controls Review**
   A revie w of controls for a specific application system. This would involve an examination of the controls over the input, processing, and output of system data. Data communications issues, program and data security, system change control, and data quality issues are also considered.

3. **System Development Review**
   A review of the development of a ne w application system. This involves an evaluation of the development process as well as the product. Consideration is also given to the general controls over a new application, particularly if a new operating environment or technical platform will be used.

Integrated Audit

This is a combination of an operational audit, department review, and IS audit application controls review. This type of review allows for a very comprehensive examination of a functional operation within the University.

Investigative Audit

This is an audit that takes place as a result of a report of unusual or suspicious activity on the part of an individual or a department. It is usually focused on specific aspects of the work of a department or individual. All members of the campus community are invited to report suspicions of improper activity to the Director of Internal Auditing Services on a confidential basis. Her direct number is 562-985-4818.

Follow-up Audit

These are audits conducted approximately six months after an internal or external audit report has been issued. They are designed to evaluate corrective action that has been taken on the audit issues reported in the original report. When these follo w-up audits are done on external auditors' reports, the results of the follo w-up may be reported to those external auditors.

Types of energy audit

The term energy audit is commonly used to describe a broad spectrum of energy studies ranging from a quick walk-through of a facility to identify major problem areas to a comprehensive analysis of the implications of alternative energy efficiency measures sufficient to satisfy the financial criteria of sophisticated investors. Numerous audit procedures have been developed for non-residential (tertiary) buildings. Audit is required to identify the most efficient and cost-effective Energy Conservation Opportunities (ECOs) or Measures (ECMs). Energy conservation opportunities (or measures) can consist in more efficient use or of partial or global replacement of the existing installation.
When looking to the existing audit methodologies developed in IEA-ECBCS Annex 11, by ASHRAE and by Krarti (2000), it appears that the main issues of an audit process are:

- The analysis of building and utility data, including study of the installed equipment and analysis of energy bills;
- The survey of the real operating conditions;
- The understanding of the building behaviour and of the interactions with weather,

occupancy and operating schedules;

- The selection and the evaluation of energy conservation measures;
- The estimation of energy saving potential;
- The identification of customer concerns and needs.

Common types/levels of energy audits are distinguished below, although the actual tasks performed and level of effort may vary with the consultant providing services under these broad headings. The only way to ensure that a proposed audit will meet your specific needs is to spell out those requirements in a detailed scope of work. Taking the time to prepare a formal solicitation will also assure the building owner of receiving competitive and comparable proposals.

Generally, four levels of analysis can be outlined (AS HRAE):

- **Level 0** – Benchmarking: This first analysis consists in a preliminary Whole Building Energy Use (WBEU) analysis based on the analysis of the historic utility use and costs and the comparison of the performances of the buildings to those of similar buildings. This benchmarking of the studied installation allo ws determining if further analysis is required;

- **Level I** – Walk-through audit: Preliminary analysis made to assess building energy efficiency to identify not only simple and low-cost improvements but also a list of energy conservation measures (EC Ms, or energy conservation opportunities, ECOs) to orient the future detailed audit. This inspection is based on visual verifications, study of installed equipment and operating data and detailed analysis of recorded energy consumption collected during the benchmarking phase;

- **Level II** – Detailed/General energy audit: Based on the results of the pre-audit, this type of energy audit consists in energy use survey in order to provide a comprehensive analysis of the studied installation, a more detailed analysis of the facility, a breakdown of the energy use and a first quantitative evaluation of the ECOs/EC Ms selected to correct the defects or improve the existing installation. This level of analys is can involve advanced on-site measurements and sophisticated computer based simulation tools to evaluate precisely the selected energy retrofits;

- **Level III** – Investment- Grade audit: Detailed Analysis of Capital-Intensive Mo difications focusing on potential costly ECOs requiring rigorous engineering study.

Benchmarking

The impossibility of describing all possible situations that might be encountered during an audit means that it is necessary to find a way of describing what constitutes good, average and bad energy performance across a range of situations. The aim of benchmarking is to answer this question. Benchmarking mainly consists in comparing the measured consumption with reference consumption of other similar buildings or generated by simulation tools to identify excessive or unacceptable running costs. As mentioned before, benchmarking is also necessary to identify buildings presenting interesting energy saving potential. An important issue in benchmarking is the use of performance indexes to characterize the building.

These indexes can be:

- Comfort indexes, comparing the actual comfort conditions to the comfort requirements;
- Energy indexes, consisting in energy demands divided by heated/conditioned area, allowing comparison with reference values of the indexes coming from regulation or similar buildings;
- Energy demands, directly compared to “reference” energy demands generated by means of simulation tools.

Walk-through or Preliminary Energy Audit (PEA)

The preliminary audit (alternatively called a simple audit, screening audit or walk-through audit) is the simplest and quickest type of audit. It involves minimal intervie ws with site-operating personnel, a brief review of facility utility bills and other operating data, and a walk-through of the facility to become familiar with the building operation and to identify any glaring areas of energy waste or inefficiency.

Typically, only major problem areas will be covered during this type of audit. Corrective measures are briefly described, and quick estimates of implementation cost, potential operating cost savings, and simple payback periods are provided. A list of energy conservation measures (EC Ms, or energy conservation opportunities, ECOs) requiring further consideration is also provided. This level of detail, while not sufficient for reaching a final decision on implementing proposed measure, is adequate to prioritize energy-efficiency projects and to determine the need for a more detailed audit.

Considerable savings are possible through small improvements in the “house keeping” practices, and the cumulative effect of many such small efficiency improvements could be quite significant. These can be identified by a short survey, observation and measurements. Many energy conscious industries have already achieved considerable progress in this area.

Approach to Preliminary Energy Audit (PEA)

This essentially involves preliminary data collection and analyses. The PEA is based on collection of available data, analysis, observation and inference based on experience and judgment is carried out within a short time.

The PEA is the first step in implementing an energy conservation programme, and consists of essentially collecting and analyzing data without the use of sophisticated instruments. The ability and experience on the part of Energy Auditor will influence the degree of its success.

Normally the results of the audit would depend on:-

Experience of the auditor	Availability and completeness of data
Physical size of the facility	Depth of analysis of available data
Complexity of operations within the facility	Awareness of energy matters within the facility

Broadly, the audit is carried out in Six steps:-

1. Organize resources
    - Manpo wer/time frame

- Instrumentation

2. Identify data requirements
    - Data forms
3. Collect data
    a. Conduct informal interviews
        - Senior management
        - Energy manager/Coordinator
        - Plant engineer
        - Operations and production management and personnel
        - Administrative personnel
        - Financial manager
    b. Conduct plant walkthrough/visual inspection
        - Material/energy flow through plant
        - Major functional departments
        - Any installed instruments, including utility meters
        - Energy report procedures
        - Production and operational reporting procedures
        - Conservation opportunities
4. Analyze data
    a. Develop data base
        - Historical data for all energy suppliers
        - Time frame basis
        - Other related data
        - Process flo w sheets
        - Energy-consuming equipment inventory
    b. Evaluate-data
        - Energy use-consumption, cost and schedules
        - Energy consumption indices
        - Plant operations
        - Energy savings potential
        - Plant energy management program
        - Preliminary Energy Audit
5. Develop action plan
    - Conservation opportunities for immediate implementation
    - Projects for further study
    - Refinement of corporate energy
    - Resources for detailed energy audit
        - Systems for test
        - Instrumentation: portable and fixed
        - Manpo wer requirements
        - Time frame
6. Implementation
    - Implementation identified low cost/no cost projects
    - Perform detailed audit

The PEA is essentially, as the name implies a preliminary data collection and its analysis process. Readily available data on the plant's energy systems and energy –using processes or equipment are obtained and studied. The operation and condition of equipment are observed by going around the plant. These provides basis to develop recommendations for immediate short term measures and to provide quick and rough estimates of savings that are possible and achievable. A preliminary study usually

Identifies and assesses obvious areas for energy savings such as stream leaks, compressed air leaks, poor or miss ing insulation, condensate recovery, idling equipment, deterioration and deficiencies in combustion and heat transfer equipment etc. and serves to identify specific areas for the detailed plant energy study.

Detailed Energy Audit (DEA)

This would be a comprehensive energy study using portable energy monitoring instruments. The essential part of this audit is carrying out various measurements and analyses covering individually every significant energy consuming plant item/processes, to determine their efficiencies and loss of energy at that point, and potential energy savings.

The Detailed plant energy study is a comprehensive analyses and evaluation of all aspects of energy generation, distribution and utilization within plant. The analyses is based on consistent and detailed accounting of all energy inputs into a system and all energy outputs from a system which results in the development of energy and mass balance. At the plant level, the analyses require time series data on a daily, monthly, or yearly basis, on the quantities of all forms of primary energy flowing into the plant, e.g. coal, fuel, oil, electricity, etc. And production figures of major products, by-products and waste products, at the department or sectional level. Information is required on the quantity of energy forms consumed, and the production figures of intermediate products. At the equipment level, in addition to the quantities of energy forms and material products, process parameters such as temperature, pressure, flow rate, etc. are also required.

Data generation and collection is an essential and critical element of a detailed energy audit study. Difficulties in getting data required generally arise due to unavailability of historical records. The acquisition of actual operating data through existing or ne w permanently installed instruments or portable test instruments cannot be overemphasized in this context.

Measurements are critical in any serious effort to conserve energy. Apart from helping to quantify energy consumption, measurements also provide a means to monitor equipment performance and check equipment condition. Examples of measurements and instrument types are:

1. Flow/Velocity: Orifice plate, Picot tube, Ventura tube, Turbine meter, Vortex shedding flow meter
2. Temperature: Thermometers - Bimetallic, Resistance etc., Thermocouple, Radiation pyrometer.
3. Pressure: Bourdon gauge Diaphragm gauge, Manometers
4. Stack Gas Analysis: Orsat apparatus, Oxygen analyzers, Carbon dioxide analyzers, Carbon monoxide analyzers.
5. Heat flow: Thermography equipment

6. Electrical: Multimeter, Ammeter, Wattmeter, Power Factor meter, Light meter

7. Stream Trap Testing: Stethoscope, Ultrasonic Detector

The duration of DEA, studies depend on plant size and complexity. Whereas preliminary energy study can be carried out in a fe w days, the detailed study would require anywhere from few weeks to months to years of effort.

Long term approach

These are still short term solutions. The opportunities for improving the efficiency of energy use in the long term, ho wever, lie in applying techniques and technologies of conservation to ne w plants. Proper attention to the efficient use of energy at the design stage is vitally important.

General audit

The general audit (alternatively called a mini-audit, site energy audit or detailed energy audit or complete site energy audit) expands on the preliminary audit described above by collecting more detailed inf ormation about facility operation and by performing a more detailed evaluation of energy conservation measures. Utility bills are collected for a 12 to 36 month period to allo w the auditor to evaluate the facility's energy demand rate structures and energy usage profiles. If interval meter data is available, the detailed energy profiles that such data makes possible will typically be analyzed for signs of energy waste. Additional metering of specific energy-consuming systems is often performed to supplement utility data. In-depth intervie ws with facility operating personnel are conducted to provide a better understanding of major energy consuming systems and to gain insight into short and longer term energy consumption patterns. This type of audit will be able to identify all energy-conservation measures appropriate for the facility, given its operating parameters. A detailed financial analysis is performed for each measure based on detailed implementation cost estimates; site-specific operating cost savings, and the customer's investment criteria. Sufficient detail is provided to justify project implementation.

Invest ment-grade audit

In most corporate settings, upgrades to a facility's energy infrastructure must compete for capital funding with non-energy-related investments. Both energy and non-energy investments are rated on a single set of financial criteria that generally stress the expected return on investment (ROI). The projected operating savings from the implementation of energy projects must be developed such that they provide a high level of confidence. In fact, investors often demand guaranteed savings. The investment-grade audit expands on the detailed audit described above and relies on a complete engineering study in order to detail technical and economical issues necessary to justify the investment related to the transformations.

Simulation-based energy audit procedure for non-residential buildings

A complete audit procedure, very similar to the ones proposed by AS HRAE and Krarti (2000), has been proposed in the frame of the AUDITAC[10] and HARMO NAC[11] projects to help in the implementation of the EPB ("Energy Performance of Buildings") directive in Europe and to fit to the current European market.

The follo wing procedure proposes to make an intensive use of modern BES tools at each step of the audit process, from benchmarking to detailed audit and financial study:

- Benchmarking stage: While normalization is required to allo w comparison bet ween data recorded on the studied installation and reference values deduced from case studies or statistics. The use of simulation models, to perform a code-compliant simulation of the installation under study, allows assessing directly the studied installation, without any normalization needed. Indeed, applying a simulation-based benchmarking tool allows an individual normalization and allows avoiding size and climate normalization.

- Preliminary audit stage: Global monthly consumptions are generally insufficient to allow an accurate understanding of the building's behaviour. Even if the analysis of the energy bills does not allow identifying with accuracy the different energy consumers present in the facility, the consumption records can be used to calibrate building and system simulation models. To assess the existing system and to simulate correctly the building's thermal behaviour, the simulation model has to be calibrated on the studied installation. The iterations needed to perform the calibration of the model can also be fully integrated in the audit process and help in identifying required measurements and critical issues.

- Detailed audit stage: At this stage, on-site measurements, sub-metering and monitoring data are used to refine the calibration of the BES tool. Extensive attention is given to understanding not only the operating characteristics of all energy consuming systems, but also situations that cause load profile variations on short and longer term bases (e.g. daily, weekly, monthly, annual). When the calibration criteria is satisf ied, the savings related to the selected ECOs/EC Ms can be quantified.

- Investment-grade audit stage: At this stage, the results provided by the calibrated BES tool can be used to assess the selected ECOs/EC Ms and orient the detailed engineering study.

Specific audit techniques

Infrared thermography audit

The advent of high resolution thermography has enabled inspectors to identify potential issues within the building envelope by taking a thermal image of the various surfaces of a building. For purposes of an energy audit, the thermographer will analyze the patterns within the surface temperatures to identify heat transfer through convection, radiation, or conduction. It is important to note that the thermography ONLY identifies SURFACE temperatures, and analysis must be applied to determine the reasons for the patterns within the surface temperatures. Thermal analysis of a home generally costs between 300 and 600 dollars.

For those who cannot afford a thermal inspection, it is possible to get a general feel for the heat loss with a non contact infrared thermometer and several sheets of reflective insulation. The method involves measuring the temperatures on the inside surfaces of several exterior walls to establish baseline temperatures. After this, reflective barrier insulation is taped securely to the walls in 8-foot (2.4 m) by 1.5-foot (0.46 m) strips and the temperatures are measured in the center of the insulated areas at 1 hour intervals for 12 hours (The reflective barrier is pulled away from the wall to measure the temperature in the center of the area which it has covered.). The best manner in which to do this is when the temperature differential (Delta T) between the inside and outside of the structure is at least 40 degrees. A well insulated wall will commonly change approximately 1 degree per hour if the difference bet ween external and internal temperatures is an average of 40 degrees. A poorly insulated wall can drop as much as 10 degrees in an hour.

Pollution audits

With increases in carbon dioxide emissions or other greenhouse gases, pollution audits are now a prominent factor in most energy audits. Implementing energy efficient technologies help prevent utility generated pollution.

Online pollution and emission calculators can help approximate the emissions of other prominent air pollutants in addition to carbon dioxide.

Pollution audits generally take electricity and heating fuel consumption numbers over a t wo year period and provide approximations for carbon dioxide, VOCs, nitrous oxides, carbon monoxide, sulfur dioxide, mercury, cadmium, lead, mercury compounds, cadmium compounds and lead compounds.

ENERGY INDEX

Energy may be purchased in various units, for example, coal in tones; gas in ft^3, m^3, therms; oil in gallons, litres, tons, barrels etc. the relevant conversion units from one system to the other are given below:

Units and conversion factors.

General

1 short ton (ton) = 2000 lb
1 metric ton (tonne) = 1000 kg
1 ton = 0.907185 tonne
1 barrel = 42 U.S. gallons = 159.0 liters
1 barrel of crude oil ~ 0.136 tonne
1 square mile = 640 acres = 2.590 km^2
1 hectare = 10^{-2} km^2 = 2.471 acres

Energy units

1 calorie (thermochemical) = 4.184 J
1 calorie (15 °C) = 4.1858 J
1 calorie (IT) = 4.1868 J
1 calorie (mean) = 4.1900 J
1 Btu = 251.9958 calories
1 Btu (thermochemical) = 1054.35 J
1 Btu (59 °F) = 1054.80 J
1 Btu (IT) = 1055.06 J
1 Btu (mean) = 1055.87 J
1 kilowatt-hour (kWh) = 3.6 x 10^6 J
1 kilowatt-hour (kWh) = 3412 Btu (IT)
1 therm = 100,000 Btu
1 electron-volt = 1.6022 x 10^{-19} J

Large-scale units

1 quad = 10^9 MBtu = 10^{15} Btu
1 exajoule (EJ) = 10^{18} J

Assu med efficiency in electricity generation
(for calculating "primary energy")

Source	DOE/EIA	OECD/IEA
nuclear power	0.320	0.33
hydroelectric	0.332[a]	1.00
biomass	0.332[a]	
wind and solar	0.332[a]	1.00
geothermal	0.163	0.10

a. Set equal to efficiency for fossil fuels.

Heat content of fuels

	MBtu[a]	GJ[a]
Nominal equivalents:		
1 barrel of crude oil	5.80	6.12
1 tonne of crude oil	39.68	41.87
1 short ton of coal	25.18	26.57
1000 ft^3 of natural gas	1.000	1.055

1 terawatt-year (TWyr) = 8.76 x 10^{12} kWh

	Quad[a]	EJ
1 quad	1.000	1.055
1 EJ	0.948	1.000
1 TWyr (100% effic)	29.89	31.54
1 TWyr (33 % effic)	90.6	95.6
10^9 tonne coal equiv	27.76	29.29
10^9 barrel oil equiv	5.80	6.12
10^9 tonne oil equiv[b]	39.68	41.87
10^9 tonne oil equiv[c]	42.43	44.77

a. Based on IT Btu.
b. As used by OECD/IEA (Ref. 4).
c. As used in Ref. 6.

Average for U.S., 1995:

1 bbl petroleum prod	5.358	5.653
1 ton coal	20.852	22.000
1000 ft^3 of natural gas	1.028	1.085
1 bbl petroleum products:		
propane	3.836	4.047
aviation gasoline	5.048	5.326
motor gasoline	5.253	5.542
distillate fuel oil	5.825	6.146
residual fuel oil	6.287	6.633
Other:		
1 cord dry wood[b]	21.5	22.7
1 tonne ^{235}U[c]	8 x 10^7	8 x 10^7

a. 1 MBtu = 10^6 Btu (IT); 1 GJ = 10^9 J
b. 1 cord of dry wood = 1.25 ton
c. Ignoring n-capture in ^{235}U and ^{238}U.

Unit s of power

1 watt (W) = 1 J/sec
1 horsepo wer = 746 W
10^6 bbl of crude oil/day ~ 2.12 quad/yr

Exam ple 1:

An office block uses 40X10^3 gallons of fuel oil per year for heating purposes. The calorific value is 175 X10^3 Btu/gal. The fuel consumption may be expressed in litres or m^3.

40X10^3 gal = 40 X$10^3$4.545 litres = 182X10^3 litres = 182 m^3
The calorific value may be quoted as 10^3 J/L
175X10^3 Btu/gal = 175X10^3 X0.2321 X10^3 J/L = 40600X10^3 J/L = 40.6X10^9 J/L
The total theoretical heat available becomes:

(a) 40X10^3 gal X 175X10^3 Btu/gal = 7.00 X10^9 Btu/year
(b) 182X10^3 L X 40600X10^3 J/L = 7.39X10^{12} J/year
(c) 182 m^3 X 40.6 X10^9 J/L = 7.39 X10^{12} J/year

Exam ple 2:

Consider a company using three energy forms – oil, gas and electricity. The annual energy consumption is shown below in various energy units. Each of these energy types may be represented as a percentage of the total energy used and tabulated as an energy balance.

Energy type	Consumption	Energy	Energy (J)	Energy (Wh)
Oil	10X10^3 gal	1.775X10^9 Btu	1.872X10^{12}	0.520X10^9
Gas	5X10^3 therm	5X10^3 therm	0.526X10^{12}	0.146X10^9
Electricity	995X10^3 KWh	995X10^3 KWh	0.358X10^{12}	0.995X10^9
		Total	2.754X10^{12}	1.661X10^9

Note: Calorific value of oil: 18.3X10 Btu/lb; Density of fuel: 9.7 lb/gal

Percentage Energy Balance:

Energy Form	Percentage
Oil	67.9
Gas	19.1
Electricity	13.0
Total	100.0

Energy index is a useful parameter to monitor and compare energy consumption of specific products manufactured by the industry.Energy index is the figure obtained by dividing energy consumption by production output, and the index may be calculated weekly, monthly or annually. Although the total energy indices are sufficient for monitoring purposes, a record of the individual energy indices should be maintained. In the event of an increase or decrease (due to perhaps a conservation measure) in energy index, the particular source can be investigated immediately.

Exam ple 3:
If the company in Example 2 produces 100 $X10^3$ tons of a particular product, calculate the ebergy indices.

Oil energy index: $0.520X10^9$ Wh/$100X10^9$ = $5.20X10^3$ Wh/ton of product
Gas energy index: $0.146X10^9$ Wh/$100X10^9$ = $1.46X10^3$ Wh/ton of product
Electricity energy index: $0.995X10^9$ Wh/$100X10^9$ = $9.95X10^3$ Wh/ton of product
Total energy index: $1.661X10^9$ Wh/$100X10^9$ = $16.61X10^3$ Wh/ton of product

COST IN DEX

The cost index is another parameter which can be used to monitor and assess energy consumption by a company. The cost index is defined as the cost of energy divided by the production output. An individual cost index can be determined for each energy form and for the total energy consumption by the company.

Exam ple 1:
Table belo w sho ws energy costs for a company using coke, gas and electricity. This company produces $15X10^3$ tons per year. Calculate cost indices.

Energy Type	Consumption	Costs
Coke	$1.5X10^3$ (tons)	$108.0X10^3$
Gas	18 $X10^3$ (therms)	$3.6X10^3$
Electricity	1 $X10^9$ (Wh)	$22.5X10^3$
	Total	$134.1X10^3$

Coke cost index = 108.0 $X10^3$/15 $X10^3$ (tons) = 7.2/ton
Gas cost index = 3.6 $X10^3$/15 $X10^3$ (tons) = 0.2/ton
Electricity cost index = 22.5 $X10^3$/15 $X10^3$ (tons) = 1.5/ton
Total cost index = 134.1 $X10^3$/15 $X10^3$ (tons) = 8.9/ton

REPRESENTATION OF ENERGY CONSUMPTION

Several methods of representing energy flows and energy consumption are available and these may be graphical or tabular. Most popular among them are Pie chart and the Sankey diagram.

Pie Chart

Energy usage is plotted on a circular chart where the quantity of a particular type is represented as a segment of a circle. The size of the segment will be proportional to the energy consumption using a particular fuel (energy form or source) relative to total energy use. The energy units must be rationalized to the same units.

A **pie chart** (or a **circle graph**) is a circular chart divided into sectors, illustrating proportion. In a pie chart, the arc length of each sector (and consequently its central angle and area), is proportional to the quantity it represents. When angles are measured with 1 turn as unit then a number of percent is identified with the same number of centiturns. Together, the sectors create a full disk. It is named for its resemblance to a pie which has been sliced. The sizes of the sectors are calculated by converting between percentage and degrees or by the use of a percentage protractor. The earliest known pie chart is generally credited to William Playfair's Statistical Breviary of 1801.

The pie chart is perhaps the most widely used statistical chart in the business world and the mass media. However, it has been criticized, and some recommend avoiding it, pointing out in particular that it is difficult to compare different sections of a given pie chart, or to compare data across different pie charts. Pie charts can be an effective way of displaying information in some cases, in particular if the intent is to compare the size of a slice with the whole pie, rather than comparing the slices among them. Pie charts work particularly well when the slices represent 25 to 50 % of the data, but in general, other plots such as the bar chart or the dot plot, or non-graphical methods such as tables, may be more adapted for representing certain information.

Example

The following example chart is based on preliminary results of the election for the European Parliament in 2004. The table lists the number of seats allocated to each party group, along with the derived percentage of the total that they each make up. The value in the last column, the derived central angle of each sector, is found by multiplying the percentage by 360°.

Group	Seats	Percent (%)	Central angle (°)
EUL	39	5.3	19.2
PES	200	27.3	98.4
EF A	42	5.7	20.7
EDD	15	2.0	7.4
ELDR	67	9.2	33.0
EPP	276	37.7	135.7
UEN	27	3.7	13.3
Other	66	9.0	32.5
Total	732	99.9*	360.2*

*Because of rounding, these totals do not add up to 100 and 360.

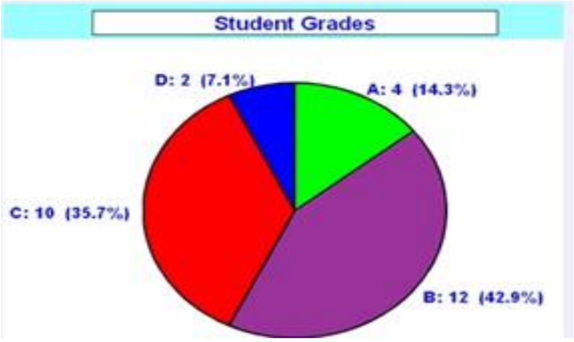
The size of each central angle is proportional to the size of the corresponding quantity, here the number of seats. Since the sum of the central angles has to be 360°, the central angle for a quantity that is a fraction Q of the total is $360Q$ degrees. In the example, the central angle for the largest group (European People's Party (EPP)) is 135.7° because 0.377 times 360, rounded to one decimal place(s), equals 135.7.

Exam ple: Stu dent Grades

Here is ho w many students got each grade in the recent test:

A	B	C	D
4	12	10	2

And here is the pie chart:



Pie Chart - A special chart that uses "pie slices" to show relative sizes of data.

Imagine you just did a survey of your friends to find which kind of movie they liked best.

Here are the results:

Table: Favorite Type of Movie				
Comedy	**Action**	**Romance**	**Drama**	**SciFi**
4	5	6	1	4

You could sho w that by this pie chart:

It is a really good way to show relative sizes: it is easy to see which movie types are most liked, and which are least liked, at a glance.

You can create graphs like that using our Data Graphs (Bar, Line and Pie) page.

Ho w to Make Them Yourself

First, put your data into a table (like above), then add up all the values to get a total:

Comedy	Action	Romance	Drama	SciFi	TOTAL
4	5	6	1	4	**20**

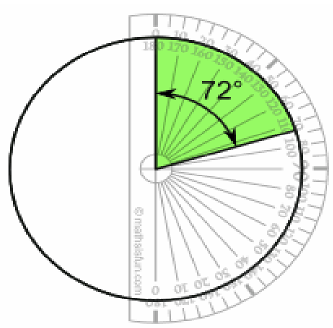
Next, divide each value by the total and multiply by 100 to get a percent:

Comedy	Action	Romance	Drama	SciFi	TOTAL
4	5	6	1	4	**20**
4/20 = **20%**	5/20 = **25%**	6/20 = **30%**	1/20 = **5%**	4/20 = **20%**	**100%**

Now you need to figure out how many degrees for each "pie slice" (correctly called a sector). A Full Circle has 360 degrees, so we do this calculation:

Comedy	Action	Romance	Drama	SciFi	TOTAL
4	5	6	1	4	**20**
4/20 = **20%**	5/20 = **25%**	6/20 = **30%**	1/20 = **5%**	4/20 = **20%**	**100%**
4/20 × 360° = **72°**	5/20 × 360° = **90°**	6/20 × 360° = **108°**	1/20 × 360° = **18°**	4/20 × 60° = **72°**	**360°**

Now you are ready to start drawing!
Draw a circle.
Then use your protractor to measure the degrees of each sector.



Sankey Diagram

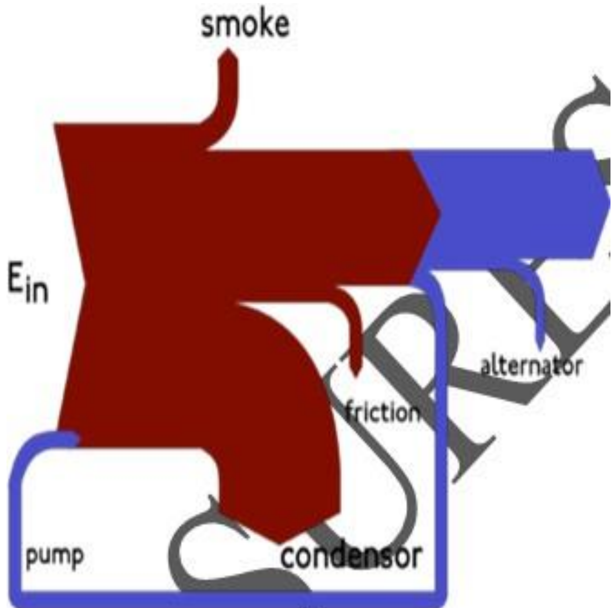
Sankey diagrams are a specific type of flow diagram, in which the width of the arrows is shown proportionally to the flow quantity. They are typically used to visualize energy or material or cost transfers between processes.

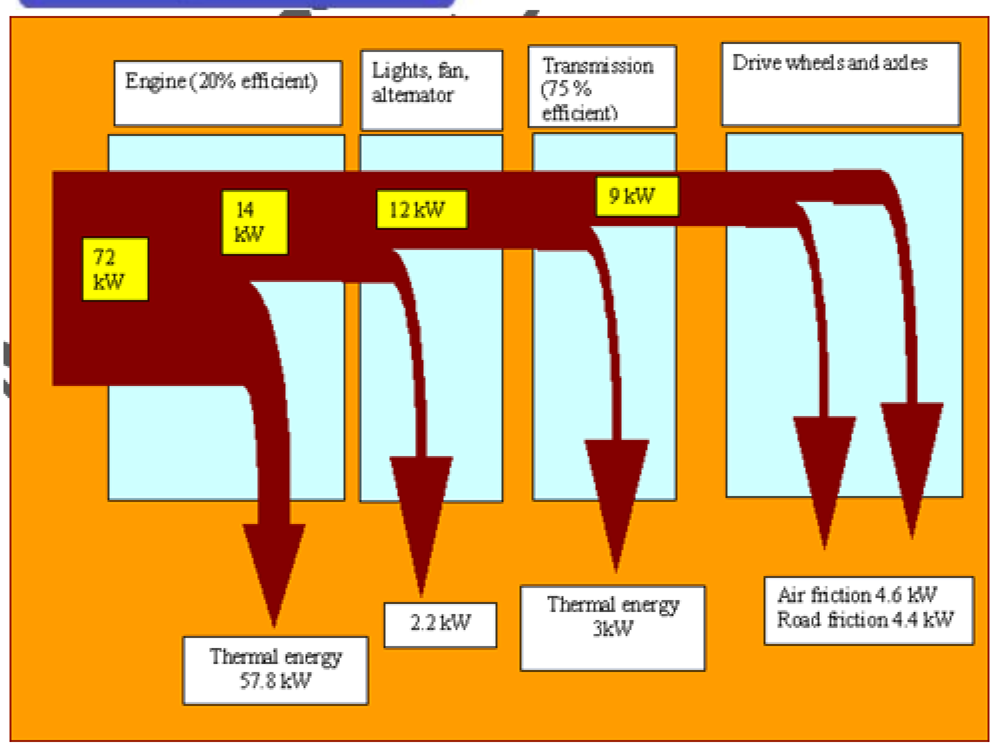
Applications

They are also commonly used to visualize the energy accounts or material flow accounts on a regional or national level. Sankey diagrams put a visual emphasis on the major transfers or flows within a system. They are helpful in locating dominant contributions to an overall flo w. Often, Sankey diagrams sho w conserved quantities within defined system boundaries, typically energy or mass, but they can also be used to show flows of non-conserved quantities such asexergy. Sankey Diagrams drop their arrows when energy is being used.

One of the most famous Sankey diagrams is Charles Minard's Map of Napolean's Russian Campaign of 1812. It is a flo w map, overlaying a Sankey diagram onto a geographical map. It was created in 1869.

Sankey diagrams are named after Irish Captain Matthew Henry Phineas Riall Sankey, who used this type of diagramin 1898 in a publication on the energy efficiency of a steam engine (see reproduction in[1], page 8). While the first charts in black and white were merely used to display one type of flow (e.g. steam), using colors for different types of flows has added more degrees of freedom to Sankey diagrams.

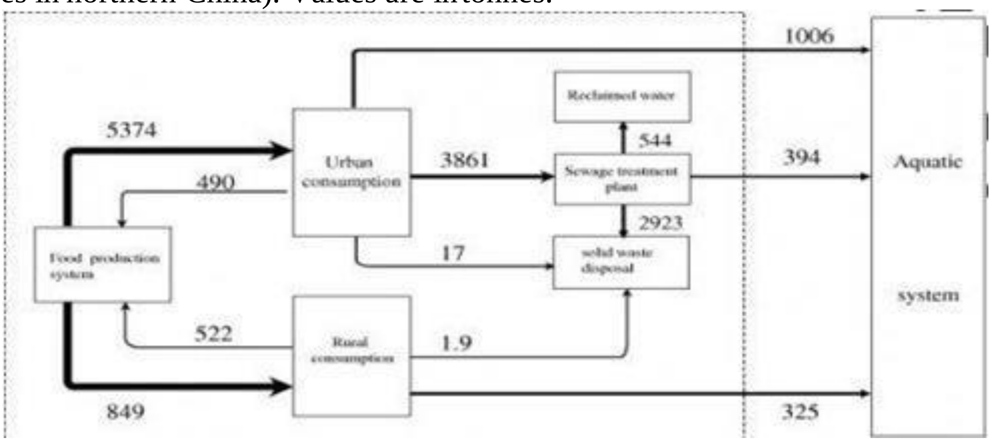




Show it with Sankey Diagrams

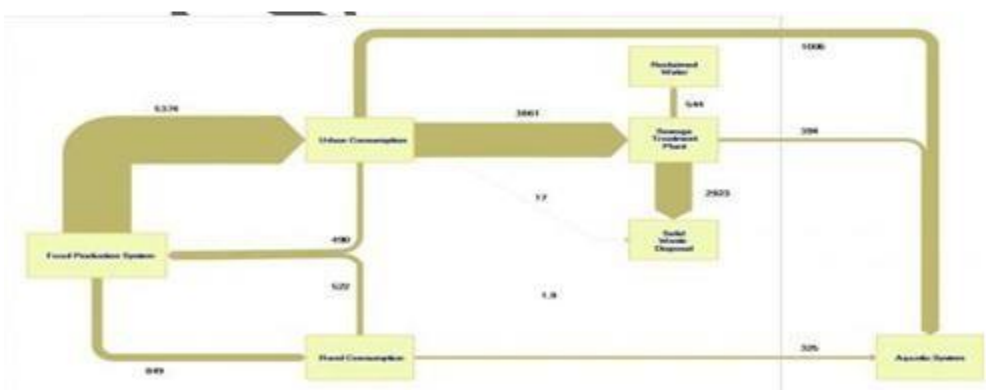
Phosporus in the natural environment and the food chain has been a topic of several posts on my blog. So it didn’t come as a surprise to find yet another diagram on phoshphorus flows over at Nels’s MFA Diagram blog (one of the blogs I follow closely, see blogroll).

MF A diagrams have their focus on the nodes and the build-up of stocks. Sometimes they get a touch of Sankey diagram with the arro ws having different magnitudes. The MF A diagram belo w is for phosphorous flo ws in China 2008 (original source: Min Qiao, Yuan- Ming Zheng, Yong-Guan Zhu, 2011. Material flo w analysis of phosphorus through food consumption in t wo megacities in northern China). Values are in tonnes.



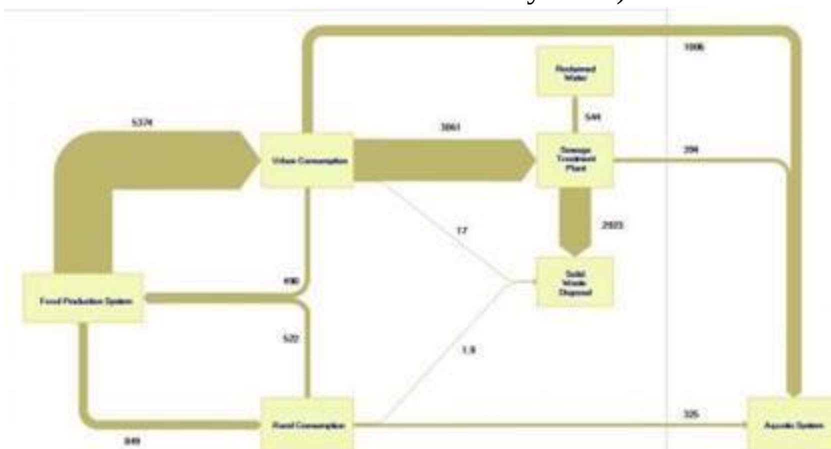
We can detect arrows with three different brush widths (my guess is 1px, 2px and 4 px), each standing for a value range into which the actual flow quantity falls. This may, ho wever, bes somewhat misleading when having a quick glance at the diagram.

I quickly “translated” the above diagram to a Sankey diagram with flo w values being actually to scale.



Here it is quite clear where the major phosphorus flows are located (from food production via urban consumption to se wage treatment plant and solid waste disposal: 2923 out of 5374 tons end up here). The other flo ws are comparatively small, with the phoshporous flow going directly to the aquatic system worth a mention. Two small flo ws in the center of the diagram are negligible, they are in fact so tiny in comparison to the major flows that they even don’t show up (or just as a hairline) here.

I have therefore added a minimum width of 1 px for small flows so that the annual 17 tons from urban consumption and the 1.9 tons from rural consumption to the solid waste disposal are at least visible (albeit not to scale with the other flows any more).

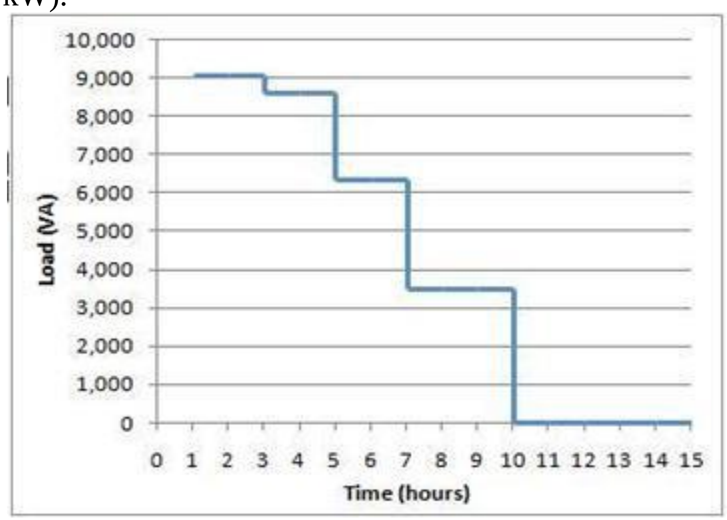


Load Profiles

Introduction

The energy load profile (hereafter referred to as simply "load profile") is an estimate of the total energy demanded from a power system or sub-system over a specific period of time (e.g. hours, days, etc). The load profile is essentially a two-dimensional chart showing the instantaneous load (in Volt-Amperes) over time, and represents a convenient way to visualize how the system loads changes with respect to time.

Note that it is distinct from the electrical load schedule - the load profile incorporates a time dimension and therefore estimates the energy demand (in kWh) instead of just the instantaneous load / power (in kW).



Why do the calculation?

Estimating the energy demand is important for the sizing of energy storage devices, e.g. batteries, as the required capacity of such energy storage devices depends on the total amount of energy that will be drawn by the loads. This calculation is also useful for energy efficiency applications, where it is important to make estimates of the total energy use in a system.

When to do the calculation?

A load profile needs to be constructed whenever the sizing of energy storage devices (e.g. batteries) is required. The calculation can be done once preliminary load information is available.

Calculation Methodology

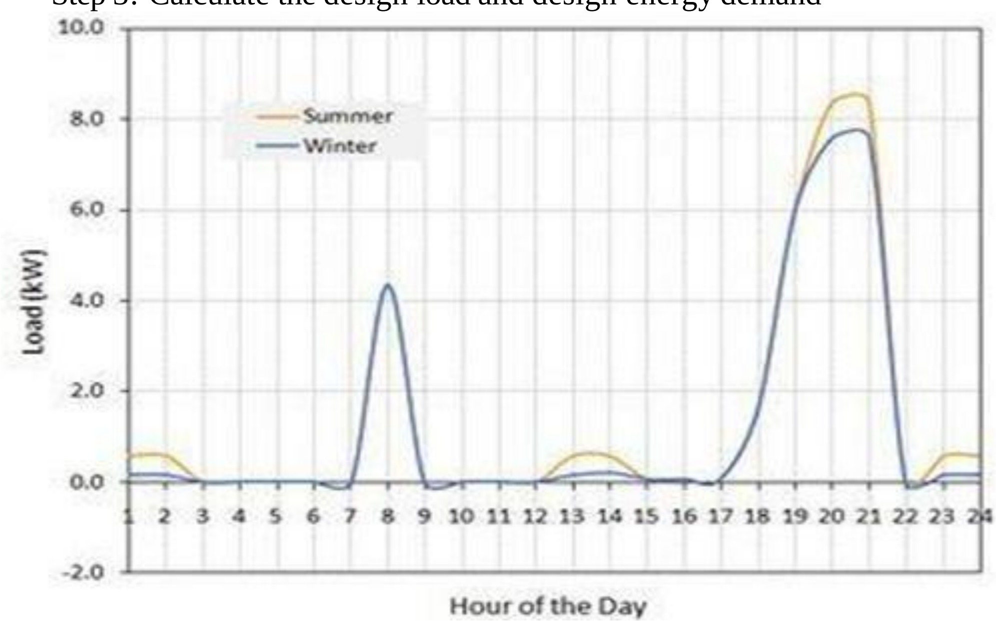
There are two distinct methods for constructing a load profile:

1) **Autonomy** method is the traditional method used for backup power applications, e.g. UP S systems. In this method, the instantaneous loads are displayed over an autonomy time, which is the period of time that the loads need to be supported by a backup power system in the event of a power supply interruption.

2) **24 Hour Profile** method displays the average or expected instantaneous loads over a 24 hour period. This method is more commonly associated with standalone power system applications, e.g. solar systems, or energy efficiency applications.

Both methods share the same three general steps, but with some differences in the details:

- Step 1: Prepare the load list
- Step 2: Construct the load profile
- Step 3: Calculate the design load and design energy demand



Step 1: Prepare the Load List

The first step is to transform the collected loads into a load list. It is similar in form to the electrical load schedule, but is a little simplified for the purpose of constructing a load profile. For instance, instead of categorizing loads by their load duty (continuous, intermittent or standby), it is assumed that all loads are operating continuously.

Ho wever, a key difference of this load list is the time period associated with each load item:

In the **autonomy method**, the associated time period is called the "autonomy" and is the number of hours that the load needs to be supported during a po wer supply interruption. Some loads may only be required to ride through brief interruptions or have enough autonomy to shut do wn safely, while some critical systems may need to operate for as long as possible (up to several days).

In the **24 hour profile** method, the associated time period is represented in terms of " ON" and "OFF" times. These are the times in the day (in hours and minutes) that the load is expected to be switched on and then later turned off. For loads that operate continuously, the ON and OFF time would be 0:00 and 23:59 respectively. A load item may need to be entered in t wice if it is expected to start and stop more than once a day.

Calculating the Consu med Load VA

For this calculation, we are interested in the consumed apparent power of the loads (in VA). For each load, this can be calculated as follo ws:

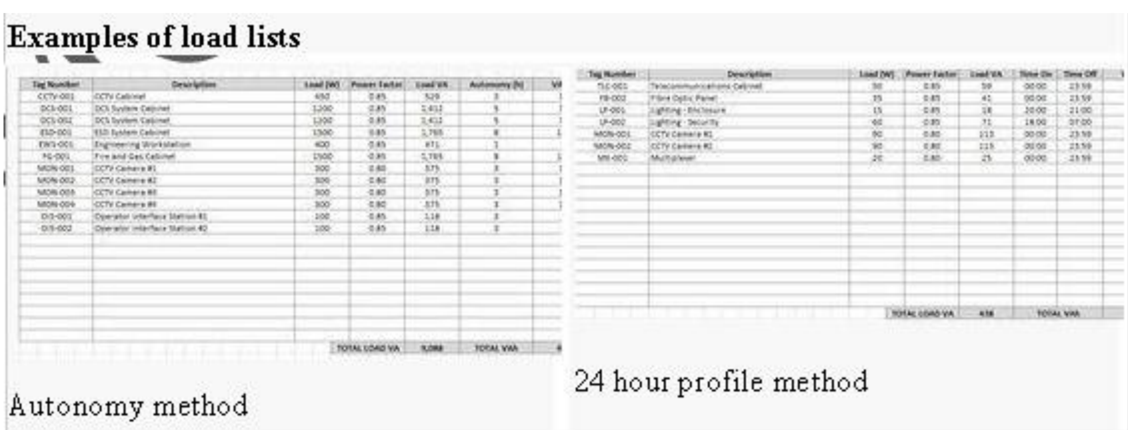
$$S_l = \frac{P_l}{\cos\phi \times \eta}$$

Where S_l is the consumed load apparent power (VA)

P_l is the consumed load power (W)

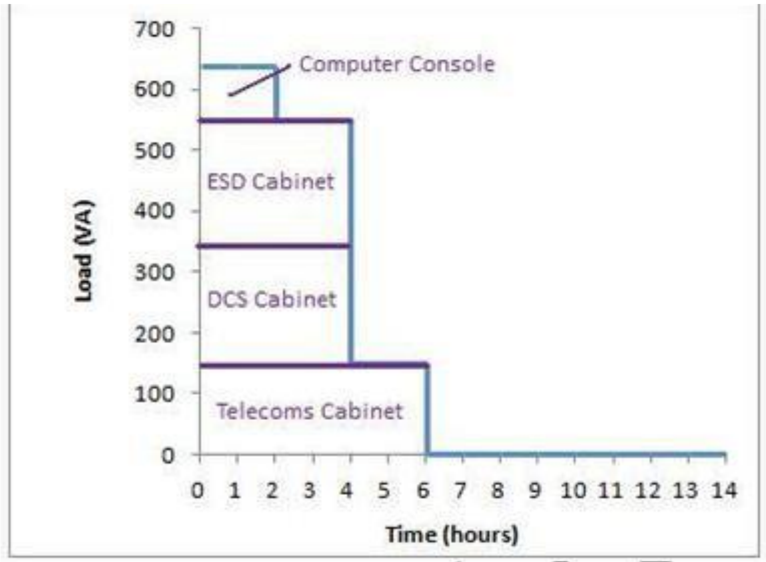
$\cos\varphi$ is the load power factor (pu)

η is the load efficiency (pu)



Step 2: Construct t he Load Profile

The load profile is constructed from the load list and is essentially a chart that sho ws the distribution of the loads over time. The construction of the load profile will be explained by a simple example:



Load profile constructed for this example

Suppose the following loads were identified based on the Autonomy Method:

De scription	Load (VA)	Autonomy (h)
DCS Cabinet	200	4
ESD Cabinet	200	4
Telecommunications Cabinet	150	6
Computer Console	90	2

The load profile is constructed by stacking "energy rectangles" on top of each other. An energy rectangle has the load VA as the height and the autonomy time as the width and its area is a visual representation of the load's total energy. For example, the DCS Cabinet has an energy rectangle of height 200 (VA) and width 4 (hours). The load profile is created by stacking the widest rectangles first, e.g. in this example it is the Telecommunications Cabinet that is stacked first.

For the 24 Hour method, energy rectangles are constructed with the periods of time that a load is energized (i.e. the time difference bet ween the ON and OFF times).

Step 3: Calculate Design Load and Energy Demand

De sign Load

The design load is the instantaneous load for which the po wer conversion, distribution and protection devices should be rated, e.g. rectifiers, inverters, cables, fuses, circuit breakers, etc. The design can be calculated as follo ws:

$$S_d = S_p(1 + k_g)(1 + k_c)$$

Where S_d is the design load apparent po wer (VA)

S_p is the peak load apparent power, derived from the load profile (VA)

k_g is a contingency for future load gro wth (%)

k_c is a design margin (%)

It is common to make considerations for future load gro wth (typically somewhere between 5 and 20%), to allow future loads to be supported. If no future loads are expected, then this contingency can be ignored. A design margin is used to account for any potential inaccuracies in estimating the loads, less-than-optimum operating conditions due to improper maintenance, etc. Typically, a design margin of 10 % to 15 % is recommended, but this may also depend on Client preferences.

Exam ple : From our simple example above, the peak load apparent po wer is 640VA. Given a future gro wth contingency of 10 % and a design margin of 10 %, the design load is:

VA

De sign Energy Demand

The design energy demand is used for sizing energy storage devices. From the load profile, the total energy (in terms of VAh) can be computed by finding the area underneath the load profile curve (i.e. integrating instantaneous power with respect to time over the autonomy or 24h period). The design energy demand (or design VAh) can then be calculated by the following equation:

Where E_d is the design energy demand (VAh)

is the total load energy, which is the area under the load profile (VAh)

is a contingency for future load gro wth as defined above (%)

is a design contingency as defined above (%)

Exam ple : From our simple example above, the total load energy from the load profile is 2,680VAh. Given a future growth contingency of 10 % and a design margin of 10 %, the design energy demand is:

$$E_d = 2,680 \times (1 + 0.1)(1 + 0.1) = 3,242.8 \text{ Vah}$$

Energy Conservation Schemes

Development of an energy conservation programme can provide savings by reduced energy use. Ho wever, it is economical to implement an energy conservation program only when savings can offset implementation cost over a period of time. Potential areas of conserving energy and a logical analysis of the methods or techniques of conservation would provide a systematic and disciplined approach to the entire conservation strategy as a sequel to the energy audit. Some established conservation trends are replacement, retrofit, process innovation, fuel conservation and co-generation.

It is generally considered that investment for energy conservation should be judged by exactly the same criteria as for any other form of capital investment. Energy conservation measures may be classified on an economic basis and fall into the follo wing three categories:

(a) **Short term**: These measures usually involve changes in operating practices resulting in little or no capital expenditure.
(b) **Medium term**: Low-cost modifications and improvements to existing equipment where the pay-back period is less than two years and often under one year.
(c) **Long term**: Modifications involving high capital costs and which frequently involve the implementation of new techniques and new technologies.

While the first two categories together can achieve savings of the order of 5 -10 %, capital expenditure using existing and new technology may achieve a further 10-15%. It is impossible to give a comprehensive list of all items in each category but selected examples are given for each section.

Short- term energy conservation schemes

Items in this group can be considered as a tightening of operational control and improved housekeeping.

(a) Furnace efficiencies: Greater emphasis should be placed on minimum excess combustion air. Oxygen levels of flue gases should be continually monitored and compared with target values. Oil burners must be cleaned and maintained regularly.

(b) Heat exchangers: In the case of heat where useful heat is transferred from product streams to feed streams, careful monitoring of performance should be carried out to determine optimum cleaning cycles. Frequency of cleaning will generally increase as a result, with consequent improved heat recovery.

(c) Good housekeeping: Doors and windo ws should be kept closed as much as possible during the heating season. Wear natural light is sufficient, do not use artificial light. Avoid excessive ventilation during the heating season. Encourage staff to wear clothing appropriate to the temperature of the working areas.

(d) Use of steam: Major steam leaks should be repaired as soon as possible after they occur: often a firm specializing in ‘on stream’ maintenance can be used. One crude distillation columns where live steam is used for stripping purposes, the amount required should be optimized and carefully controlled.

(e) Electrical po wer: In industries where all the electrical po wer is 'imported' conservation measures can reduce the annual electricity costs by 10–15 percent. Steam driven turbines may prove more economical as prime movers. Natural air cooling may be sufficient and therefore induced–draught fans may be taken out of commission. Pumping costs can sometimes be saved by utilizing gravity to move products from one tank to another. Where possible, use off-peak electricity.

Medium -term energy conse rvation sche mes
Significant savings in energy consumption are often available for quite modest outlays of
Capital based on a pay-back period of less than t wo years,

(a) Insulation: Improving insulation to prevent cold air leaking into the building and also, improving insulation thickness was determined at a time when fuel oil was **Rs 6** per tone and, consequently, at present fuel oil prices, optimum thicknesses have increased appreciably. In addition, in older plants lagging may have deteriorated to varying degrees. For an outlay of **Rs25000,** savings of **Rs60000** per annum were achieved.

    In all oil refinery the lagging on the process steam system was up rated to new optimum thicknesses and the **Rs20000** invested in the project was recouped within a year

(b) Heating Systems: Improving the time and temperature control of the heating systems in buildings should result in substantial energy savings.

(c) Replacing air compressors

(d) Instrumentation: To measure and control the energy conservation parameters, adequate instrumentation must be provided or operators will soon lose interest in maintaining efficiencies if they are working with inadequate an unreliable instruments.

(e) Process modifications: Many of these schemes will depend on the nature of the industry concerned, however, one general scheme will be considered. Steam condensate, if uncontaminated, may be used as boiler feed water. Improved condensate return systems can increase the amount recovered. The effect will be to increase the heat recovered in the condensate and at the same time reduce raw water and treatment costs.

    In one instance 10000 Kg/h of condensate was recovered for an investment of **Rs10000;** the pay-back time was less than six months.

(f) Burners: The control and amount of atomizing stream is important and often in furnaces and boilers the amount of atomizing steam is far in excess of design.
    In a hospital t wo fuel oil-fired boilers were examined and in some instances it was found that 1 kg steam/kg fuel oil was being utilized. The oil burners were replaced and the atomizing steam requirements are no w 0.1 kg steam/kg fuel oil. The pay-back for an outlay of **Rs12000** was ten months.

(g) Electrical Po wer Savings: Considerable savings may be made by adjusting the electrical power factor correction.

Capacitors were installed in one particular company at a cost of **Rs 10000**. The po wer factor was increased from 0.84 to 0.97 reducing the maximum demand level by over 14 percent. The pay-back time was nine months.
To increase plant capacity two feed pumps may be run in parallel to achieve the required feed rate. When replacement, for mechanical reasons, becomes necessary it is more economical to replace the pump by a single pump having a higher capacity.

Long-term energy conse rvation sche mes
To obtain further economics in energy consumption required the spending of significant amounts of capital, although, in many cases, the return on capital for the long-term investment may not be as good as that of the medium term. Full financial evaluation is needed, using the appraisal techniques discussed in Unit- V, to ensure the investment is economically viable.

(a) Heater modifications: The installation of heating tubes and air pre-heaters to extract more heat from furnace flue gases.
(b) Improved Insulation: Additional lagging of heated storage tanks. This type of project often comes within the medium-term group.
(c) Heat recovery: improved heat recovery in the processing areas by additional heat exchange schemes.

Many of the energy projects that have been outlined may be adopted by a wide variety of companies. However, some are more specific in their application and it is necessary to consider the contribution of energy costs to companies and energy usage by different industries.

The ABCs of Energy Conservation Schemes can be used as a checklist to identify the areas of deficiency and adopt the right approach for energy savings.

A	**B**	**C**
Adjustable frequency drives Ambient air reset controls Analysis of audit results	Balancing energy Blow-down controllers Break-even analysis	Co-generation Chiller optimization Copper fins in cooling/ heating
D	**E**	**F**
Demand control Delay monitoring and avoidance DDC management systems	Economizer control Efficient equipment selection Energy audit and analysis	Fenestration techniques Filter loading control Fan efficiency optimization
G	**H**	**I**
Glazing systems for heat gain Gas cooling General housekeeping	Heat energy tacking Heat recovery methods High efficiency criteria	Insulation Infiltration control Inspections
J	**K**	**L**
Job-task analysis Joint sealing and testing Justify retrofits	Kettle heat control kWh and kW reduction keg temperature control	Lighting Load calculation/shedding Life-cycle cost analysis
M`	**N**	**O**

Ma intenance Metering Monitoring	Non conventional methods Novel technologies Natural gas use	Occupancy sensors Optimization Over-rating avoidance

P	Q	R
Peak demand shaving Power factor corrections Pay-back period	Quality	Retrofits Return air systems Rate of return
S	**T**	**U**
Solar energy Steam traps Selection criteria	Time of day Thermostat settings Temperature control	U-values Utilities Utility meter close to site
V	**W**	**X,Y,Z**
Variable air volume boxes Variable supply air set point Voltage selection	water conservation waste heat recovery water treatment	XTMR losses Yearly cost and savings Zone controls

Measurements in energy audits

A home energy audit can help you find some surpris ing ways to save energy and money.

Conserving energy at home is a great idea for many reasons. It cuts do wn on energy costs, and because most of the energy we use comes from fossil fuels, using less is beneficial for the environment, too.

In many ways, saving energy can be pretty simple. You can find dozens of different ways to conserve — such as turning down your thermostat in the winter, putting a blanket on your water heater or switching to more efficient light bulbs. But most homes are so inefficient that even after you've done all the easy home improvements, there are still dozens of ways to save money and energy. How do you identify them all and then decide which to do first?

Unfortunately, the improvements that save you the most energy over time tend to be expensive. Before you spend hundreds — or even thousands — of dollars on home improvements, such as buying a new furnace, installing insulation or putting in new windo ws, it's nice to know ho w much energy they'll actually save. Just as important, you'll want to know ho w long these home energy upgrades will take to pay for themselves and start saving you money.
These questions aren't just for older homes — ne w homes often have significant energy problems, says Ken Riead of Hathmore Technologies in Independence, Mo. Riead is a home energy rater (one type of certification for home energy auditors). He trains other energy raters and has been working in the field of energy efficiency and rene wable energy since the 1970s.

"New houses typically aren't as solidly constructed as older houses," Riead says. "New homes can leak more air, causing health and comfort problems, and the quality of the wood and other building components can be poor. Insulation is often very sloppily installed and, in many cases, miss ing entirely."

A home energy audit can help, he explains. "Most homeowners aren't knowledgeable about ho w to look for these problems, nor ho w to properly correct them. Unless your home is an Energy Star home or has undergone energy testing, you will likely experience high energy bills and comfort problems, so it is well worth having an energy audit performed," Riead says.

Presentation of Energy Audit Results

10 ENERGY AUDIT REPORT

5 ENERGY AUDIT REPORT

The report should outline the objectives and scope of audit, description of characteristics and operational conditions of equipment/systems audited, findings in the audit, EMOs identified, corresponding savings and implementing costs, recommendations on EMO implementation and programme and any other follow-up actions.

This Section presents the suggested format for the report of a Detailed Audit. As the report is to suit for the need of the auditor, the auditor may choose to adopt the suggested format in whole or in part or adopt a totally different format. For Walk-through Audit, the auditor may trim down the report by deleting items not involved.

5.1 Executive Summary

The energy audit report provides the building management a quick overview of the scope of audit, EMOs identified, recommended actions justified by savings achievable and briefing on implementation plan. If there are EMOs of similar nature (e.g. replacement with electronic ballasts for lightings in different floors), they should be grouped under a common heading with cumulative savings shown. To draw the building owners' attention to the importance of implementing the EMOs, the cost of the estimated energy savings should be clearly identified.

5.2 Format of Energy Audit Report

5.2.1 Introduction

This part aims to describe the following topics:-

a) The building audited - numbers of floors, floor areas, usage, occupancy, hours of operation, year built, etc., layouts and schematics to be attached as appendix;
b) Objectives, such as studying the building energy consumption with a view to identifying EMOs for implementation, setting target savings, considering long term energy management programme, etc.;
c) Scope of audit, covering the installations to be studied such as HVAC Installation, Electrical Installation, Lift & Escalator systems, Plumbing & Drainage Systems or any particular equipment/systems, the depth of the study, the parties involved (end-user, building management, O&M personnel, etc.); and
d) Members of the audit team, and audit consultant employed, if any.

5.2.2 Description of Equipment/ Systems Audited

This part aims to focus on the following issues:-

a) Describe equipment/systems audited, their corresponding capacities and ratings, design conditions, etc., equipment schedules, schematics and layout drawings to be included as appendix.
b) Make use of information provided by the building management, O&M personnel and end-users and site surveys.
c) State the design conditions if known, and if not known the conditions adopted as base reference and calculations in the audit.

It should include the following contents:-

a) Zoning of systems according to building height or usage;
b) HVAC Installation for different areas –
type of system e.g. VAV, CAV, FCU, etc.; types of controls; type and numbers of chillers, pumps, heat rejection methods, etc. and their locations;
c) Lighting Installation –
type of lighting for different areas and type of control and zoning;
d) Electrical Installation –
numbers of transformers and low voltage main switchboards and their locations and size or ratings of main distribution cables/busducts;
e) Lift Installation and Escalator Installation –
capacity, zoning, quantity, floors/areas served and types of control, types of drive;
f) Plumbing and Drainage System;
g) Hot Water System –
type of system; and
h) Other notable energy consuming equipment/systems.

5.2.3 Findings

This part aims to focus on description of the results of the site surveys and should include:-

a) Findings in a systematic format such as in order of systems (e.g. first on HVAC Installation, then on Lighting Installation, etc.) or in order of floors (e.g. from lowest level to top floor), or in order of usage (e.g. general office, private office, common corridor, lift lobby, etc.);
b) Descriptions of floors/areas with special requirements (e.g. 24-hour operation, low space temperature for computer room, etc.);
c) Calculation on cooling load, heating load, lighting load, electrical load and annual energy consumption (detailed calculations should be included as appendix);
d) Findings on O&M procedures and practices; and
e) Preliminary identification of possible EMOs against corresponding findings.

The descriptions should focus on issues related to possible EMOs and provide systematic numbering to findings for purpose of easy cross-reference. **Appendix J** serves as references.

5.2.4 Analysis and Identification of Energy Management Opportunities

This part focuses on the detailed analysis and identification of EMOs and should include:-

a) Comparison on actual performances of equipment/systems against original design (if information available) and/or actual site measurements for any discrepancies and identify the causes thereof;
b) Possible EMOs and corresponding substantiations (calculations on achievable energy savings and detailed descriptions as appendix);
c) Implementation costs for EMOs (making reference to corresponding reference numbers assigned to the findings, detailed calculations, schematics and drawings included as appendix);
d) Comparison on the different solutions to the same EMOs, as appropriate;
e) Classification of the EMOs into categories (Cat. I, Cat. II or Cat. III);
f) Listing of EMOs in a systematic format such as in order of system (e.g. first on HVAC Installation, then on Lighting Installation, etc.) or in order of floors (e.g. from lowest level to top floor) or in order of usage (e.g. general office, private office, common corridor, lift lobby, etc.);
g) Programme for implementation of the EMOs;
h) Identification of areas for further study, if any;
i) Indication of parties concerned in the implementation of EMOs and the difficulties that may encounter and general methodologies to overcome them; and
j) Initial investment and payback of each EMO in the summary.

5.2.5 Recommendations

This part aims to focus on:-

a) The initial investment and payback period of each EMO.
b) The summary of recommendations in a systematic order.
c) Grouping items of similar nature/location/usage together or group according to their categories (Cat. I, Cat. II and Cat. III).

UNIT – II
ENERGY EFFICIENT MOTORS

Energy efficient motors, factors affecting efficiency, loss distribution, constructional details, characteristics – variable speed, variable duty cycle systems, RMS hp – voltage variation – voltage unbalance – over motoring – motor energy audit.

ENERGY EFFICIENT MOTORS:

Energy efficient motors (EEM) are the ones in which, design improvements are incorporated specifically to increase operating efficiency over motors of s tandard design (see figure). Design improvements focus on reducing intrinsic motor losses. Improvements include the use of lower-loss silicon steel, a longer core (to increase active material), thicker wires (to reduce resistance),thinner laminations, smaller air gap between stator and rotor, copper instead of aluminum bars in the rotor, superior bearings and a smaller cooling fans, etc.

Energy-efficient motors operate with efficiencies that are typically 4 to 6% higher than the standard motors. In keeping with the stipulations of the BIS, energy-efficient motors are designed to operate without loss in efficiency at loads between 75% and 100% of rated capacity. This may result in major benefits in varying load applications. The power factor is about the same or may be higher than for standard motors. Furthermore energy-efficient motors have lower operating temperatures and levels, greater ability to accelerate higher-inertia loads, and are less affected by supply voltage fluctuations.

Energy efficient motors cover a wide range of ratings and the full load efficiencies are higher by 3 to 7%. The mounting dimensions are also maintained as per IS1232 to enable easy replacement. As a result of the modifications to improve performance, the costs of energy-efficient motors are higher than those of standard motors by about 30%. The higher cost will often be paid back rapidly in saved operating costs, particularly in new applications or end-of-life motor replacements. In cases where existing motors have not reached the end of their useful life, the economics will be less positive.

Because the favorable economics of energy-efficient motors are based o savings in operating costs, there may be certain cases which are economically ill-suited to energy-efficient motors. These include highly intermittent duty or special torque applications such as hoists and cranes, traction drives, punch presses, machine tools and centrifuges.

In addition, energy efficient designs of multi-speed motors are generally not available. Further, energy-efficient motors are not yet available for many special applications, e.g. for flame-proof operation in oil-field or fire pumps or for very low speed applications (below 750 rpm). Also, most energy-efficient motors produced today are designed only for continuous duty cycle operation.

Given the tendency of over-sizing on the one hand and ground realities like: voltage, frequency variations, efficacy of rewinding in case of a burnout, on the other hand, benefits of EEMs can be achieved only by careful selection, implementation, operation and maintenance efforts of energy managers. Summary of energy efficiency improvements in EEMs is given in the following Table.

Energy Efficient Motors

Power Loss Area	Efficiency Improvement
1. Stator I^2R	Use of more copper and larger conductors increase cross sectional area of stator windings. This lowers resistance (R) of the windings and reduces losses due to current flow (I).
2. Rotor I^2R	Use of larger rotor conductor bars increase size of cross section, lowering conductor resistance (R) and losses due to current flow (I).
3. Iron	Use of thinner gauge, lower loss core steel reduces eddy current losses. Longer core adds more steel to the design, which reduces losses due to lower operating flux densities.
4. Friction & Windage	Use of low fan design reduces losses due to air movement.
5. Stray Load Loss	Use of optimized design and strict quality control procedures minimizes stray load losses.

Measures adopted for energy efficiency address each loss specifically as under:

FACTORS AFFECTING EFFICIENCY AND LOSS DISTRIBUTION

A fundamental issue that can affect a motor's energy usage is its suitability for the intended application. Motors are designed to operate most efficiently at their nameplate rating. The nameplate rating of the motor is commonly disregarded by motor users! Imagine in a sugar mill, their supply voltage is 480V but the nameplate voltages of motors are 440V, 460V, and 480V. No doubt 50% of their motor inventories were rewound. Selecting the wrong motor for a particular application or operating the motor outside its recommended parameters will decrease the motor's performance, introducing additional losses into the electrical system.

There are many factors affecting performance of AC motor that will affect its efficiency and will end-up burn motor windings. Restoring motor efficiency after rewound becomes a problem.

As long as nobody is given the responsibility for company-wide electric motor asset management, employees in the production environment will continue to act on an ad hoc basis, maintaining, repairing, and replacing motors in the same way they have in the past. The obvious driver for change usually escapes notice since the losses that are generated by a sub-optimal motor are scattered among different cost centers: energy consumption, material waste, lost revenue, extra working hours, reduced productivity, reduced production quality, et cetera. By assigning an individual — either inside the company or outsourced — to electric motor asset management, electric motors will receive the focus they deserve.

A. Motor Performance

There is a wealth of information about a motor's performance buried in the characteristics of the electrical signals at the motor's terminals. With the motor's nameplate data and these electrical characteristics, it is possible to quantify many energy savings opportunities for a given motor. The fundamental electrical characteristics include the voltage, current, and frequency data for each phase. By collecting data on these fundamental characteristics, monitoring devices can provide additional information needed to maximize energy savings including:

- Voltage variations
- Voltage unbalance
- Motor load (based on current)
- Total harmonic distortion
- Power Factor

B. Voltage Variance

Induction motors are at times operated on circuits of voltage other than those for which the motors are rated. Under such conditions, the performance of the motor will vary from the rating, as shown in Figure 2. The following are some of the operating results caused by small variation of voltage:

- Motor temperature
- Power factor
- Starting torque
- Slip

From Figure 2, a 10% voltage variation increase motor load by 2.5 – 3.5%, reduce efficiency by 1%, reduce power factor by 10%, and etc.

C. Voltage Unbalance

Voltage unbalance (including single phasing) is both a leading cause of motor failures and a major contributor to energy losses in motors. The subsequent current unbalances that result produce additional losses in the motor. The effect of unbalanced voltages on polyphase induction motors is equivalent to the introduction of a "negative sequence voltage" having a rotation opposite to that occurring with balanced voltages. This negative sequence voltage produces in the air gap a flux rotating against the rotation of the rotor, tending to produce high currents. The unbalance voltage is defined as:

The impacts of voltage unbalance are as follows:

- Increase in winding temperatures. The increase in winding temperature causes additional power losses and a significant drop in motor efficiency

• Increase vibrations and noise

D. Motor load

Motor load increases when there are stresses coming from bearing and unusual mechanical loads. 50% of machinery problems, electric motor in particular are caused by excessive load due to unbalance, misalignment, and belt tension. Figure 3, 4, and 5 showed the impact of misalignment to motor load.

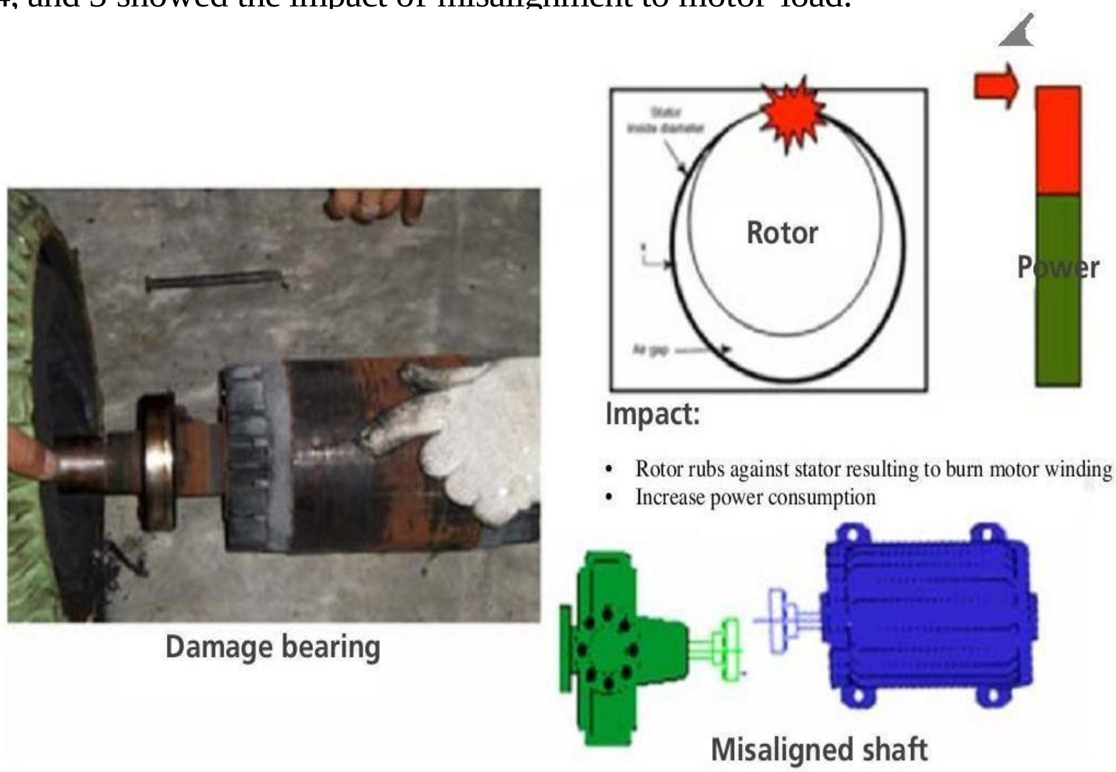


Figure 3 - Impact of misalignment in power consumption

Figure 4 - 97.9 watts is drawn by motor with aligned shaft. Courtesy of Rotating Equipment Specialists, LLC

Figure 5 - 122.1 watts is drawn by motor with misaligned shaft. Courtesy of Rotating Equipment Specialists, LLC

Other stresses such as: heat, power supply anomalies, humidity, and contamination work in conjunction with time to degrade components. Motors will survive for several hundred thousand operating hours when these stresses are minimized with the use of technologies to maintain the motor and its drive systems as well as well trained technical personnel.

E. Total Harmonic Distortions

Harmonic distortion is the change in the waveform of the supply voltage from the ideal sinusoidal waveform. It's caused by the interaction of distorting customer loads with the impedance of the supply network. Its major adverse effects are the heating of transformers, capacitors, induction motors, and the overloading of neutral conductors that are not rated to carry large currents. Therefore, monitoring Total Harmonic Distortion (THD) is very important to utilities.

F. Power Factor

The term power factor is defined as a ratio of the current drawn that produces real work to the total current drawn. Like most aspects of modern electrical systems, power factor is a complex issue intertwined with utility rate structures, economic consideration and system capacities.

Stator and Rotor I^2R Losses

These losses are major losses and typically account for 55% to 60% of the total losses. I^2R losses are heating losses resulting from current passing through stator and rotor conductors. I^2R losses are the function of conductor resistance and the square of current. Resistance of conductor is a function of conductor material, length and cross sectional area. The suitable selection of copper conductor size will reduce the resistance. Reducing the motor current is most readily accomplished by decreasing the magnetizing component of current. This involves lowering the operating flux density and possible shortening of air gap. Ro tor I^2R losses are a function of the rotor conductors (usually aluminum) and the rotor slip. Utilization of copper conductors will reduce the winding resistance. Motor operation closer to synchronous speed will also reduce rotor I^2R losses.

CORE LOSSES

Core losses are those found in the stator-rotor magnetic steel and are due to hysteresis effect and eddy current effect during 50 Hz magnetization of the core material. These losses are independent of load and account for 20-25% of the total losses.The hysteresis losses which are a function of flux density are reduced by utilizing low-loss grade of silicon steel laminations. The reduction of flux density is achieved by suitable increase in the ore length of stator and rotor. Eddy current

losses are generated by circulating current within the core steel laminations. These are reduced by using thinner laminations.

Friction and Windage Losses

Friction and windage losses result from bearing friction, windage and circulating air through the motor and account for 8-12% total losses. These losses are independent of load. The reduction in heat generated by stator and rotor losses permits the use of smaller fan. The windage losses also reduce with the diameter of fan leading to reduction in windage losses.

Stray Load-Losses

These losses vary according to square of the load current and are caused by leakage flux induced by load currents in the laminations and account for 4 to 5% of total losses. These losses are reduced by careful selection of slo t numbers, tooth/slot geometry and air gap.

Constructional Details

The efficiency of energy efficient motors is higher due to the following constructional features:

1. By increasing the amount of copper in the motor (≥60%) which reduces the resistance (Ohmic) loss in the winding & temperature rise. Performance improves because of increased thermal mass.
2. Use of more & thinner laminations of high quality motor steel reduces core losses in the stator and rotor.
3. Narrowing of air gap between stator and rotor increases the intensity of magnetic flux, thereby improving the motor ability to deliver the same torque at reduced power. Increasing the length of stator and rotor increases the net flux linkages in the air gap to the same effect.
4. More complex rotor bar designs enable good starting torque with efficient full speed operation.
5. Improved overall design reduces windage losses and stray loadlosses.

Applications

Energy efficient motors hold their efficiency better at part loads enhancing their advantage over standard motors. Economic benefits of installing energy efficient motors can be recognized in three situations:

- In a new applications (Plant expansion)
- In lieu of rewinding of failed motors
- Proactive replacement for in-service standard motors

Energy efficient motors are more cost effective than standard motors in the above cases. Efficient of EEMs is 4 – 6 % higher compared to the efficiency of standard motors.

Energy efficiency motors run cooler, and therefore have potentially longer life than their standard efficiency counterparts.

Characteristics – variable Speed, Variable Duty Cycle Diagrams

The single most potent source of energy savings in induction motor system lies not in the motor, but rather in the controls that govern its operation. Adjustable speed, intelligent controls and other ways of modifying or controlling motor behavior hold great promise for improving performance and efficiency in drive systems.

Need for using controls

Induction motors are well suited to single speed, constant output applications. However, there are large numbers of motor/ load/ system combinations where single speed operation does not efficiently meet the process requirements, usually due to two common factors.

- Oversized motor: motors are often oversized for their loads causing not only reduced efficiency, but also reduced power factor, and in many cases increased energy consumption in the load because of reduced slip.
- Varying Load: Many applications require modulated output from a motor/load/system. These systems are sized to provide the maximum output under the worst operating conditions, but rarely require this much flow (output). The excess energy is wasted, usually by some form of throttling.

Controlling motor speed to load requirements provides many benefits, including increased energy efficiency and improved power factor. Adjustable speed capability can significantly improve productivity of many manufacturing processes by reducing scrap, enabling quality manufacturing during transition times and allowing more control over start up and shut down.

Following are the benefits of VSDs:

- Matching motor and load to output
- Improved process precision
- Improved power factor
- Improved tool life
- Increased production & flexibility
- Faster response
- Extend operating range

- Electrical isolation
- Driving multiple motors
- Throttled load saving (throttling is the most energy inefficient operation)
- Cube-law load savings ($P \propto N^{3}$)

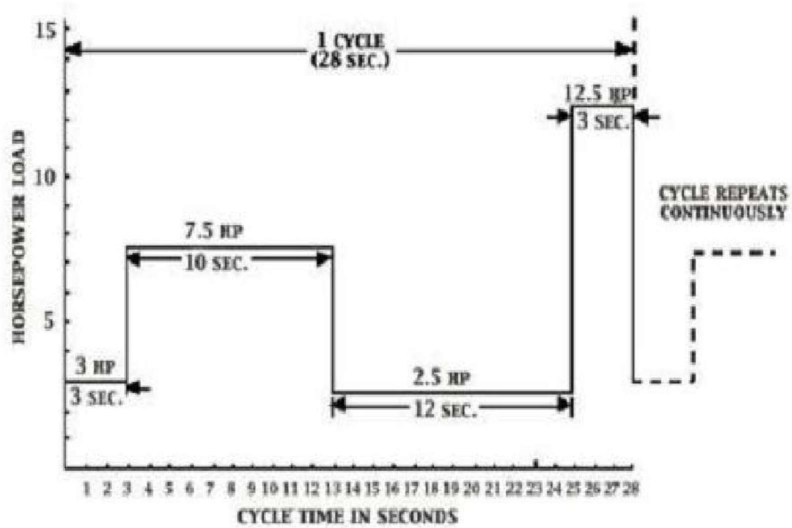
RMS HORSEPOWER LOADING

There are great applications especially in hydraulics and hydraulically-driven machines that have greatly fluctuating load requirements. In some cases, the peak loads last for relatively short periods during the normal cycle of the machine. At first glance, it might seem that a motor would have to be sized to handle the worst part of the load cycle. For example, if a cycle included a period of time where 18HP is required, then the natural approach would be to utilize a 20 HP motor. A more practical approach to these types of “duty cycle loads” takes advantage of an electric motor’s ability to handle substantial overload conditions as long as the period of overload is relatively short compared to the total time involved in the cycle.

The method of calculating whether or not the motor will be suitable for a particular cycling application is called the RMS (root mean squared) horsepower loading method. The calculations required to properly size a motor for this type of application are relatively simple.

The RMS calculations take into account the fact that heat buildup within the motors is very much greater at a 50% overload than it is under normal operating conditions. Thus, the weighted average horsepower is what is significant. RMS calculations determine the weighted average horsepower.

In addition to reducing the size and cost of a motor for a particular application,
RMS loading also helps improve the overall efficiency and power factor on a duty cycle-type load. For example, when an oversized motor is operated on a light load, the efficiency is generally fairly low. So working the motor harder (with a higher average horsepower) will generally result in improved overall efficiency and reduced operating cost. In order to use the RMS method of horsepower determination, the duty cycle has to be spelled out in detail as shown in the following example.



Step	Horsepower	Duration (seconds)
1	3	3
2	7.5	10
3	2.5	12
4	12.5	3
Repeats continuously.		

In order to determine the RMS loading for the previous cycle, we can use the formula:

$$\text{RMS HP} = \sqrt{\frac{HP_1^2 \times t_1 + HP_2^2 \times t_2 + HP_3^2 \times t_3 + HP_4^2 \times t_4 + \cdots HP_x^2 \times t_x}{t_1 + t_2 + t_3 + t_4 + \cdots t_x}}$$

The easiest way to approach this type of calculation is to make several columns as shown below and fill in the details underneath.

Step	Horsepower	HP^2	Duration (seconds)	HP^2 x Time
1	3.0	9.0	3	27.0
2	7.5	56.3	10	563.0
3	2.5	6.3	12	75.6
4	12.5	156.3	3	468.8
Total			28	1134.4

In this case, the total time of the cycle is 28 seconds and the summation of horsepower squared times time for the individual steps in the cycle is 1134.4. When inserted into the equation, the RMS horsepower comes out to be:

At first glance, it appears that a 7-1/2 HP motor would be adequate to handle the loading required by this duty cycle. One further check has to be made and that is to determine if the motor has adequate pullout torque (breakdown torque) to handle the worst portion of the duty cycle (12.5 hp load for 3 seconds) without stalling. In this case, one would have to refer to the manufacturer's data for the motor and determine the percent of pullout torque that is available.

VOLTAGE VARIATON AND VOLTAGE UNBALANCE

Voltage unbalance degrades the performance and shortens the life of a three-phase motor. Voltage unbalances at the motor stator terminals causes phase current unbalance far out of proportion the voltage unbalance. Unbalanced currents lead to torque overheating, which results in a shorter winding insulation life.

Voltage unbalance is defined by the National Electrical Manufacturers Association (NEMA) as 100 times the absolute value of the maximum deviation of the line voltage from the average voltage on a three-phase system, divided by the average voltage. For example, if the measured line voltages are 462,463, and 455 volts, the average is 460 volts. In this case, the voltage unbalance is:

$$(460-455)/ 460*100=1.1\%$$

It is recommended that the voltage unbalances at the motor terminals not exceed 1% Common causes of voltage unbalance include:

- Faulty operation of power factor correction equipment
- Unbalanced or unstable utility supply
- Unbalanced transformer bank supplying a three-phase load that is too large for the bank
- Unidentified single-phase to ground faults
- An open circuit on the distribution system primary

The efficiency of a rewound, 1800-RPM, 100-hp motor is given as a function of voltage unbalanced and motor load in the following table
The general trend of efficiency reduction with increased voltage unbalanced is observed for all motors at all load conditions.

Table: Motor efficiency under Conditions of voltage Unbalance

Motor Load %of Full	Motor Efficiency, %		
	Voltage Unbalance		
	Nominal	1%	2.5%
100	94.4	94.4	93.0
75	95.2	95.1	93.9
50	96.1	95.5	94.1

Voltage unbalance is probably the leading power quality problem that results in motor overheating and premature motor failure. If unbalanced voltages are detected, a thorough investigation should be undertaken to determine the cause. Energy and cost saving occur when corrective are taken.

Example:

Assume that the motor tested as shown in the above table was fully loaded and operated for 8000 hours per year, with an unbalanced voltage of 2.5%. With energy priced at $0.o5/kWh, the annual energy and cost saving, after corrective actions are taken, are:

Annual energy saving = 100 hp*0.746kw/hp*8000hrs/yrs x (100/93-100/94.4)
=**9517kwh**

Annual cost saving = 9517 kwh x $0.05/kwh=**$476**

Over all saving may be much larger because an unbalanced supply voltage may be power numerous motors.

OVER MOTORING
MOTOR ENERGY AUDIT

Five basic concepts of Energy conservation in Drive Power are as follows:

- Drive power is huge- **think big,**
- Motors are part of a system –**think systems,**
- Optimize the applications &process-**deliver service,**
- The further the downstream savings, the higher is the upstream benefits- **start downstream,**
- Pursue integration package of savings opportunities rather than isolated measures because many savings are inter –dependent –**integrate measures**

Energy Conservation in Electric Motors (load Equipment)

For improving the efficiency use of energy it is important to know the typical load on the motor over its duty cycle. It would be misleading to measure only the current drawn under load and draw conclusion. For example, a typical 25HP motor draws about 60% of its rated full load current when delivering on ly 45% of its rated output. Hence it is required to measure input power, current, voltage, power factor, frequency, and speed of operation.

- Collection of nameplate details of motor and load equipment
- Measurement of voltage, current, power, apparent power, power factor, frequency and annual operating hours for major loads.
- Calculation of load factor for major loads.
- Checking for light loads on large motors
- Check if valves are always used for flow control in pumps, fans and blowers.
- Check if flow from pumps, fans and blowers are changing continuously.
- Check if the set discharge pressure is at the lowest permissible limit of operation in the compressor.
- Check for proper maintenance of major equipment i.e. cleaning measuring temperature, dust, vibration, noise, lubrication and coupled condition.

Power Factor Correction at Motorend

As noted earlier, induction motors are characterized by power factors less than unity, leading to lower overall efficiency (and higher overall operating cost) associated with a plant's electrical systems. Capacitors connected in parallel (shunted) with the motor are typically used to improve the power factor. The impacts of PF correction include reduced KVA demand (and hence reduced utility demand charges), reduced I^2R losses in cables upstream of the capacitor (and hence reduced energy charges), reduced voltage drop in the cables (leading to improved voltage regulation), and in increase in the overall efficiency of the plant electrical system.

It should be noted that PF capacitor improves power factor from the point of installation back to the generating side. It means that, if a PF capacitor is installed at the starter terminals of the motor, it won't improve the operating PF of the motor, but the PF from starter terminals to the power generation side will improve the benefits of PF would be only on upstream side.

The size of capacitor required for a particular motor depends upon the no -load reactive KVA (KVAr) drawn by the motor, which can be determined only from no-load testing of the motor. In general, the capacitor is then selected to not exceed 90% of the no-load KVAr of the motor. Higher capacities could result in

Over-voltages and motor burn-outs. Alternatively, typical power factors of standard motors can provide the basic for conservative estimates of capacitor ratings to use for different size motors. The capacitor rating for power factor correction by direct connection to induction motors is shown in table.

Capacitor rating for power factor correction by Direct Connection of Induction Motors

Motor Rating (HP)	Capacitor rating (KVAr) for Motor Speed					
	3000	**1500**	**1000**	**750**	**600**	**500**
5	2	2	2	3	3	3
7.5	2	2	3	3	4	4
10	3	3	4	5	5	6
15	3	4	5	7	7	7
20	5	6	7	8	9	10
25	6	7	8	9	9	12
30	7	8	9	10	10	15
40	9	10	12	15	16	20
50	10	12	15	18	20	22
60	12	14	15	20	22	25
75	15	16	20	22	25	30
100	20	22	25	26	32	35
125	25	26	30	32	35	40
150	30	32	35	40	45	50
200	40	45	45	50	55	60
250	45	50	50	60	65	70

From the above, it may be noted that required capacitive kVAr increases with decrease in speed of motor, as the magnetizing current requirement of a low speed motor is more compared to the high speed motor for the same HP. Since a reduction in line current and associated energy efficiency gains are reflected backwards from the point of application of the capacitor, th e maximum improves in overall system efficiency is achieved when the capacitor is connected across the motor terminals, as compared to somewhere further upstream in the plant's electrical system. However, economies of scale associated with the cost of capacitors and the associated labor cost will place an economic limit on the lowest desired capacitor size.

POWER FACTOR IMPROVEMENT

Power factor – methods of improvement, location of capacitors, Pf with non linear loads, effect of harmonics on power factor, power factor motor controllers.

Definition

The power factor of an AC electric power system is defined as the ratio of the **active (true or real) power** to the **apparent power**

Where

- **Active (Real or True) Power** is measured in watts (W) and is the power drawn by the electrical resistance of a system doing useful work.
- **Apparent Power** is measured in volt-amperes (VA) and is the voltage on an AC system multiplied by all the current that flows in it. It is the vector sum of the **active** and the **reactive power.**
- **Reactive Power** is measured in volt-amperes reactive (VAR). Reactive Power is power stored in and discharged by inductive motors, transformers and solenoids

Reactive power is required for the magnetization of a motor but doesn't perform any action. The reactive power required by inductive loads increases the amounts of apparent power - measured in kilovolt amps (kVA) - in the distribution system. Increasing of the reactive and apparent power will cause the power factor - PF - to decrease.

It is common to define the Power Factor - PF - as the cosine of the phase angle between voltage and current - or the "cosφ".

Power factor is an important measurement in electrical AC systems because

- an overall power factor less than 1 indicates that the electricity supplier need to provide more generating capacity than actually required
- the current waveform distortion that contributes to reduced power factor is caused by voltage waveform distortion and overheating in the neutral cables of three-phase systems

Example - Power Factor

An industrial plant draws 200 A at 400 V and the supply transformer and backup UPS is rated

200 A × 400 V = 80 kVA.
If the power factor - PF - of the loads is only 0.7 - only
80 kVA × 0.7 = 56 kW

of real power is consumed by the system. If the power factor is close to 1 (purely resistive circuit) the supply system with transformers, cables, switchgear and UPS could be made considerably smaller.

Any power factor less than 1 means that the circuit's wiring has to carry more current than what would be necessary with zero reactance in the circuit to deliver the same amount of (true) power to the resistive load.

A low power factor is expensive and inefficient and some utility companies may charge additional fees when the power factor is less than 0.95. A low power factor will reduce the electrical system's distribution capacity by increasing the current flow and causing voltage drops.

"Leading" or "Lagging" Power Factors

Power factors are usually stated as "leading" or "lagging" to show the sign of the phase angle.

- With a purely resistive load current and voltage changes polarity in step and the power factor will be 1. Electrical energy flows in a single direction across the network in each cycle.
- Inductive loads - transformers, motors and wound coils - consumes reactive power with current waveform lagging the voltage.
- Capacitive loads - capacitor banks or buried cables - generates reactive power with current phase leading the voltage.

Inductive and capacitive loads stores energy in magnetic or electric fields in the devices during parts of the AC cycles. The energy is returned back to the power source during the rest of the cycles.

Typical Motor Power Factors

Power (hp)	**Speed (rpm)**	**Power Factor**		
		½ load	**¾ load**	**full load**
0 - 5	**1800**	**0.72**	**0.82**	**0.84**
5 - 20	**1800**	**0.74**	**0.84**	**0.86**
20 – 100	**1800**	**0.79**	**0.86**	**0.89**
100 - 300	**1800**	**0.81**	**0.88**	**0.91**

1 hp = 745.7 W

Methods of improvement

Power factor with Non-linear loads

A non-linear load on a power system is typically a rectifier (such as used in a power supply), or some kind of arc discharge device such as a fluorescent lamp, electric welding machine, or arc furnace. Because current in these systems is interrupted by a switching action, the current contains frequency components that are multiples of the power system frequency. Distortion power factor is a measure of how much the harmonic distortion of a load current decreases the average power transferred to the load.

Non-sinusoidal components

Non-linear loads change the shape of the current waveform from a sine wave to some other form. Non-linear loads create harmonic currents in addition to the original (fundamental frequency) AC current. Filters consisting of linear capacitors and inductors can prevent harmonic currents from entering the supplying system.

In linear circuits having only sinusoidal currents and voltages of one frequency, the power factor arises only from the difference in phase between the current and voltage. This is "displacement power factor". The concept can be generalized to a total, distortion, or true power factor where the apparent power includes all harmonic components. This is of importance in practical power systems that contain non-linear loads such as rectifiers, some forms of electric lighting, electric arc furnaces, welding equipment, switched-mode power supplies and other devices.

A typical multimeter will give incorrect results when attempting to measure the AC current drawn by a non-sinusoidal load; the instruments sense the average value of a rectified waveform. The average response is then calibrated to the effective, RMS value. An RMS sensing multimeter must be used to measure the actual RMS currents and voltages (and therefore apparent power). To measure the real power or reactive power, a watt meter designed to work properly with non-sinusoidal currents must be used.

LOCATION OF CAPACTIORS

Compensation can be carried out by a fixed value of capacitance in favorable circumstances. Sometimes compensation is more-commonly effected by means of an automatically controlled stepped bank of capacitors.

Note: when the installed reactive powers of compensation exceed 800kVAr and the load is continuous and stable, it is often found to be economically advantageous to install capacitor banks at high voltage.

Compensation at L.V:

At low voltage, compensation is provided by:

- Fixed-valued capacitor;
- Equipment providing automatic regulation or banks which allow continuous adjustment according to requirements, as loading of the installation changes.

Fixed Capacitors

This arrangement employs one or more capacitor (s) to form a constant level of compensation. Control may be:

- Manual: by circuit breaker or load-break switch;
- Semi-automatic : by contactor;
- Direct connection to an appliance and switched with it.

These capacitors are applied:

- At the terminals of inductive devices(motor and transformers)
- At bus bars supplying numerous small motors and inductive appliance for which individual compensation would be too expensive;
- In cases where the level of load is reasonable constant.

Automatic Capacitor Banks

This kind of equipment provides automatic control of compensation, maintain within close limits, a selected level of power factor. Such equipment is applied at points in an installation where the active power and/ or reactive -power variations are relatively large, for example:

- At the bus bars of a general power distribution board;

Power factor correction in non-linear loads

Passive PFC

The simplest way to control the harmonic current is to use a filter: it is possible to design a filter that passes current only at line frequency (50 or 60 Hz). This filter reduces the harmonic current, which means that the non-linear device now looks like a linear load. At this point the power factor can be brought to near unity, using capacitors or inductors as required. This filter requires large-value high-current inductors, however, which are bulky and expensive.

A passive PFC requires an inductor larger than the inductor in an active PFC, but costs less.
This is a simple way of correcting the nonlinearity of a load by using capacitor banks. It is not as effective as active PFC. One example of this is a valley-fill circuit.

Passive PFCs are typically more power efficient than active PFCs. Efficiency is not to be confused with the PFC, though many computer hardware reviews conflate them. A passive PFC on a switching computer PSU has a typical power efficiency of around 96%, while an active PFC has a typical efficiency of about 94%.

Active PFC

An "active power factor corrector" (active PFC) is a power electronic system that changes the wave shape of current drawn by a load to improve the power factor. The purpose is to make the load circuitry that is power factor corrected appear purely resistive (apparent power equal to real power). In this case, the voltage and current are in phase and the reactive power consumption is zero. This enables the most efficient delivery of electrical power from the power company to the consumer.

Some types of active PFC are:

- Boost
- Buck
- Buck-boost

Active power factor correctors can be single-stage or multi-stage.

In the case of a switched-mode power supply, a boost converter is inserted between the bridge rectifier and the main input capacitors. The boost converter attempts to maintain a constant DC bus voltage on its output while drawing a current that is always in phase with and at the same frequency as the line voltage. Another switch mode converter inside the power supply produces the desired output voltage from the DC bus. This approach requires additional semiconductor switches and control electronics, but permits cheaper and smaller passive components. It is frequently used in practice.

For example, SMPS with passive PFC can achieve power factor of about 0.7–0.75, SMPS with active PFC, up to 0.99 power factor, while a SMPS without any power factor correction has a power factor of only about 0.55–0.65.

Due to their very wide input voltage range, many power supplies with active PFC can automatically adjust to operate on AC power from about 100 V (Japan) to 230 V (Europe). That feature is particularly welcome in power supplies for laptops.

EFFECT OF HARMONICS

Harmonics distortion disrupts plants. Of greatest importance is the loss of productivity. These occur because of process shutdowns due to the unexpected failure of motors, drives, power supplies or just the spurious tripping of breakers. In addition, maintenances and repair budgets can be severely stretched.

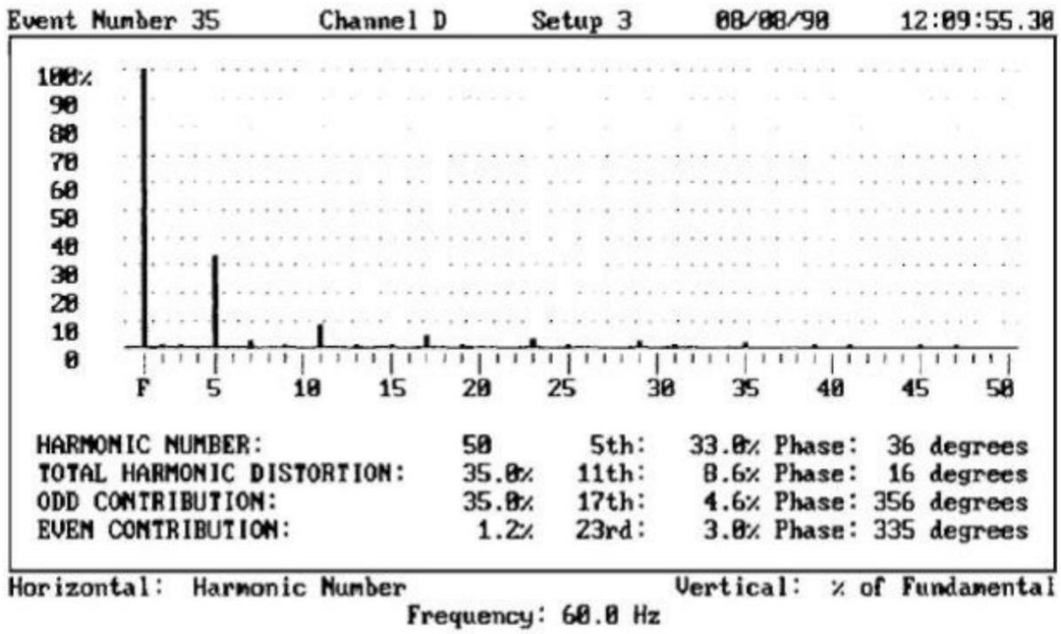
Table Effect of harmonics on various electrical equipment

EQUIPMENT	CONSEQUENCES
capacitors	blown fuses, Reduced capacitor life
Motors	Inability of fully load, mechanical fatigue reduced motor life
Fuses/ breakers	False/ spurious operation and damaged components
transformers	Increases copper and iron losses, reduced capacity, increased noise and possible insulation failure
Unility meters	Measurement errors/ higher billings
telephones	interference (low frequency hum, noise)
Drives/ power supplies	Miss-operation due to multiple zero crossing
Cables	Increased copper loss

PF MOTOR CONTROLLERS

Power factor can also be improved by using synchronous motors which can be operated at leading power factor to compensate for loads with lagging power. These synchronous motors are normally operated at no mechanical load and over-excitation. Synchronous motors re very expensive and are used only in few industries. Following problems (from JNTU previous years question papers) describe these applications.

In recent years, solid-state control devices have been developed that, when connected between a power source and an electric motor,



Event Number 35 Channel D Setup 3 08/08/90 12:09:55.30

Fnd:	54.27A	110 deg	18th:	0.1%	192 deg	35th:	1.7%	294 deg
2nd:	0.9%	85 deg	19th:	1.2%	75 deg	36th:	0.1%	240 deg
3rd:	1.2%	246 deg	20th:	0.1%	51 deg	37th:	0.6%	354 deg
4th:	0.4%	328 deg	21st:	0.5%	294 deg	38th:	0.1%	239 deg
5th:	33.0%	36 deg	22nd:	0.1%	241 deg	39th:	0.7%	237 deg
6th:	0.1%	100 deg	23rd:	3.0%	335 deg	40th:	0.1%	240 deg
7th:	2.5%	190 deg	24th:	0.1%	313 deg	41st:	1.2%	273 deg
8th:	0.2%	13 deg	25th:	1.1%	52 deg	42nd:	0.2%	217 deg
9th:	0.9%	327 deg	26th:	0.0%	100 deg	43rd:	0.4%	321 deg
10th:	0.1%	332 deg	27th:	0.6%	269 deg	44th:	0.0%	298 deg
11th:	8.6%	16 deg	28th:	0.1%	281 deg	45th:	0.7%	219 deg
12th:	0.2%	303 deg	29th:	2.3%	310 deg	46th:	0.1%	226 deg
13th:	1.3%	110 deg	30th:	0.2%	266 deg	47th:	1.0%	251 deg
14th:	0.1%	117 deg	31st:	0.8%	21 deg	48th:	0.1%	222 deg
15th:	0.7%	305 deg	32nd:	0.1%	350 deg	49th:	0.3%	273 deg
16th:	0.2%	285 deg	33rd:	0.6%	254 deg	50th:	0.0%	187 deg
17th:	4.6%	356 deg	34th:	0.2%	244 deg			

T.H.D.: 35.0% ODD CONTRIB.: 35.0% EVEN CONTRIB.: 1.2%

Frequency: 60.0 Hz

FIGURE Graphic and harmonic analysis of current of a DC motor drive.

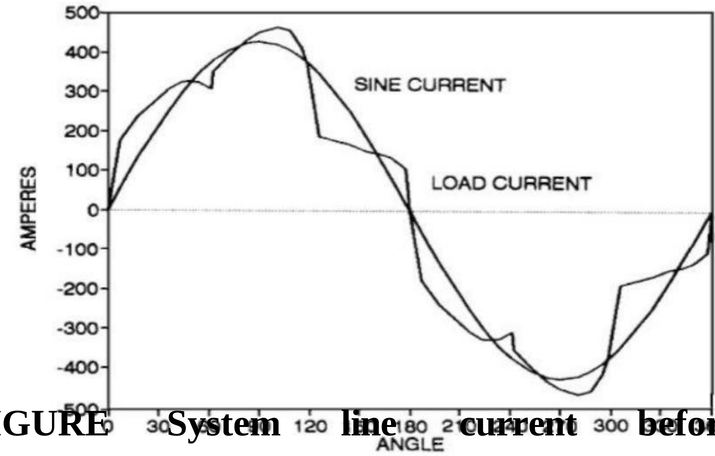


FIGURE System line current before harmonic suppression.

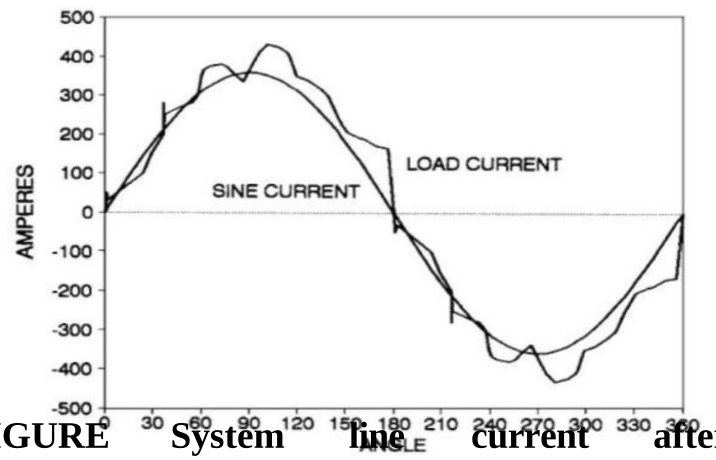


FIGURE System line current after harmonic suppression.

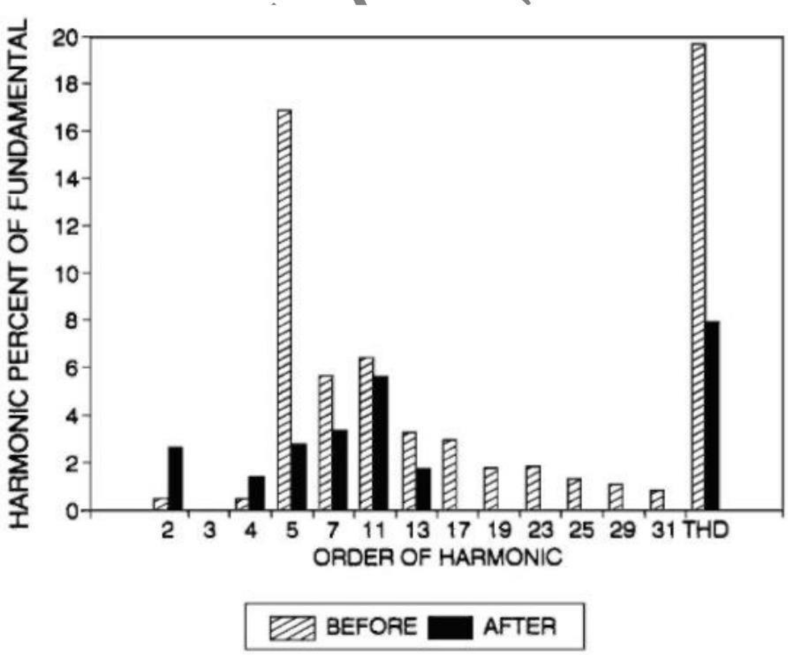


FIGURE System harmonic current comparison before and aft harmonic suppression.

FIGURE Single-phase power factor controller block diagram. Maintain an approximately constant power factor on the motor side of the controller. These devices are generally called power factor controllers. Most of the units are made under a license of U.S. Patent 4,052,648 issued to F. J. Nola and assigned to NASA.

The controller varies the average voltage applied to the motor as a function of the motor load and thus decreases the motor losses at light-load requirements.

Single-Phase Motors

For application to single-phase motors, the power factor controller consists of a triac, sensing and control circuits, and a firing circuit for the triac, as shown in Fig. The power factor controller sensing circuit monitors the phase angle between the voltage and current and produces a signal proportional to the phase angle. This signal is compared to a reference signal that indicates the desired phase angle. This comparison produces an error signal that provides the timing for firing the triac or SCR and causes the phase angle to remain constant when the load changes. Typical motor voltage and current waveforms are shown in Figs. If the phase angle increases, the control circuit adjusts the triac firing angle to decrease the average voltage applied to the motor. Conversely, if the phase angle decreases, the control circuit adjusts the firing angle of the triac to increase the average voltage applied to

The power factor of the motor is the cosine of the phase angle between the motor voltage and current. Therefore, with this control system, by maintaining the phase angle constant, the motor operates at an approximately constant power factor over the load range. The maximum power factor is the power factor of the motor at the rated load with the triac full on. The minimum power factor will be determined by the minimum voltage setting for no-load operation. This voltage setting must be high enough to provide stable operation and prevent the motor from stalling on the sudden application of load. However, the lower the no-load voltage, the higher the power savings at no load.How are power savings achieved by decreasing the motor voltage at light loads? The motor losses can be grouped into three categories:

1. Constant losses, such as friction and windage
2. Magnetic core losses, which are some function of the applied voltage
3. I2R losses, which are a function of the square of the motor current, includ ing rotor losses

For a given load condition, the net losses, and hence the motor power input, decrease with a decrease in voltage as long as the magnetic core losses decrease more than the I2R losses increase. In addition, there is some increase in losses due to harmonics added to the motor input voltage by the triac switching and the losses in the controller.

In some instances, the increased harmonic content of the input voltage will result in increased motor noise.

The amount of power saved with a power factor controller depends on the duty cycle of the application. Typical power savings under various loads and duty cycles are shown in Fig. 4.24. The power savings are shown as a percent of the full voltage input and as a function of the percent running times at full load versus running at a light load. To result in significant power savings, at least 50%

Single-phase power factor motor controller power savings. of the running time should be at one-fourth load or less. Typical applications of this type may be drill presses and cutoff saws used in production processes. Figure 4.22 shows an oscilloscope picture of the motor voltage and current at no load for a single motor controlled by a power factor controller. Figure 4.23 shows an oscilloscope picture of the motor voltage and current of the same motor with load applied to the motor. Note the constant angle between the zero crossing of the voltage and current in both cases.

Three-Phase Motors

More recently, the application of power factor motor controllers has been extended to three-phase motors. In some cases, this has been accomplished by adding a power-saver module to existing

Three-phase power factor motor controller block diagram. solid-state three-phase motor controllers. These solid-state controllers generally include other features such as current limit, timed acceleration, phase unbalance,

undervoltage, and overload protection. The power factor control function is accomplished by sensing the phase angle between the motor voltage and current. This signal is fed back and compared with a reference, and the difference is used to feed the input signal voltage to the SCRs in the power module.

The feedback voltage from the power factor sensing circuit will change the average voltage applied to the motor in accordance with the load on the motor. This reduces both the motor current and voltage under light-load conditions. The circuit is designed to react to load changes to prevent stalling of the motor on instantaneous load changes. Most of the controllers have provisions for setting the minimum no-load voltage; this voltage is generally 65% of rated full voltage. Figure 4.25 is a typical block diagram for the three-phase controller. The three-phase power factor controllers have potential applications in which the duty cycle for the motor is varying from light or no load to full load as a step function. Examples of potential applications are ripsaws, conveyors, rock crushers, and centrifuges.

The potential power saving when a power factor controller is an applied to a three-phase motor is substantially lower than whe such a controller is applied to a single-phase motor. Figure 4.26 illustrates the power saving when the controller is applied to a three-phase motor for various duty cycles and loads. These curves depend on the ratio of the no-load losses of the motor. However, it appears that the power factor controller shows significant power savings only on those three-phase motor applications in which the motor operates at no load or light loads over 75% of the operating time. To apply a power factor controller properly, the load characteristics, motor characteristics, and load cycle must be known. In addition, one must determine how the controller-motor combination will respond to the load cycle. Only then can the potential power saving and economic payback analysis be made.

UNIT III
LIGHTING AND ENERGY INSTRUMENTS

Good lighting system design and practice, lighting control, lighting energy audit – Energy Instruments – watt meter, data loggers, thermocouples, pyrometers, lux meters, tongue testers, application of PLC's

GOOD LIGHTING SYSTEM DESIGN AND PRACTICE

Lighting is an essential service in all the industries. The power consumption by the industrial lighting varies between 2 to 10% of the total power depending on t he type of industry. In hotels, lighting consumes up to 30% of total electrical energy. Innovation and continuous improvement in the field of lighting has given rise to tremendous energy saving opportunities in this area.
Lighting is an area, which provides a major scope to achieve energy efficiency at the design stage, by incorporating modern energy efficient lamps, luminaries and gears, apart from good operational practices.

Basic Terms in Lighting System and Features

A. Lamps
Lamp is equipment, which produces light. The most commonly used lamps are described briefly as follows:

- **Incandescent lamps:**

Incandescent lamps produce light by means of filament heated to incandescence by the flow of electric current through it. The principal parts of an incandescent lamp, also known as GLS (General Lighting Service) lamp include the filament, the bulb, the fill gas and the cap.

- **Reflector Lamp:**

Reflector lamps are basically incandescent, provided with a high quality internal mirror, which follows exactly the parabolic shape of lamp. The reflector is resistant to corrosion, thus making the lamp maintenance free and output efficient.

- **Gas discharge lamps:**

The light from a gas discharge lamp is produced by the excitation of gas contained in either a tabular or elliptical outer bulb.

The most commonly used discharge lamps are as follows:

1) Fluorescent tube lamps (FTL)
2) Compact Fluorescent Lamps (CFL)
3) Mercury Vapor Lamps (HPMV)

4) Sodium Vapor Lamps (HPSV)
5) Metal Halide Lamps

B. luminaire:

Luminaire is a device that distributes filters or transforms the light emitted from one or more lamps. The luminaire all the parts necessary for fixing and protecting the lamps, except the lamps themselves. In some cases, luminaires also include the necessary circuit auxiliaries, together with the means for connecting them to the electric supply. The basic physical principles used in optical luminarie are reflection, absorption, transmission and refraction.

C. Control gear

The gears used in the lighting equipment are as follows:

- **Ballast**

The current limiting device, to counter negative resistance characteristics of any discharge lamps. In case of fluorescent lamps, it aids the initial voltage build-up for starting.

- **Igniters:**

These are used for starting high intensity Metal Halide and Sodium vapor lamps.

D. ILLUMINANCE:

This is the quotient of the luminous flux incident on a element of the surface at a point of surface containing the point, by the area of that element. The light ing level produced by a lighting installation is usually qualified by the illuminance produced on a specified plane. In most, cases this plane is the major plane of the tasks in the interior and is commonly called the working plane. The illuminance provided by an installation affects both the performance of the tasks and the appearance of the space.

F. Lux (lx)

This is the illuminance produced by a luminous flux of one lux, uniformly distributed over a surface area of one square meter. One lux is equal to one luen per square meter.

G. Luminous Efficacy (Im/W)

This is the ratio of luminous flux emitted by a lamp to the power consumed by the lamp. It is a reflection of efficiency of energy conversion from electricity to light form.

H. Color Rendering Index (RI)

Is a measure of the degree to which the colors of surfaces illuminated by a given light source confirm to those of the same surfaces under a reference illuminant; suitable allowance having been made for the state of Chromatic adaptation.

Data Loggers

Introduction

What is data logging?
It is the process of using a computer to collect data through sensors, analyze the data and save and output the results of the collection and analysis.

Data logging is commonly used in scientific experiments and in monitoring systems.

DATA LOGGER

A data logger (also data logger or data recorder) is an electronic device that records data over time or in relation to location either with a built in instrument or sensor or via external instruments and sensors.

They generally are small, battery powered, portable and equipped with a microprocessor, internal memory for data storage and sensors.

Some data loggers interface with a personal computer and utilize software to activate the data logger and view and analyze the collected data, while others have a local interface device (keypad, LCD) and can be used as a stand-alone device.

The sensors may communicate with the logger through a cable or wireless link and m ay sense temperature, humidity pressure flow, wind speed, current, voltage, resistance and most of other physical parameters that are important in monitoring and controlling processes.

One of the primary benefits of using data loggers is the ability to automatically collect data on a 24-hour basis.

DATA LOGGING Vs DATA ACQUISITION

The term data logging and data acquisition are used interchangeably.
However in historical context they are quite different.
A data logger is a data acquisition system, but a data acquisition system is not necessarily a data logger.
Data loggers typically have slower sample rates.

APPLICATIONS

Soil moisture level recording.
Road traffic counting
Vehicle testing
Monitoring of relays status in railway signaling

THERMOCOUPLES

Introduction

In electrical engineering and industry, thermocouples are widely used temperature sensors.
They are cheap and interchangeable standard connectors, and can measure a wide range of temperatures.

Thermocouples alloys are commonly available as wires.

What is thermocouple sensor?
A thermocouple is a thermocouple device used to measure temperatures accurately.
It consists of two dissimilar metals having different thermal and electrical properties joined together at one end so that potential difference generated between the contact points measures the temperature.

Principle of operation:
The principle is that when one junction is heated, an EMF is produced causing a current to flow round the loop. The EMF generated is given by $\log E = A \log t + B$

Where t = temperature and A& B are constants depending upon the wires forming the junction.

Thermocouples Types:

A Thermocouple is available in different combinations of metals or calibrations.
The four most common calibrations are J, K, and T & E.
The high temperature calibrations are R, S, and C & GB.
Other types of Thermocouples include beaded wire Thermocouple & Thermocouple probe.

How do we choose a Thermocouple type?
Thermocouples are very often used in industry as they are simple & can be used to measure wide range of temperatures

The following criteria are used in selecting a thermocouple:

Temperature range
Chemical resistance of thermocouple (or) sheath material.
Vibration resistance
Installation requirements.

Type K

Type K (chromel {90% nickel and 10% chromium}—alumel {95% nickel, 2% manganese, 2% aluminium and 1% silicon}) is the most common general purpose thermocouple with a sensitivity of approximately 41 µV/°C, chromel positive relative to alumel.[9] It is inexpensive, and a wide variety of probes are available in its −200 °C to +1250 °C / -330 °F to +2460 °F range. Type K was specified at a time when metallurgy was less advanced than it is today, and consequently characteristics may vary considerably between samples. One of the constituent metals, nickel, is magnetic; a characteristic of thermocouples made with magnetic material is that they undergo a deviation in output when the material reaches its Curie point; this occurs for type K thermocouples at around 350 °C. Wire color standard is yellow (+) and red (-).

It is the most commonly used for general purpose thermocouples.
It is inexpensive and available in wide variety or probes.
They are available in -200^{0}C to 1350^{0}C range.

Type E

Type E (chromel–constantan) has a high output (68 µV/°C) which makes it well suited to cryogenic use. Additionally, it is non-magnetic. Wide range is −50 to 740 °C and Narrow range is −110 to 140 °C. Wire color standard is purple (+) and red (-).
It has high output (68µv/^{0}C) which makes it well suited for no. of applications.

Type J

Type J (iron–constantan) has a more restricted range than type K (−40 to +750 °C), but higher sensitivity of about 55 µV/°C. The Curie point of the iron (770 °C) causes an abrupt change in the characteristic, which determines the upper temperature limit. Wire color standard is white (+) and red (-).
It is less popular than K due to its limited range (-40^{0}C to 750^{0}C)

Type T

Type T (copper – constantan) thermocouples are suited for measurements in the −200 to 350 °C range. Often used as a differential measurement since only copper wire touches the probes. Since both conductors are non-magnetic, there is no Curie point and thus no abrupt change in characteristics. Type T thermocouples have a sensitivity of about 43 µV/°C.
It is available in the range of -200^{0}C to 350^{0}C.

COMMON THERMOCOUPLE TEMPARATURE RANGES

Calibration	Temperature range	Standard. limits of error	Specific. Limits of error
J	0 C to 750 C	Greater than 2.2 C	Greater than 1.1 C
K	-200 C to 1250 C	Greater than 2.2 C	Greater than 1.1 C
E	-200 C to 900 C	Greater than 1.7 C	Greater than 1.0 C
T	-250 C to 350 C	Greater than 1.0 C	Greater than 0.5 C

Advantages & Disadvantages

Advantages

1. These are cheaper than the resistance thermometers.
2. These are very convenient for measuring the temperature at one particular point in a piece of apparatus.

Disadvantages

1. They have lower accuracy.
2. Complex Circuitry.

Applications

Thermocouples are most suitable for measuring over a large temperature range up to 1800^0C.

They are used as relays and also as protective devices in starters etc.

PYROMETER

Introduction

Pyrometer is any non-contacting device that intercepts and measures thermal radiation.

This measure is used to determine temperature, often of the object's surface.

Pyrometer was originally coined to denote a device capable of measuring temperatures of objects above incandescence (i.e. objects bright to human eye).

Pyrometer is used for measurement of high

temperature **RADIATION PYROMETER**

Optical pyrometers work on the basic principle of using the human eye to match the brightness of the hot object to the brightness of a calibrated lamp filament inside the instrument.

The optical system contains filters that restrict the wavelength-sensitivity of the devices to a narrow wavelength band around 0.65 to 0.66 micons.

APPLICATIONS

Pyrometers are suited especially to the measurement of moving objects (or) any surfaces that can't be reached (or) can't be touched.

Pyrometers are used to measure wide temperature ranges above 1700^0C.

LUX METER

Lux meters (or) Light meters measures illumination in terms of luxes (lx).

A Lux is equal to the total intensity of light that falls on a one square meter surface i.e., one foot away from the point source of light.

Most lux meters consist of a body, light sensor & display.

The light that falls on to the light sensor contains energy i.e., converted to electric current. In turn the amount of current depends on the amount of light that strikes the light sensor. Lux meter read the electrical current, calculate the appropriate value and output the result to an analog, digital (or) video display.

The light usually contains different colors at different wavelengths; the reading represents the combined effects of all the wavelengths.

Typically standard colors (or) colors temperature are expressed in degrees klv. The standard color temperatures for the calibration of most lux meters is 2856^0K Selecting lux meter requires an analysis of performance specifications, display types & special features.

Performance specifications include sensor diameter, illumination range, accuracy, lux resolution, humidity range and optimum temperature range.

Several display types are available i.e. Analog devices display values on a dial usually with a needle (or) pointer.

Digital devices display values as numbers or letters.

Some lux meters are portable, handheld devices other are designed to sit atop desk or bench top.

Tongue testers

In electrical and electronic engineering, a **current clamp** or **current probe** is an electrical device having two jaws which open to allow clamping around an electrical conductor. This allows properties of the electric current in the conductor to be measured, without having to make physical contact with it, or to disconnect it for insertion through the probe. Current clamps are usually used to read the magnitude of a sinusoidal current (as invariably used in alternating current (AC) power distribution systems), but in conjunction with more advanced instrumentation the phase and waveform are available. Very high alternating currents (1000 A and more) are easily read with an appropriate meter; direct currents, and very low AC currents (milliamperes) are more difficult to measure.

Types of current clamp

Current transformer

A common form of current clamp comprises a split ring made of ferrite or soft iron. A wire coil is wound round one or both halves, forming one winding of a current transformer. The conductor around which it is clamped forms the other winding. Like any transformer this type works only with AC or pulse waveforms, with some examples extending into the megahertz range.

When measuring current, the subject conductor forms the primary winding and the coil forms the secondary.

This type may also be used in reverse, to inject current into the conductor, for example in EMC susceptibility testing to induce an interference current. Usually, the injection probe is specifically designed for this purpose. In this mode, the coil forms the primary and the test conductor the secondary.

Iron vane

In the iron vane type, the magnetic flux in the core directly affects a moving iron vane, allowing both AC and DC to be measured, and gives a true RMS value for non-sinusoidal AC waveforms. Due to its physical size it is generally limited to power transmission frequencies up to around 100 Hz.

The vane is usually fixed directly to the display mechanism of an analogue (moving pointer) clamp meter.

Hall Effect

The Hall Effect type is more sensitive and is able to measure both DC and AC, in some examples up to the kilohertz (thousands of hertz) range. This type was often used with oscilloscopes, and with high-end computerized digital multimeters, however, they are becoming common place for more general use.

Multi-conductor

Traditional current clamps will only work if placed around one conductor of the circuit under test because if it is placed around both, the magnetic fields would cancel. A relatively recent development is a clamp meter that has several sensor coils around the jaws of the clamp. This type can be clamped around standard 2 or 3 conductor single phase cables and will provide readout of the current flowing through the load. A version for three phase circuits does not currently exist, but in such circuits the individual conductors are usually accessible.

Clamp meter

An electrical meter with integral AC current clamp is known as a clamp meter, clamp -on ammeter or tong tester.

In order to use a clamp meter, only one conductor is normally passed through the probe; if more than one conductor is passed through then the measurement would be the vector sum of the currents flowing in the conductors and would depend on the phase relationship of the currents. In particular if the clamp is closed around a two-conductor cable carrying power to equipment the same current flows down one conductor and up the other, with a net current of zero. Clamp meters are often sold with a device that is plugged in between the power outlet and the device to be tested. The device is essentially a short extension cord with the two conductors separated, so that the clamp can be placed around only one conductor.

The reading produced by a conductor carrying a very low current can be increased by winding the conductor around the clamp several times; the meter reading divided by the number of turns is the current, with some loss of accuracy due to inductive effects.

Clamp meters are used by electricians, sometimes with the clamp incorporated into a general purpose multimeter.

It is simple to measure very high currents (hundreds of amperes) with the appropriate current transformer. Accurate measurement of low currents (a few milliamperes) with a current transformer clamp is more difficult.

UNIT – IV
DEMAND SIDE MANAGEMENT – I

Introduction to DSM, concept of DSM, benefits of DSM, different techniques of DSM – time of day pricing, multi – utility power exchange model, time of day models for planning.

Introduction to DSM

Demand side management (DSM) has been traditionally seen as a means of reducing peak electricity demand so that utilities can delay building further capacity. In fact, by reducing the overall load on an electricity network, DSM has various beneficial effects, including mitigating electrical system emergencies, reducing the number of blackouts and increasing system reliability. Possible benefits can also include reducing dependency on expensive imports of fuel, reducing energy prices, and reducing harmful emissions to the environment. Finally, DSM has a major role to play in deferring high investments in generation, transmission and distribution networks. Thus DSM applied to electricity systems provides significant economic, reliability and environmental benefits.

When DSM is applied to the consumption of energy in general—not just electricity but fuels of all types—it can also bring significant cost benefits to energy users (and corresponding reductions in emissions). Opp ortunities for reducing energy demand are numerous in all sectors and many are low-cost, or even no-cost, items that most enterprises or individuals could adopt in the short term, if good energy management is practiced.

Concept of DSM

Cost reduction – many DSM and energy efficiency efforts have been introduced in the context of integrated resource planning and aimed at reducing total costs of meeting energy demand;

Environmental and social improvement - energy efficiency and DSM may be pursued to achieve environmental and/or social goals by reducing energy use, leading to reduced green house gas emissions;

Reliability and network issues – ameliorating and/or averting problems in the electricity network through reducing demand in ways which maintain system reliability in the immediate term and over the longer term defer the need for network augmentation;

Improved markets - short-term responses to electricity market conditions ("demand response"), particularly by reducing load during periods of high market prices caused by reduced generation or network capacity.

Advantages to Demand Side Management

1. Better usage of existing generating and distribution infrastructure.
2. Less efficient/environmentally unfriendly generating capacity can be decommissioned.
3. Load can be matched to variable renewable energy availability.
4. Lower generating and transmission costs.
5. Lower transmission and distribution losses.
6. Reduction in "spinning reserve" costs.
7. Less intrusive load shedding.
8. More consumer growth capacity.
9. Better maintenance opportunities.
10. More availability (less black-outs).

The aims of the DSM are:

- To introduce the concept of demand-side management for residential, commercial and industrial energy users.
- To give an overview of the different types of demand-side measures.
- To show how housekeeping and preventative maintenance in commerce and industry can be used to reduce energy demand.
- To describe energy auditing and routine data collection and monitoring, and to indicate their benefits.
- To outline information dissemination on demand-side management.
- To provide an overview of the major implementation challenges for DSM Programmes.

Benefits of DSM

Demand Side Management (DSM) is a program that encourages energy users to make use of energy efficient designs. DSM presents a great chance for different power utilities to limit their GHG emissions while promoting energy conservation as well as lower emissions. This DSM approach is actually aimed at both the customers and the utility companies encouraging lower and more effective energy consumption. The following are a few benefits of DSM.

1. Environmental benefits

Rather than building new electrical plants for responding to the increase in customer demand for electricity, electricity producers could possibly attempt to limit the demand for power. Usually, they offer incentives of special programs having lower tariffs as well as higher efficiency appliances. This greatly assists in meeting the environment protection goals since it is going to reduce the emissions of pollutants into the atmosphere.

2. Controls load

It is an undeniable fact that the demand for electricity varies from one p erson to the next and there is a huge difference between night and day consumption. On the other hand, utility firms prefer constant usage in order to make the most out of their investment. Such a problem is easily solved with the assistance of demand side management. In such cases, lower night tariffs are introduced or other financial incentives to ensure constant power usage.

3. Cost effective

Through using the DSM approaches, you can be able to save a lot of money in electrical costs as well as maintenance costs. There is a large market nowadays of energy efficient appliances that you can use. Through using these appliances, the energy consumption will go down significantly and thus you will not require spending as much money in comparison to other firms that do not use the DSM approach.

The major drawback of DSM is that DSM based resolutions usually increase the complexity of the situation and they are not competitive.

• Reducing generation margin.
• Improving efficiency of system operation.

• Improving transmission and distribution grid investment and operation efficiency.
• Managing demand-supply balance in system with intermittent renewable and distributed power systems.
- Reduction in customer energy bills.
- Reduction in need for new power plant, transmission and distribution network.
- Stimulating economic development.
- Creating long term jobs due to new innovation and technologies.
- Increases the competitiveness of local enterprises.
- Reduction in air pollution.
- Reduces dependency on foreign energy source.
- Reduction in peak power prices for electricity.
- reducing dependency on expensive imports of fuel,
- reducing energy prices, and
- reducing harmful emissions to the environment.

Different techniques of DSM

- Night-time heating with load switching.
- Direct load control: remotely controllable switch that can turn power to a load or appliance on or off.
- Load limiters: limit the power that can be taken by individual consumers.
- Commercial/industrial programs: i.e. load-interruptible programs.
- Frequency regulation: dealing with fluctuation in frequency.
- Time-of-use pricing: reflect the production and investment cost structure where rates are higher (lower) during peak (off-peak) periods.
- Demand bidding: customer reduces the consumption of electricity at a certain predetermined price.
- Smart metering: tracking amount of electricity using to manage costs and consumption.

Time of day pricing

It is widely recognized that the cost of producing electricity varies from hour to hour. This conclusion holds true under virtually any method of calculating costs. As indicated previously, the most significant type of cost is marginal cost. The marginal cost of producing electricity varies widely, depending upon the total load and the particular generating units used to serve this load. The theory behind time-of - day rates is simply to vary the price of electricity in accordance with fluctuations in production costs. When the cost of production is high, the price would also be high. Conversely, when the cost of production is low, the price would be low.

Time of day pricing is actually a special case of marginal cost pricing. Since marginal cost theory suggests that prices should be equal to marginal cost s, and marginal costs vary from hour to hour, the price of electricity should logically vary from hour to hour. The efficiency advantages of such a pricing system are readily apparent. For example, if additional electricity costs 20 cents per KWH at a particular moment, it is hardly efficient to charge just 3 cents per KWH. If the utility charged the higher amount, some (perhaps many) customers would cut down on their usage of electricity by adjusting thermostats, turning off lights, and the like. Obviously, for these "flexible" or "adjustable" uses, customers are willing to pay the lower amount of 3 cents per KWH, but not 20 cents. Yet for every KWH which is eliminated, the utility's costs will be reduced by 20 cents. The situation is economically inefficient: the utility spends 20 cents per KWH to produce electricity which is worth far less to its customers. If the utility charged a price equal to the marginal cost of producing electricity, consumers would continue only those uses which were worth as much as the cost of producing the electricity.

The equity advantages of time- of - day pricing are also apparent. To illustrate, there are two customers who are the same in every way except for their consumption patterns. The first customer only uses electricity l ate at night when the marginal costs of production are very low, like 1 cent per KWH; the second customer only uses electricity at the peak usage hours of the day when the marginal costs of production are very high, like 10 cents per KWH. Given their usage, it is hardly fair to charge them same price. Under a time- of -day pricing system, this inequity can be corrected because the nocturnal user is charged less than the peak- hour consumer.

Practical Difficulties with Time- of - Day Pricing

In theory, marginal cost pricing can be applied with a high degree of exactness: a different price is charged every hour, depending upon the marginal costs of the system. In fact, many utilities use this type of pricing system when they interchange power with other utilities. The actual marginal costs of the selling utility are calculated for each hour when the power is interchanged; this rate is used as the price charged the purchasing utility.

Realistically, such a pricing system cannot be applied to all customers, even though it is theoretically possible. When two utilities interchange power, a rather substantial amount of electricity is normally involved. Thus, the transaction cost of calculating the bill under such a complicated pricing system is small, relative to the tot al value of the transaction. But if the transaction costs per KWH are very high for small customers, a complicated pricing system would not be appropriate.

Can Time- of - Day Pricing be Practically Applied to Industrial Customers

For smaller industrials and large commercial customers, the situation is less clear. Although it might be impractical to implement a time- of - day pricing system where the price changed every hour, it does seem feasible to adopt a more simplified approach with two or three different price levels. If properly designed, this approach would be a major improvement over the timeless rates now used; it could be simple enough for customers to understand and modify their usage patterns, if they wished.

For residential and small commercial customers, there are considerable practical difficulties with adopting a universal time- of - day pricing system. Metering costs alone are a major obstacle. Also, these customers are less likely to acquire the necessary knowledge to adapt their purchasing decisions to a time - of - day pricing system.

Multi-utility power exchange model

Multi-utility relates to companies offering a wide range of services and/or products. In the business market, this type of service provision usually relates to energy, environmental services, waste issues, infrastructure and/or telecom services. In the consumer market, it often concerns a combined offering of services in the field of energy and digital products and servic es (telephony, internet and television). Providers like these are also referred to as multi-service providers. So it often concerns services and products in relation to public utilities. Multi-utility has a relation with cross-selling, offering complementary products and services.

In a multiple (multi-utility or multi-country) integrated system setting, each integrated system “speaks” with its neighbor in terms of spot prices at their common borders; they buy or sell energy at the spot price of the specific instant and location. The resulting operating point is the same as the one achieved under a fully centralized dispatch. When dispatching the utilities, the control center associated to each system must not discriminate between its own generators’ power and power offered by the neighboring systems through tie-lines, except for economic reasons. A multi-utility setting consisting of three coordinated areas is shown in Fig. 1. Each regional ISO operates its own power system and interacts with the RSC. When power exchanges are to be scheduled, the RSC starts an iterative procedure in which the utilities send tie-line power-flow information to the RSC

Time of day models for planning

Time of day modeling procedures integrated into the four-step travel demand modeling process offer a more accurate and robust mechanism for obtaining time-of-day based estimates of travel demand and link volumes. These procedures account for differences across trip purposes, modes, and origin-destination pairs. Some of the issues that motivate the modeling of travel demand by time of day include, but are not limited to the following:

- Design hour traffic volumes for roadway design and level of service analysis
- Transit analysis
- Vehicular emissions and air quality analysis
- Assessing impact of congestion management programs
- Evaluating travel demand management strategies
- Evaluating variable (time-of-day based) pricing policies
- Analysis of peak spreading (time of day of travel choices)
- Analysis of intelligent transportation systems

DEMAND SIDE MANAGEMENT – II

Load management, load priority technique, peak clipping, peak shifting, valley filling, strategic conservation, energy efficient. Management and Organization of Energy Conservation awareness Programs.

Load management

Load management is the process of balancing the supply of electricity on the network with the electrical load by adjusting or controlling the load rather than the power station output. This can be achieved by direct intervention of the utility in real time, by the use of frequency sensitive relays triggering circuit breakers (ripple control), by time clocks, or by using special tariffs to influence consumer behavior. Load management allows utilities to reduce demand for electricity during peak usage times, which can, in turn, reduce costs by eliminating the need for peaking power plants. In addition, peaking power plants also often require hours to bring on-line, presenting challenges should a plant go off-line unexpectedly. Load management can also help reduce harmful emission, since peaking plants or backup generators are often dirtier and less efficient than base load power plants. New load-management technologies are constantly under development — both by private industry and public entities.

Load Priority Technique

Load Priority Technique Works on individual loads priority for operation (in service and out of service). This is mainly influenced by the production schedule. The load priority could also be connected directly with the rate communication system (i.e., differential tariff system). However in the present work, while deciding priorities of various loads for operation, only production schedule is considered in consultation with the concerned section superintendents.

In developing load priority technique, non-interruptible loads are classified as high priority loads (to remain in ON condition) and the interruptible loads are classified as low priority loads. Two priority lists are prepared in consultation with the various section superintendents namely:-

1. Priority for switching OFF
2. Priority for switching ON

The load demand on the industry is continuously monitored at acceptable time intervals. If the demand exceeds beyond the permitted limit then the "Low Priority Loads" to the extent of exceeded value of load are cut-off. If the load demand is less than the permitted limit then the loads which were interrupted in the previous time slots were switched on based on the "priority for switching ON".

The success of load priority technique is totally dependent upon the development of various load priorities for operation which will not disturb the production schedule and gives enough scope for reduction of load demand. This DSM alternative creates possibilities for the consumers to reduce peaks and fill out valleys in their load curves. Thus resulting in an almost flat load curve. It also helps to maintain consumer lifestyle by reducing the unscheduled outages. As there is a strict control over the maximum demand penalty for the consumer.

Peak Clipping

Clipping is a form of waveform distortion that occurs when an amplifier is overdriven and attempts to deliver an output voltage or current beyond its maximum capability. Driving an amplifier into clipping may cause it to output power in excess of its published ratings.

Reduction of the maximum demand for electric power from an electrical utility, often achieved by direct control of customer loads by signals directed to customer appliances.

A common form of distortion in telephones and other auditory transmission systems in which the peaks of the waveform are flattened off—to only one or two per cent of their original height in severe peak clipping—transforming the waveform into a sequence of rectangular pulses. When applied to speech it has surprisingly little effect on its intelligibility, 80 or 90 per cent of words still being correctly interpreted by listeners when the clipping is severe.

The DISTORTION caused when the GAIN of an amplifier is increased to a point where the high points, or peaks, of the SIGNAL or WAVEFORM are cut off at a level where the amplifying circuits are driven beyond their overload point. Also called over-MODULATION.

Peak clipping may be avoided by gain reduction, COMPRESSION of the signal, or by the use of a LIMITER.

Compare: RECTIFICATION, SWITCH.

Positive and negative clipping of a sine wave.

Peak clipping—where the demand peaks (high demand periods) are “clipped” and the load is reduced at peak times. This form of load management has little overall effect of the demand but focuses on reducing peak demand.

Peak Clipping - Or the reduction of the system peak loads, embodies one of the classic forms of load management. Peak clipping is generally considered as the reduction of peak load by using direct load control. Direct load control is most commonly practiced by direct utility control of either service to customer facilities or of customers' appliances. While many utilities consider this as means to reduce peaking capacity or capacity purchases and consider control only during the most probable days of system peak, direct load control can be used to reduce operating cost and dependence on critical fuels by economic dispatch.

Peak Shifting

Peak Shifting is a highly cost-effective method of reducing electric utility expenses. When electric utility commercial or industrial customers use electricity can make a big difference on their monthly electric bills. By shifting the time of day that electric power is used, a commercial or industrial customer can reduce their "demand charge" portion of their electric bill during peak times of the day. This reduces the overall cost of power each month for the customer.

Unlike most products, electricity can’t be stored after it's generated. Electricity must be generated - and consumed - at the time of demand by a utility's customer. Electricity usage continuously varies throughout the day, and varies from month- to-month and season-to-season. Each day, there are "peak" demand periods of usage during which time the electric utilities must generate additional amounts of electricity to meet these peak demands for all of their customers.

To meet this additional peak demand for electricity utilities use “peaking generators” also called "peaking plants" or simply "peakers." These peaking plants are the least efficient methods of generating power, meaning they generate less power with more fuel (and their associated greenhouse gas emissions) compared with the utility's base-load generators. These peaking plants typically burn oil or natural gas to produce the electricity and are brought on line only during "peak periods" of the day and run for short periods.

While peaking generators generally cost less to build than other types of generators, they also have relatively high fuel costs because they are typically much less efficient in the use of fuel.

Therefore, "Peak Shifting" is a method that addresses shifts the time of day when electricity is used; reducing the need for peaking plants and can reduce a commercial or industrial customer's electric bills, if correctly implemented.

Because the vast majority of electricity is generated in direct, instantaneous response to demand, costs of electricity differ dramatically between high demand (“on peak”) and low demand (“off peak”) periods.

By installing energy storage on the grid, both utilities and consumers are able to shift their demand out of on-peak periods and into off peak periods, flattening their energy consumption profile:

This reduces energy costs for the average user on the system, regardless of whether or not they are the user of time-shifted electricity. Commercial electric customers on time-of-use rate schedules have a compelling financial opportunity in the form of energy arbitrage. Peak shifting also lessens the total effect of electric vehicle charging on the grid, and makes electric vehicles less expensive per mile.

Valley Filling

The process of making an energy production and delivery system more efficient by encouraging additional energy use during periods of lowest system demand. Valley filling programs are usually accompanied by load shifting programs, often with the aim of shifting peak demand usage to low demand periods, but the term can refer to any program or strategy aimed at filling the valley. An essential component of nearly all demand-side management programs.

Valley Filling - Is the second classic form of load management and applies to both gas and electric systems. Valley filling encompasses building off-peak loads. This may be particularly desirable where the long-run incremental cost is less than the average price of energy. Adding properly priced off-peak load under those circumstances decreases the average price. Valley filling can be accomplished in several ways, one of the most popular of which is new thermal energy storage (water heating and/or space heating) that displaces loads served by fossil fuels.

Valley filling—where the demand valleys (low demand periods) are “filled” by building off-peak capacities. This form of load manage-ment can be achieved by thermal energy storage (water heating or space heating) that displaces fossil fuel loads.

Strategic Conservation

Strategic Conservation - Is the load shape change that results from programs directed at end use consumption. Not normally considered load management, the change reflects a modification of the load shape involving a reduction in consumption as well as a change in the pattern of use. In employing energy conservation, the planner must consider what conservation actions would occur naturally and then evaluate the cost-effectiveness of possible intended programs to accelerate or stimulate those actions. Examples include weatherization and appliance efficiency improvement.

Strategic conservation is the load shape change that results from utility-stimulated programmes directed at end use consumption. This is represented schematically in figure II.

Figure II.—Strategic load conservation

Not normally considered load management, the change reflects a modification of the load shape involving a reduction in sales as well as a change in the pattern of use. In employing energy conservation, the utility planner must consider what conservation actions would occur naturally and then evaluate the cost-effectiveness of possible intended utility programmes to accelerate or stimulate those actions. An example is appliance efficiency improvement.

Strategic Conservation is a process that produces tools to aid decision makers in identifying, prioritizing, pursuing, and protecting those specific tracts of land that will most effectively and efficiently achieve the land trust's mission.

Energy Efficient Equipment

Energy consumed by appliances and equipment is a major source of greenhouse gas emissions in Australia. Improving the energy efficiency of appliances is a key objective for all Australian Governments.

The main policy tools that are used to improve the energy efficiency of appliances and equipment, in the residential, commercial and industrial sector, and save money for all Australians, are mandatory Minimum Energy Performance Standards (MEPS) and mandatory Energy Rating Labels.

Since 1986 the Energy Rating Label has appeared on refrigerators and freezers in New South Wales and Victoria. Since that time, the label has applied to more product lines and is used in both Australia and New Zealand, with all states and territories having regulations in place over time.

In 1992 a national body, the Equipment Energy Efficiency Program (E3) was established to coordinate these activities. On 30 May 2012 the Greenhouse and Energy Minimum Standards (GEMS) Bill 2012 was introduced into federal Parliament with a proposed commencement date of 1 October 2012. Providing that the legislation is passed, the E3 Program will operate under national legislation, replacing the patchwork of state regulations the E3 Program has been operating under to date.

The Program will continue to be administered by the Australian Government (currently through the Department of Climate Change and Energy Efficiency), with continued input from state and territory governments and the New Zealand Government (through the Energy Efficiency Conservation Authority).

E3 reports to the Energy Efficiency Working Group (E2WG) under the National Framework for Energy Efficiency (NFEE), and ultimately to the Select Council on Climate Change. More recently the work of E3 has been adopted as a measure under the National Strategy on Energy Efficiency and the National Part nership Agreement on Energy Efficiency.

Products are considered for inclusion within the program on the basis that the community will benefit from their regulation. The individual product energy efficiency target is either the equivalent of world-best regulatory target or a more stringent level developed specifically for Australia. This market intervention has proved to be an extremely cost effective mechanism for reducing energy demand and greenhouse gases produced by consumer appliances, commercial and industrial equipment.

Efficient energy use, sometimes simply called energy efficiency, is the goal of efforts to reduce the amount of energy required to provide products and services. For example, insulating a home allows a building to use less heating and cooling energy to achieve and maintain a comfortable temperature. Installing fluorescent lights or natural skylights reduces the amount of energy required to attain the same level of illumination compared with using traditional incandescent light bulbs. Compact fluorescent lights use one-third the energy of incandescent lights and may last 6 to 10 times longer. Improvements in energy efficiency are most often achieved by adopting a more efficient technology or production process.

Energy efficiency and renewable energy are said to be the twin pillars of sustainable energy policy and are high priorities in the sustainable energy hierarchy. In many countries energy efficiency is also seen to have a national security benefit because it can be used to reduce the level of energy imports from foreign countries and may slow down the rate at which domestic energy resources are depleted.

Energy efficiency is "using less energy to provide the same service".

The best way to understand this idea is through examples: When you replace a single pane window in your house with an energy-efficient one, the new window prevents heat from escaping in the winter, so you save energy by using your furnace or electric heater less while still staying comfortable. In the summer, efficient windows keep the heat out, so the air conditioner does not run as often and you save electricity.

When you replace an appliance, such as a refrigerator or clothes washer, or office equipment, such as a computer or printer, with a more energy-efficient model, the new equipment provides the same service, but uses less energy. This saves you money on your energy bill, and reduces the amount of greenhouse gases going into the atmosphere.

Energy efficiency is not energy conservation. Energy conservation is reducing or going without a service to save energy. For example: Turning off a light is energy conservation. Replacing an incandescent lamp with a compact fluorescent lamp (which uses much less energy to produce the same amount of light) is energy efficiency.

Management and Organization of Energy Conservation awareness Programs

Most successful organizations and individuals set goals, develop plans to meet them and continually monitor their progress. To put together a plan that will work for the unique requirements of your company, follow these six easy steps:

- Step 1 – Establish a clear vision: Create goals that are specific, measurable, attainable, realistic and trackable ("SMART").
- Step 2 – Create the team: Appoint an energy champion who will develop the plan, obtain approval to proceed, build your team and manage

implementation. Build your team to include decision makers as well as a diverse group that represents your workplace.

- Step 3 – Know your workplace: Figure out who are your target audiences to determine the tools you will use to communicate with them. Consider the audience's size, where it's located and whether it is located in multiple facilities.
- Step 4 – Develop your communications plan: Identify and document what you need to say to your employees, and how to say it. Define your key messages; choose a communications style that is consistent with that used in your organization, and then list out the activities, schedule and budget you'll need to make your plan work.
- Step 5 – Implement your plan: Educate your employees/occupants/students in energy-conserving habits and behaviours. Deliver the activities you and your team have selected. Monitor the program and its effects, and lead by example.
- Step 6 – Recognize and reward : Reward those who have contributed to achieving your goals. Annual programs can help remind your employees and occupants of their energy-saving habits and accomplishments.

Load Management Options

Direct Load Control (DLC) – Utility has control of directly switching off customer loads
Interruptible Load Control (ILC) - Utility provides advance notice to customers to switch off loads
Time of Use (TOU) Tariffs – price signal provided – customer decides response

Load management programmes—changing the load pattern and encouraging less demand at peak times and peak rates:

- Load leveling
- Load control

Tariff incentives and penalties

Load leveling

Load levelling helps to optimize the current generating base-load without the need for reserve capacity to meet the periods of high demand.

UNIT V
ENERGY ECONOMIC ANALYSIS

The time value of money concept, developing cash flow models, payback analysis, depreciation, taxes and tax credit – numerical problems.

The time value of money concept

Money has time value. A rupee today is more valuable than a year hence. It is on this concept "the time value of money" is based. The recognition of the time value of money and risk is extremely vital in financial decision making.

REASONS FOR TIME VALUE OF MONEY

Money has time value because of the following reasons:

1. Risk and Uncertainty :Future is always uncertain and risky. Outflow of cash is in our control as payments to parties are made by us. There is no certainty for future cash inflows. Cash inflows is dependent out on our Creditor, Bank etc. As an individual or firm is not certain about future cash receipts, it prefers receiving cash now.
2. Inflation:In an inflationary economy, the money received today, has more purchasing power than the money to be received in future. In other words, a rupee today represents a greater real purchasing power than a rupee a year hence.
3. Consumption:Individuals generally prefer current consumption to future consumption.
4. Investment opportunities:An investor can profitably employ a rupee received today, to give him a higher value to be received tomorrow or after a certain period of time.

Thus, the fundamental principle behind the concept of time value of money is that, a sum of money received today, is worth more than if the same is received after a certain period of time. For example, if an individual is given an alternative either to receive `10,000 now or after one year, he will prefer `10,000 now. This is because, today, he may be in a position to purchase more goods with this money than what he is going to get for the same amount after one year.
Thus, time value of money is a vital consideration in making financial decision.
Let us take some examples:

EXAMPLE 1:A project needs an initial investment of `1,00,000. It is expected to give a return of `20,000 per annum at the end of each year, for six years. The project thus involves a cash outflow of `1,00,000 in the 'zero year' and cash inflows of `20,000 per year, for six years. In order to decide, whether to accept or reject the project, it is necessary that the Present Value of cash inflows received annually for six years is ascertained and compared with the initial investment of `1,00,000. The firm will accept the project only when the Present Value of cash inflows at the desired rate of interest exceeds the initial investment or at least equals the initial investment of `1,00,000.

EXAMPLE2:A firm has to choose between two projects. One involves an outlay of `10 lakhs with a return of 12% from the first year onwards, for ten years. The other requires an investment of `10 lakhs with a return of 14% per annum for 15 years commencing with the beginning of the sixth year of the project. In order to make a choice between these two projects, it is necessary to compare the cash outflows and the cash inflows resulting from the project. In order to make a meaningful comparison, it is necessary that the two variables are strictly comparable. It is possible only when the time element is incorporated in the relevant calculations. This reflects the need for comparing the cash flows arising at different points of time in decision-making.

VALUATION CONCEPTS

The time value of money establishes that there is a preference of having money at present than a future point of time. It means (a) That a person will have to pay in future more, for a rupee received today. For example: Suppose your father gave you `100 on your tenth birthday. You deposited this amount in a bank at 10% rate of interest for one year. How much future sum would you receive after one year? You would receive `110

Future sum = Principal + Interest

= 100 + 0.10 × 100

= `110

What would be the future sum if you deposited `100 for two years? You would now receive interest on interest earned after one year. Future sum = 100 × 1.10

2

=`121

We express this procedure of calculating as Compound Value or Future Value of a sum.

(b) A person may accept less today, for a rupee to be received in the future. Thus, the inverse of compounding process is termed as discounting. Here we can find the value of future cash flow as on today.

TECHNIQUES OF TIME VALUE OF MONEY

There are two techniques for adjusting time value of money. They are:

1. Compounding Techniques/Future Value Techniques
2. Discounting/Present Value Techniques

The value of money at a future date with a given interest rate is called future value. Similarly, the worth of money today that is receivable or payable at a future date is called Present Value.

Compounding Techniques/Future Value Technique

In this concept, the interest earned on the initial principal amount becomes a part of the principal at the end of the compounding period.

FOREXAMPLE:Suppose you invest `1000 for three years in a saving account that pays 10 per cent interest per year. If you let your interest income be reinvested, your investment will grow as follows

This process of compounding will continue for an indefinite time period.
The process of investing money as well as reinvesting interest earned there on is called Compounding. But the way it has gone about calculating the future value will prove to be cumbersome if the future value over long maturity periods of 20 years to 30 years is to be calculated. A generalised procedure for calculating the future value of a single amount compounded annually is as follows:

Formula: $\boxed{FV_n = PV(1 + r)^n}$

In this equation $(1 + r)^n$ is called the future value interest factor (FVIF).

where, FV_n = Future value of the initial flow n year hence

PV = Initial cash flow

r = Annual rate of Interest

n = number of years

By taking into consideration, the above example, we get the same result.

$$FV_n = PV\,(1 + r)^n$$
$$= 1{,}000\ (1.10)^3$$
$$FV_n = 1331$$

FUTURE VALUE OF MULTIPLE CASH FLOWS

The above illustration is an example of multiple cash flows.

The transactions in real life are not limited to one. An investor investing money in instalments may wish to know the value of his savings after 'n' years. The formulae is

$$FV_n = PV\left(1 + \frac{r}{m}\right)$$

where FV_n = Future value after 'n' years

PV = Present value of money today

r = Interest rate

m = Number of times compounding is done in a year.

ILLUSTRATION 5:

(*i*) A company offers 12% rate of interest on deposits. What is the effective rate of interest if the compounding is done on

(*a*) Half-yearly

(*b*) Quarterly

(*c*) Monthly

(*ii*) As an alternative, the following rates of interest are offered for choice. Which basis gives the highest rate of interest that is to be accepted?

Basis of Compounding	Interest Rate
Yearly	12%
Half-yearly	11.75%
Quarterly	11.50%
Monthly	11.25%

SOLUTION:

(*i*) The formula for calculation of effective interest is as below:

$$EIR = \left(1 + \frac{r}{m}\right) - 1$$

(*A*) When the compounding is done on half-yearly basis:

$$EIR = \left[\left(1 + \frac{.12}{2}\right)^2 - 1\right]$$

$$= 1.1236 - 1$$

$$= 12.36\%$$

(*B*) When the compounding is done on quarterly basis

$$EIR = \left[1 + \frac{.12}{4}\right]^4 - 1$$

$$= 0.1255$$

$$= 12.55\%$$

(*C*) When the compounding is done on monthly basis

$$EIR = \left[1 + \frac{.12}{12}\right]^{12} - 1$$

$$= 0.1268$$

Basis of Compounding	Interest Rate	EIR
Yearly	12%	12%
Half-yearly	12%	12.36%
Quarterly	12%	12.55%
Monthly	12%	12.68%

(*ii*) When the compounding is done on half-yearly basis

$$
\begin{aligned}
EIR &= \left[1+\frac{.1175}{2}\right]^2 - 1 \\
&= 0.1209 \\
&= 12.09\%
\end{aligned}
$$

When the compounding is done on quarterly basis:

$$
\begin{aligned}
EIR &= \left[1+\frac{0.1150}{4}\right]^4 - 1 \\
&= .1200 \\
&= 12\%
\end{aligned}
$$

When the compounding is done on monthly basis

$$
\begin{aligned}
EIR &= \left[1+\frac{0.1125}{12}\right]^{12} - 1 \\
&= 0.1184 \\
&= 11.84\%
\end{aligned}
$$

Thus, out of all interest rate, interest rate of 11.75% on half-yearly compounding works out to be the highest effective interest rate *i.e.*, 12.09% so this option is to be accepted.

ILLUSTRATION 6: Find out the effective rate of interest, if nominal rate of interest is 12% and is quarterly compounded.

SOLUTION:

$$EIR = \left[\left(1+\frac{r}{m}\right)^m - 1\right]$$

$$= \left[\left(1+\frac{.12}{4}\right)^4 - 1\right]$$

$$= [(1 + 0.03)^4 - 1]$$

$$= 1.126 - 1$$

$$= 0.126$$

$$= 12.6\% \text{ p.a.}$$

Growth Rate

The compound rate of growth for a given series for a period of time can be calculated by employing the future value interest factor table (*FVIF*)

EXAMPLE:

Years	Profit (in Lakhs)
1	95
2	105
3	140
4	160
5	165
6	170

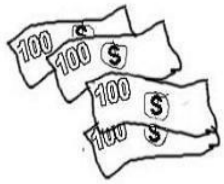
How is the compound rate of growth for the above series determined? This can be done in two steps:

(*i*) The ratio of profits for year 6 to year 1 is to be determined *i.e.*, $\frac{170}{95} = 1.79$

(*ii*) The $FVIF_{r,n}$ table is to be looked at. Look at a value which is close to 1.79 for the row for 5 years. The value close to 1.79 is 1.762 and the interest rate corresponding to this is 12%. Therefore, the compound rate of growth is 12 per cent.

Developing cash flow models

Basic Cash Flow Model



- A Cash Flow projection is an estimate of cash generated from the project over a period of time. It is not just the initial cash returned.
- Cash Flow (CF) is basically the cash available after all expenses are paid. Cash Flow analysis considers the coverage of expenses and debt service. Debt service consists of the principal and interest payments. The money that remains after paying such expenses is the Cash Flow.

A summarized Cash Flow schedule for an Income Property for one year could be as follows:

Gross Income (Gross Revenue)	**$ 200,000**
less: Losses (or bad debts)	**2,000**
plus: miscellaneous income	**1,000**
equal: Effective Gross Income	**199,000**
less: Operating Expenses	**70,000**
less: Replacement Reserve	**10,000**
equal: Net Operating Income	**119,000**
less: Interest	**75,000**
less: Principal payment	**8,250**
equal: Cash Flow	**$ 35,750**

Note: For Cash Flow projections of a new development, losses would not be appropriate but Brokerage Commissions paid on lot sales would be deducted from Gross Income. Instead of Replacement Reserves, a Cash Flow projection for a new development would consider Contingency Funds. This Cash Flow model is a Before Tax model.

Discounted cash flow

In finance, **discounted cash flow** (**DCF**) analysis is a method of valuing a project, company, or asset using the concepts of the time value of money. All future cash flows are estimated and discounted to give their present values (PVs) — the sum of all future cash flows, both incoming and outgoing, is the net present value (NPV), which is taken as the value or price of the cash flows in question.
Using DCF analysis to compute the NPV takes as input cash flows and a discount rate and gives as output a price; the opposite process — taking cash flows and a price and inferring a discount rate, is called the yield.
Discounted cash flow analysis is widely used in investment finance, real estate development, and corporate financial management.

Discount rate

The most widely used method of discounting is exponential discounting, which values future cash flows as "how much money would have to be invested currently, at a given rate of return, to yield the cash flow in future." Other methods of discounting, such as hyperbolic discounting, are studied in academia and said to reflect intuitive decision-making, but are not generally used in industry.

The discount rate used is generally the appropriate Weighted average cost of capital (WACC), that reflects the risk of the cashflows. The discount rate reflects two things:

1. The time value of money (risk-free rate) – according to the theory of time preference, investors would rather have cash immediately than having to wait and must therefore be compensated by paying for the delay.
2. A risk premium – reflects the extra return investors demand because they want to be compensated for the risk that the cash flow might not materialize after all.

Discounted cash flows

The discounted cash flow formula is derived from the future value formula for calculating the time value of money and compounding returns.

Thus the discounted present value (for one cash flow in one future period) is expressed as:

where

- *DPV* is the discounted present value of the future cash flow (*FV*), or *FV* adjusted for the delay in receipt;
- *FV* is the nominal value of a cash flow amount in a future period;
- *i* is the interest rate, which reflects the cost of tying up capital and may also allow for the risk that the payment may not be received in full;
- *d* is the discount rate, *which* is *i*/(1+*i*), i.e. the interest rate expressed as a deduction at the beginning of the year instead of an addition at the end of the year;
- *n* is the time in years before the future cash flow occurs.

Where multiple cash flows in multiple time periods are discounted, it is necessary to sum them as follows:

for each future cash flow (*FV*) at any time period (*t*) in years from the present time, summed over all time periods. The sum can then be used as a net present value figure. If the amount to be paid at time 0 (now) for all the future cash flows is known, then that amount can be substituted for *DPV* and the equation can be solved for *i*, that is the internal rate of return.

All the above assumes that the interest rate remains constant throughout the whole period.

Discounted cash flows

The discounted cash flow formula is derived from the future value formula for calculating the time value of money and compounding returns.

Thus the discounted present value (for one cash flow in one future period) is expressed as:

where

- *DPV* is the discounted present value of the future cash flow (*FV*), or *FV* adjusted for the delay in receipt;
- *FV* is the nominal value of a cash flow amount in a future period;
- *i* is the interest rate, which reflects the cost of tying up capital and may also allow for the risk that the payment may not be received in full;
- *d* is the discount rate, *which* is *i*/(1+*i*), i.e. the interest rate expressed as a deduction at the beginning of the year instead of an addition at the end of the year;
- *n* is the time in years before the future cash flow occurs.

Where multiple cash flows in multiple time periods are discounted, it is necessary to sum them as follows:

for each future cash flow (*FV*) at any time period (*t*) in years from the present time, summed over all time periods. The sum can then be used as a net present value figure. If the amount to be paid at time 0 (now) for all the future cash flows is known, then that amount can be substituted for *DPV* and the equation can be solved for *i*, that is the internal rate of return.

All the above assumes that the interest rate remains constant throughout the whole period.

Continuous cash flows

For continuous cash flows, the summation in the above formula is replaced by an integration:

$$DPV = \int_0^T FV(t)\, e^{-\lambda t} dt,$$

where $FV(t)$ is now the *rate* of cash flow, and $\lambda = \log(1+i)$.

Example DCF

To show how discounted cash flow analysis is performed, consider the following simplified example.

- John Doe buys a house for $100,000. Three years later, he expects to be able to sell this house for $150,000.

Simple subtraction suggests that the value of his profit on such a transaction would be $150,000 − $100,000 = $50,000, or 50%. If that $50,000 is amortized over the three years, his implied annual return (known as the internal rate of return) would be about 14.5%. Looking at those figures, he might be justified in thinking that the purchase looked like a good idea.

$1.145^3 \times 100000 = 150000$ approximately.

However, since three years have passed between the purchase and the sale, any cash flow from the sale must be discounted accordingly. At the time John Doe buys the house, the 3-year US Treasury Note rate is 5% per annum. Treasury Notes are generally considered to be inherently less risky than real estate, since the value of the Note is guaranteed by the US Government and there is a liquid market for the purchase and sale of T-Notes. If he hadn't put his money into buying the house, he could have invested it in the relatively safe T-Notes instead. This 5% per annum can therefore be regarded as the risk-free interest rate for the relevant period (3 years).

Using the DPV formula above (FV=$150,000, i=0.05, n=3), that means that the value of $150,000 received in three years actually has a present value of $129,576 (rounded off). In other words we would need to invest $129,576 in a T -Bond now to get $150,000 in 3 years almost risk free. This is a quantitative way of showing that money in the future is not as valuable as money in the present ($150,000 in 3 years isn't worth the same as $150,000 now; it is worth $129,576 now).

Subtracting the purchase price of the house ($100,000) from the present value results in the net present value of the whole transaction, which would be $29,576 or a little more than 29% of the purchase price.

Another way of looking at the deal as the excess return achieved (over the risk-free rate) is (114.5 - 105)/(100 + 5) or approximately 9.0% (still very respectable). But what about risk?

We assume that the $150,000 is John's best estimate of the sale price that he will be able to achieve in 3 years time (after deducting all expenses, of course). There is of course a lot of uncertainty about house prices, and the outcome may end up higher or lower than this estimate.

(The house John is buying is in a "good neighborhood," but market values have been rising quite a lot lately and the real estate market analysts in the media are talking about a slow-down and higher interest rates. There is a probability that John might not be able to get the full $150,000 he is expecting in three years due to a slowing of price appreciation, or that loss of liquidity in the real estate market might make it very hard for him to sell at all.)

Under normal circumstances, people entering into such transactions are risk-averse, that is to say that they are prepared to accept a lower expected return for the sake of avoiding risk. See Capital asset pricing model for a further discussion of this. For the sake of the example (and this is a gross simplification), let's assume that he values this particular risk at 5% per annum (we could perform a more precise probabilistic analysis of the risk, but that is beyond the scope of this article). Therefore, allowing for this risk, his expected return is now 9.0% per annum (the arithmetic is the same as above).

And the excess return over the risk-free rate is now (109 - 105)/(100 + 5) which comes to approximately 3.8% per annum.

That return rate may seem low, but it is still positive after all of our discounting, suggesting that the investment decision is probably a good one: it produces enough profit to compensate for tying up capital and incurring risk with a little extra left over. When investors and managers perform DCF analysis, the important thing is that the net present value of the decision after discounting all future cash flows at least be positive (more than zero). If it is negative, that means that the investment decision would actually *lose* money even if it appears to generate a nominal profit. For instance, if the expected sale price of John Doe's house in the example above was not $150,000 in three years, but *$130,000* in three years or $150,000 in *five* years, then on the above assumptions buying the house would actually cause John to *lose* money in present-value terms (about $3,000 in the first case, and about $8,000 in the second). Similarly, if the house was located in an undesirable neighborhood and the Federal Reserve Bank was about to raise interest rates by five percentage points, then the risk factor would be a lot higher than 5%: it might not be possible for him to predict a profit in discounted terms even if he thinks he could sell the house for *$200,000* in three years.

In this example, only one future cash flow was considered. For a decision which generates multiple cash flows in multiple time periods, all the cash flows must be discounted and then summed into a single net present value.

Payback analysis

Payback period in capital budgeting refers to the period of time required for the return on an investment to "repay" the sum of the original investment. For example, a $1000 investment which returned $500 per year would have a two year payback period. The time value of money is not taken into account. Payback period intuitively measures how long something takes to "pay for itself." All else being equal, shorter payback periods are preferable to longer payback periods. Payback period is widely used because of its ease of use despite the recognized limitations described below.

To calculate a more exact payback period: Payback Period = Amount to be Invested/Estimated Annual Net Cash Flow 1 It can also be calculated using the formula:

$$\text{Payback Period} = (p - n) \div p + n_y$$

$$= 1 + n_y - n \div p \quad \text{(unit:years)}$$

Where

n_y= The number of years after the initial investment at which the last negative value of cumulative cash flow occurs.

n= The value of cash flow at which the last negative value of cumulative cash flow occurs.

p= The value of cash flow at which the first positive value of cumulative cash flow occurs.

This formula can only be used to calculate the soonest payback period; that is, the first period after which the investment has paid for itself. If the cumulative cash flow drops to a negative value some time after it has reached a positive value, thereby changing the payback period, this formula can't be applied. This formula ignores values that arise after the Payback Period has been reached.

Additional complexity arises when the cash flow changes sign several times; i.e., it contains outflows in the midst or at the end of the project lifetime. The modified payback period algorithm may be applied then. First, the sum of all of the cash outflows is calculated. Then the cumulative positive cash flows are determined for each period. The modified payback is calculated as the moment in which the cumulative positive cash flow exceeds the total cash outflow.

Depreciation

In accountancy, **depreciation** refers to two aspects of the same concept:

1. The decrease in value of assets (fair value depreciation), and
2. The allocation of the cost of assets to periods in which the assets are used (depreciation with the matching principle).

The former affects the balance sheet of a business or entity, and the latter affects the net income that they report. Generally the cost is allocated, as depreciation expense, among the periods in which the asset is expected to be used. This exp ense is recognized by businesses for financial reporting and tax purposes. Methods of computing depreciation, and the periods over which assets are depreciated, may vary between asset types within the same business. These may be specified by law or accounting standards, which may vary by country. There are several standard methods of computing depreciation expense, including fixed percentage, straight line, and declining balance methods. Depreciation expense generally begins when the asset is placed in service. For example, a depreciation expense of 100 per year for 5 years may be recognized for an asset costing 500.

Accounting concept

In determining the profits (net income) from an activity, the receipts from the activity must be reduced by appropriate costs. One such cost is the cost of assets used but not immediately consumed in the activity. Such cost so allocated in a given period is equal to the reduction in the value placed on the asset, which is initially equal to the amount paid for the asset and subsequently may or may not be related to the amount expected to be received upon its disposal. Depreciation is any method of allocating such net cost to those periods in which the organisation is expected to benefit from use of the asset. The asset is referred to as a depreciable asset. Depreciation is technically a method of allocation, not valuation, even though it determines the value placed on the asset in the balance sheet.

Any business or income producing activity using tangible assets may incur costs related to those assets. If an asset is expected to produce a benefit in future periods, some of these costs must be deferred rather than treated as a current expense. The business then records depreciation expense in its financial reporting as the current period's allocation of such costs. This is usually done in a rational and systematic manner. Generally this involves four criteria:

- cost of the asset,
- expected salvage value, also known as residual value of the asset,
- estimated useful life of the asset, and
- a method of apportioning the cost over such life

Depreciable basis

Cost generally is the amount paid for the asset, including all costs related to acquisition.[5] In some countries or for some purposes, salvage value may be ignored. The rules of some countries specify lives and methods to be used for particular types of assets. However, in most countries the life is based on business experience, and the method may be chosen from one of several acceptable methods.

Net basis

When a depreciable asset is sold, the business recognizes gain or loss based on net basis of the asset. This net basis is cost less depreciation.

Impairment

Accounting rules also require that an impairment charge or expense be recognized if the value of assets declines unexpectedly.[6] Such charges are usually nonrecurring, and may relate to any type of asset.

Depletion and amortization

Depletion and amortization are similar concepts for minerals (including oil) and intangible assets, respectively. Depreciation expense does not require current outlay of cash. However since depreciation is an expense to the P&L account, provided the enterprise is operating in a manner that covers its expenses (e.g. operating at a profit) depreciation is a source of cash in a statement of cash flows, which generally offsets the cash cost of acquiring new assets reuired to continue operations when existing assets reach the end of their useful lives.

Historical cost

Depreciation is generally recognized under historical cost systems of accounting. Some proposals for fair value accounting have no provision for depreciation expense.

Accumulated depreciation

While depreciation expense is recorded on the income statement of a business, its impact is generally recorded in a separate account and disclosed on the balance sheet as accumulated depreciation, under fixed assets, according to most accounting principles. Accumulated depreciation is known as a contra account, because it separately shows a negative amount that is directly associated with another account.

Without an accumulated depreciation account on the balance sheet, depreciation expense is usually charged against the relevant asset directly. The values of the fixed assets stated on the balance sheet will decline, even if the business has not invested in or disposed of any assets. The amounts will roughly approximate fair value. Otherwise, depreciation expense is charged against accumulated depreciation. Showing accumulated depreciation separately on the balance sheet has the effect of preserving the historical cost of assets on the balance sheet. If there have been no investments or dispositions in fixed assets for the year, then the values of the assets will be the same on the balance sheet for the current and prior year.In other words it is a method of recovering capital expenditure in installments which is called as depreciation.

Methods of depreciation

There are several methods for calculating depreciation, generally based on either the passage of time or the level of activity (or use) of the asset.

Straight-line depreciation

Straight-line depreciation is the simplest and most often used method. In this method, the company estimates the salvage value of the asset at the end of the period during which it will be used to generate revenues (useful life). (The salvage value is an estimate of the value of the asset at the time it will be sold or disposed of; it may be zero or even negative. Salvage value is also known as scrap value or residual value.) The company will then charge the same amount to depreciation each year over that period, until the value shown for the asset has reduced from the original cost to the salvage value.

Straight-line method:

$$\text{Annual Depreciation Expense} = \frac{\text{Cost of Fixed Asset} - \text{Residual Value}}{\text{Useful Life of Asset}(years)}$$

For example, a vehicle that depreciates over 5 years is purchased at a cost of \$17,000, and will have a salvage value of \$2000. Then this vehicle will depreciate at \$3,000 per year, i.e. (17-2)/5 = 3. This table illustrates the straight-line method of depreciation. Book value at the beginning of the first year of depreciation is the original cost of the asset. At any time book value equals original cost minus accumulated depreciation.

book value = original cost − accumulated depreciation Book value at the end of year becomes book value at the beginning of next year. The asset is d epreciated until the book value equals scrap value.

Book value at beginning of year	Depreciation expense in year	Accumulated depreciation at end of year	Book value at end of year
\$17,000 (original cost)	\$3,000	\$3,000	\$14,000
\$14,000	\$3,000	\$6,000	\$11,000
\$11,000	\$3,000	\$9,000	\$8,000
\$8,000	\$3,000	\$12,000	\$5,000
\$5,000	\$3,000	\$15,000	\$2,000 (scrap value)

If the vehicle were to be sold and the sales price exceeded the depreciated value (net book value) then the excess would be considered a gain and subject to depreciation recapture. In addition, this gain above the depreciated value would be recognized as ordinary income by the tax office. If the sales price is ever less than the book value, the resulting capital loss is tax deductible. If the sale price were ever more than the original book value, then the gain above the original book value is recognized as a capital gain.

If a company chooses to depreciate an asset at a different rate from that used by the tax office then this generates a timing difference in the income statement due to the difference (at a point in time) between the taxation department's and company's view of the profit.

Declining-balance method (or Reducing balance method)

Depreciation methods that provide for a higher depreciation charge in the first year of an asset's life and gradually decreasing charges in subsequent years are called **accelerated depreciation methods**. This may be a more realistic reflection of an asset's actual expected benefit from the use of the asset: many assets are most useful when they are new. One popular accelerated method is the **declining-balance method**. Under this method the book value is reduced by a fixed percentage each year.

Depreciation in year = Depreciation rate * Book Value at start of year The most common depreciation rate used is double the straight-line rate. For this reason, this technique is sometimes referred to as the **double-declining-balance method**. To illustrate, suppose a business has an asset with $1,000 original cost, $100 salvage value, and 5 years of useful life. First, the straight-line depreciation rate would be 1/5, i.e. 20% per year. Under the double-declining-balance method, double that rate, i.e. 40% depreciation rate would be used. The table below illustrates this:

Book value at beginning of year	**Depreciation rate**	**Depreciation expense**	**Accumulated depreciation**	**Book value at end of year**
$1,000 (original cost)	40%	$400	$400	$600
$600	40%	$240	$640	$360
$360	40%	$144	$784	$216
$216	40%	$86.40	$870.40	$129.60
$129.60	$129.60 - $100	$29.60	$900	$100 (scrap value)

When using the double-declining-balance method, the salvage value is not considered in determining the annual depreciation, but the book value of the asset being depreciated is never brought below its salvage value, regardless of the method used. Depreciation ceases when either the salvage value or the end of the asset's useful life is reached.

Since double-declining-balance depreciation does not always depreciate an asset fully by its end of life, some methods also compute a straight-line depreciation each year, and apply the greater of the two. This has the effect of converting from declining-balance depreciation to straight-line depreciation at a midpoint in the asset's life.

With the declining balance method, one can find the depreciation rate that would allow exactly for full depreciation by the end of the period, using the formula:

$$\text{depreciation rate} = 1 - \sqrt[N]{\frac{\text{residual value}}{\text{cost of fixed asset}}},$$

where N is the estimated life of the asset (for example, in years).

Activity depreciation

Activity depreciation methods are not based on time, but on a level of activity. This could be miles driven for a vehicle, or a cycle count for a machine. When the asset is acquired, its life is estimated in terms of this level of activity. Assume the vehicle above is estimated to go 50,000 miles in its lifetime. The per-mile depreciation rate is calculated as: ($17,000 cost - $2,000 salvage) / 50,000 miles =

\$0.30 per mile. Each year, the depreciation expense is then calculated by multiplying the number of miles driven by the per-mile depreciation rate.

Sum-of-years-digits method

Sum-of-years-digits is a depreciation method that results in a more accelerated write-off than the straight line method, and typically also more accelerated than the declining balance method. Under this method the annual depreciation is determined by multiplying the depreciable cost by a schedule of fractions.

depreciable cost = original cost − salvage value

book value = original cost − accumulated depreciation

Example: If an asset has original cost of \$1000, a useful life of 5 years and a salvage value of \$100, compute its depreciation schedule.

First, determine years' digits. Since the asset has useful life of 5 years, the years' digits are: 5, 4, 3, 2, and 1.

Next, calculate the sum of the digits: 5+4+3+2+1=15

The sum of the digits can also be determined by using the formula $(n^2+n)/2$ where n is equal to the useful life of the asset in years. The example would be shown as $(5^2+5)/2=15$

Depreciation rates are as follows:

5/15 for the 1st year, 4/15 for the 2nd year, 3/15 for the 3rd year, 2/15 for the 4th year, and 1/15 for the 5th year.

Book value at beginning year	**Total of depreciable cost**	**Depreciation rate**	**Depreciation expense**	**Accumulated value depreciation**	**Book at end of year**
\$1,000 (original cost)	\$900	5/15	\$300 (\$900 * 5/15)	\$300	\$700
\$700	\$900	4/15	\$240 (\$900 * 4/15)	\$540	\$460
\$460	\$900	3/15	\$180 (\$900 * 3/15)	\$720	\$280
\$280	\$900	2/15	\$120 (\$900 * 2/15)	\$840	\$160
\$160	\$900	1/15	\$60 (\$900 * 1/15)	**\$900**	**\$100 (scrap value)**

Units-of-production depreciation method

Under the units-of-production method, useful life of the asset is expressed in terms of the total number of units expected to be produced:

$$\text{Annual Depreciation Expense} = \frac{\text{Cost of Fixed Asset} - \text{Residual value}}{\text{Estimated Total Production}} \times \text{Actua}$$

Suppose, an asset has **original cost $70,000**, **salvage value $10,000**, and is expected to produce **6,000 units**.

Depreciation per unit = ($70,000−10,000) / 6,000 = $10

10 × actual production will give the depreciation cost of the current year.

The table below illustrates the **units-of-production** depreciation schedule of the asset.

Book value at beginning year	Units of production	Depreciation cost per unit	Depreciation expense	Accumulated depreciation	Book value at end of year
$70,000 (original cost)	1,000	$10	$10,000	$10,000	$60,000
$60,000	1,100	$10	$11,000	$21,000	$49,000
$49,000	1,200	$10	$12,000	$33,000	$37,000
$37,000	1,300	$10	$13,000	$46,000	$24,000
$24,000	1,400	$10	$14,000	**$60,000**	**$10,000 (scrap value)**

Depreciation stops when book value is equal to the scrap value of the asset. In the end, the sum of accumulated depreciation and scrap value equals the original cost.

Composite depreciation method

The composite method is applied to a collection of assets that are not similar, and have different service lives. For example, computers and printers are not similar, but both are part of the office equipment. Depreciation on all assets is determined by using the straight-line-depreciation method.

Asset	**Historical cost**	**Salvage value**	**Depreciable cost**	**Life**	**Depreciation per year**
Computers	$5,500	$500	$5,000	5	$1,000
Printers	$1,000	$100	$ 900	3	$ 300
Total	$ 6,500	$600	$5,900	4.5	$1,300

Composite life equals the total depreciable cost divided by the total depreciation per year. $5,900 / $1,300 = 4.5 years.

Composite depreciation rate equals depreciation per year divided by total historical cost. $1,300 / $6,500 = 0.20 = 20%

Depreciation expense equals the composite depreciation rate times the balance in the asset account (historical cost). (0.20 * $6,500) $1,300. Debit depreciation expense and credit accumulated depreciation.

When an asset is sold, debit cash for the amount received and credit the asset account for its original cost. Debit the difference between the two to accumulated depreciation. Under the composite method no gain or loss is recognized on the sale of an asset. Theoretically, this makes sense because the gains and losses from assets sold before and after the composite life will average themselves out.

To calculate composite depreciation rate, divide depreciation per year by total historical cost. To calculate depreciation expense, multiply the result by the same total historical cost. The result, not surprisingly, will equal to the total depreciation Per Year again.

Common sense requires depreciation expense to be equal to total depreciation per year, without first dividing and then multiplying total depreciation per year by the same number.

Tax depreciation

Most income tax systems allow a tax deduction for recovery of the cost of assets used in a business or for the production of income. Such deductions are allowed for individuals and companies. Where the assets are consumed currently, the cost may be deducted currently as an expense or treated as part of cost of goods sold. The cost of assets not currently consumed generally must be deferred and recovered over time, such as through depreciation. Some systems permit full deduction of the cost, at least in part, in the year the assets are acquired. Other systems allow depreciation expense over some life using some depreciation method or percentage. Rules vary highly by country, and may vary within a country based on type of asset or type of taxpayer. Many systems that specify depreciation lives and methods for financial reporting require the same lives and methods be used for tax purposes. Most tax systems provide different rules for real property (buildings, etc.) and personal property (equipment, etc.).

Capital allowances

A common system is to allow a fixed percentage of the cost of depreciable assets to be deducted each year. This is often referred to as a capital allowance, as it is called in the United Kingdom. Deductions are permitted to individuals and businesses based on assets placed in service during or before the assessment year. Canada's Capital Cost Allowance are fixed percentages of assets within a class or type of asset. Fixed percentage rates are specified by type of asset. The fixed percentage is multiplied by the tax basis of assets in service to determine the capital allowance deduction. The tax law or regulations of the country specifies these percentages. Capital allowance calculations may be based on the total set of assets, on sets or pools by year (vintage pools) or pools by classes of assets.

Tax lives and methods

Some systems specify lives based on classes of property defined by the tax authority. Canada Revenue Agency specifies numerous classes based on the type of property and how it is used. Under the United States depreciation system, the Internal Revenue Service publishes a detailed guide which includes a table of asset lives and the applicable conventions. The table also incorporates specified lives for certain commonly used assets (e.g., office furniture, computers, automobiles) which override the business use lives. U.S. tax depreciation is computed under the double declining balance method switching to straight line or the straight line method, at the option of the taxpayer.[7] IRS tables specify percentages to apply to the basis of an asset for each year in which it is in service. Depreciation first becomes deductible when an asset is placed in service.