International Conference on New Horizons in Science Engineering Technology (NHSET-2018)
International Journal of Scientific Research in Computer Science, Engineering and Information Technology
© 2018 IJSRCSEIT | Volume 4 | Issue 5 | ISSN : 2456-3307

# Energy Conservation and Management with Power Conversion Techiques

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**Abstract**
In this paper, we will try to understand the effectiveness and potential of power electronics technology in the field of energy conservation. We will discuss the effect of power electronics control mainly in following four areas: (1) Buildings and lighting (2) power supplies (2) smart electricity grid (4) Industrial drives. European Union is hopeful of reducing their consumption of energy (mainly electricity) as much to 25%. To achieve this aim, we require removing technological challenges in these four areas and encouraging use of efficient and latest technology available in the market. Power electronics plays a key role in area of energy saving and should promote use of information technology techniques in making buildings and electricity grids smart.
**Keywords :** Power Electronics, Energy Savings,Smart Grid, Indistrial Application.

## I. INTRODUCTION

Today the topic related to energy savings and efficient use of energy is trending resulting in global awareness. We all know that there is a shortage of main energy sources like coal and petroleum and we are trying to shift from conventional energy sources to renewable energy sources. It will lead to reduction of carbon emission and other pollutants produced from thermal power plants and vehicles using petroleum as a fuel. To cope with ever increasing demand of energy, we need to identify opportunities where we can conserve energy rather than increasing number of power plants. Many governments have developed programs to increase awareness among the public. They are promoting the policies regarding use of high efficiency technologies as they provide good energy saving potential especially in fans, refrigerator, and variable speed drive and lighting systems. They have made standards like THD should be less than 15% in the source current. European Union has developed energy conservation plans which will lead to reduce the greenhouse gases, the consumption of energy by 20% each. They have also included plans to increase use of renewable energy sources by 20%. By promoting distributed generation, the carbon emission will also reduce. US government has increased the share and investment in programs related to research and development in manufacturing clean energy technology, distributed generations. They have developed policies to reduce the greenhouse gases emission by 28% in 2020. The developed countries are also promoting to use public transport facilities rather than using individual vehicles using petroleum as source of fuels. They are also using CNG gases or natural gases in the transportation. Use of Electric vehicles (metros) wills also reducing environment pollution. The program named “Cool Earth-Innovative Energy Technology Program” is revolutionary. It aims to reduce the greenhouse gases by half by year 2050 [1].

There are two challenges mainly for the governments (1) the increasing energy demand and shortage of fossil fuels (2) the climate change. To solve these challenges, we require innovative technologies, interdisciplinary research

and develop solutions like sustainable energy sources. Government has formed energy management teams and environment control department to ensure the industries following the standard measures. This team will audit and measure the energy use patterns and the carbon emission.

The use of electricity is increasing at an accelerating rate and will be doubled in coming 10-15 years. The use of energy per capita is also related to economy and GDP of the country. The power electronics control like variable speed drives and higher star domestic equipment (fans, refrigerator, heating appliances, and compressors) should be promoted. The power electronics converters can be used to control and condition the energy to load for better performance. Research is going in the field of power electronics field to improve the efficiency and time of response of converters by opting different topologies. The power ratings and speed of power electronics switches have been considerably improved by development of IGBTS, MOSFET, PUT (Programmable unijunction transistors. The PWM techniques are used to control the output voltages in inverters are latest advancement. These technologies are very much required to extract energy from renewable resources efficiently as they are intermittent in nature [1].

The energy saving capabilities of power electronics is very less known, so each industry employ energy managers to conserve and identify opportunities[2]-[8]. In this paper, we have presented what are the opportunities to conserve energy in four key areas where energy saving potential is high. By measuring the performance of these technologies will also provide data to detect faults and further development. As electricity is the most usable form of energy, we are trying to save electrical energy. We will try to see the energy consumption in these areas, what are technologies used to conserve energy and try to find the technological gaps and challenges.

## II. BUILDINGS AND LIGHTING SYSTEM

We have selected the following four areas on the basis of share in energy consumption and large potential of energy conservation.

### *A.* ENERGY CONSUMPTION PATTERN AND INTRODUCTION

Buildings are major share-holder in energy consumption as it consumes 40% of total energy. The buildings can be further classified as commercial, domestic and industrial. The examples of commercial buildings are banks, shops, and IT sector company buildings, schools, universities and government offices. The residential and commercial buildings account for more than 65% energy consumption. The cost of electrical energy (lighting, heating and air conditioning) during the life cycle cost is more than the construction cost invested and it is 40% of the total life-cycle costs. In residential and commercial buildings, fans, room cooling and heating, refrigerators and lighting are major components of energy consumption [1]. The characterization of different buildings can be formulated by these given formulas:

Domestic end use characterization for different segments as

$E_{bc,eu} = (HH_{bc})\ (SAT_{bc,eu})\ AEC_{bc,eu})$

E=energy consumption in kWh

HH=number of households

SAT=fraction of households owning end use

AEC=average energy consumption

Commercial consumer end use

$E_{bc,eu}$ =($SM_{bc}$) ($SAT_{bc,eu}$) ($EUI_{bc,eu}$)

Industrial consumer end use

$E_{it,eu}$ = ($TC_{it}$) ($SAT_{it,eu}$)

TC=specific total sector energy consumption

It=type of industry

### *B.* ENERGY SAVINGS TECHNOLOGIES

As the largest consumption of electricity is lighting, we will see how to use technological advancement in the field of lighting to conserve energy. Initially Incandescent lights are used in residents but they are not efficient. So, the European Union replaced these Incandescent lamps by more efficient bulbs which are Compact Fluorescent Lamps and incandescent lamps with halogen technology. Fluorescent lamps are 7-10% efficient in comparison to 1.5-2.5% efficiency of incandescent lamps.

In case of hospitals, we require higher density or high lumens like 5000 lux for operation purpose. The value of car parking system lumen is 5lux and 1500 lux will be required for fine industrial work. The development of HID (high-intensity discharge) lamps like high pressure sodium lamps can be used where we require large lumens in a large area of operation. Invention of LED light is revolutionary as it is considered green lighting system but provide harmonics in supply system. The next generation lighting system will be dominated by LEDs. These new technologies like HID lamps and fluorescent lamps have to be used in series with current controlled ballasts.

In LEDs, MIT is trying to use Ga-N in silicon semiconductors so that the current will flow more efficiently. They are also trying new magnetic structure to cut the cost to 50% of earlier cost.

### *C.* ENERGY SAVINGS POTENTIAL

The technologies to control the flow of air and water rates in different pumps and fans applications should be replaced by use of Variable Speed Drives as it is the most energy efficient control technique. The use of control strategy with variable speed drives provides less power consumption and will match to actual requirement by condenser pumps. The load will be predicted by intelligent control by comparing with seasonal data like room temperature, quality of air and user behavior. The intelligent control can be wireless so less cost and no maintenance. Intelligent home system should use sensors to see when to switch on light, the level of air conditioner and refrigerator by inspecting the surrounding temperature [1].

Traditionally hydraulic lifts are used. It can be replaced with the help of electric traction with speed control can save 50% energy. The motors used for the purpose should of high ratings and efficient. The power consumption should be controlled by amount of load present.

## III. POWER SUPPLIES

### *A.* ENERGY CONSUMPTION PATTERN AND INTRODUCTION

First of all, we try to know what power supplies are. Power supplies include the converters like load converters, source converters and distribution line converters [1].

1) Source Converters: examples can be cited as voltage source converters or current source converters used to improve the performance of the system and according to type of load, they feed the system. They can be employed for control purpose to get maximum efficiency out of the system. Typical examples are MPPT in solar panels and battery power management in case of stand-alone PV system.

2) Power Distribution Converters: A reconfigurable power topology has been chosen which normally works as a series voltage conditioner and a parallel current conditioner linked by a common DC bus. In case of a line outage, the current conditioner acts an an inverter which is able to feed 30% of the nominal load during 200 ms. It is considered that this short storage time can eliminate more than 90% of the line outages.

3) Load Converters: It can improve the performance and avoid faults by fulfilling the requirements of load. The conditioning of voltage and current reaching the load according to requirements will improve the efficiency of the system. Example: electric traction will receive as much level of current and voltage as the percentage of load is present.

To obtain higher efficiency, it is advisable to design the power supplies at different levels and according to their role designated in the system. Example of lift can be given where source power must be extracted as function of load. As today it is era of power electronics control, it will be great step in energy conservation plan.

*B.* ENERGY SAVING TECHNOLOGIES

Data centers are huge potential of energy savings in case of power supplies [1]. In European Union It is predicted to have an increment to 104Twh till 2020. The main load in data centers are computers which consist of hard disks, microprocessors, UPS and CPU. The main cooling system and conversion system also consume a considerable amount of power. The desired result of better of efficiency can be obtained power management as function of load. The microprocessor and power electronics intelligent control interface helps in power management which provides the facility to prioritize the features and application to be used during low power supply. The power consumed in a microprocessor is dependent on its voltage and frequency. So by modifying the frequency and voltage level with the help of power electronics converter as function of load, overall improved efficiency is obtained. The improved efficiency can be up to 24%.

A radio base station with an output voltage 120W has a overall efficiency of less than 1.5% as shown in fig.1.

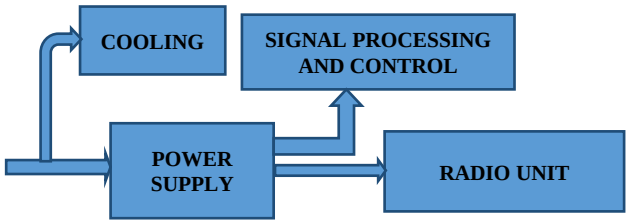


Fig. 1: Radio station block diagram

More than 40% of total power consumption is consumed by the power amplifier and in performing signal processing, DSP unit also consume 2.3kW. These two units uses power electronics switches but lesser efficiency. The ac power is rectified to feed to the radio station at poor efficiency (about 85%).

GaN High electron mobility transistor devices can be used in the place of silicon transistor so that the conduction losses will reduce. GaN can be used at microwave frequency at better efficiency in comparison to other technologies.

### *C.* ENERGY SAVINGS POTENTIAL

The integration of microprocessor with advanced and fast power electronics devices will lead to reduction in energy losses by at least 14%. The proposed new DC distribution architecture, advanced power electronics devices (efficient) and adaptation of pulse frequency modulation will provide good opportunities of energy conservation in this area.

## IV. SMART GRIDS WITH ELECTRIC VEHICLE INTEGRATION

### *A.* ENERGY CONSUMPTION PATTERN AND INTRODUCTION

We are expanding the plan related to electrification of the whole nation. We will see the increasing trend of electricity as it will be used in all segments of life and integration of vehicles to grids is also proposed. In the next decades, we will witness at least 70-80% increase in electricity consumption. The share of renewable energy sources will increase as shown in Fig.2 but conventional energy sources will continue to be the major contributor [1].

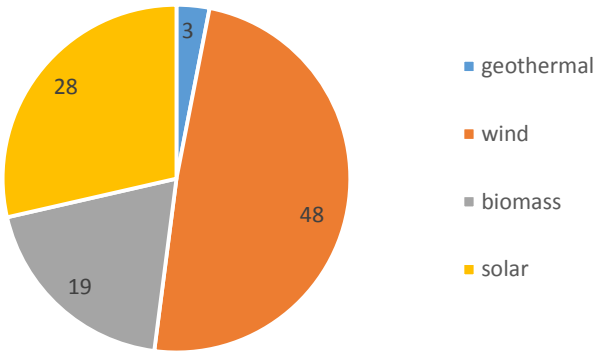


Fig. 2 Percentage share of different renewable energy source

The total energy contributed by these renewable sources is 600TWh which is 3-4% of total energy consumption. The shortage of fossil fuels and environmental conditions are pushing us for opting less concentrated sources like wind energy conversion system, photo-voltaic cells. These energy sources are clean but the efficiency of these sources are quite less. In wind energy conversion system, we are making advancement by adaptation of power electronics control and better efficient generators. The different topologies are proposed for WECS. The MPPT algorithms for extracting the maximum energy from both PV cells and Wind energy system require the use of power electronics semiconductor devices and microprocessors. We are putting steps forward for a smart grid with IT technologies and distributed power generations systems.

The smart grids will be promote the idea of distributed generations. The integration of renewables sources and adding the Information technologies and net metering system will provide efficient and reliable smart grids. The integration of large scale public transport (electric vehicles) is also a feature of smart grids. It provides solution to ever increasing fuel prices and the climate situations. The developed countries are investing a lot of money in the area of plug-in electric vehicles on the road by year 2020.

### *B.* ENERGY SAVING TECHNOLOGIES

The key features of Smart Grids are (1) Integration of distributed generation system (2) improvement in index like reliability and efficiency (3) Demand Response (4) Plug-in Electric vehicles

Power electronics will play a crucial role in the Wind Energy Conversion Systems integration to the grid [2-8]. It is an intermittent source of energy and variable speed generators like squirrel cage induction generator or wound rotor induction generator can be employed [5]-[8]. Power electronics will required for the matching purpose (characteristics of grid and wind turbines). For applying the MPPT algorithm, we require the use of power electronics converters like chopper or rectifier. Power electronics can also be used to control frequency, active power and reactive power control [1].

Photo-voltaic cells require the converters for converting the DC output of cells to AC to feed the AC grids or utility. MPPT algorithms can be employed to extract maximum power from the solar arrays. For using MPPT algorithms, there are different topologies in application like centralized technology, Multi-string technology; string technology and latest one are AC modules technology. In these all technologies, we are using inverter and chopper for better control of power and efficient conversion of power. It is also seen that by using the MPPT, the effect of shading can be reduced to 50%.

The latest technology in EHV transmission is HVDC. In this HVDC, we are using high ratings converter station. The latest technology in FACTS devices are STATCOM and SVC. The government is planning for the Electric vehicles but that will require charging of EVs [1]. Batteries are crucial part of these plug-in Electric Vehicles. So, we can try to adopt the demand side management to charge the batteries during night hours at which surplus energy can be provided to them by the grids. The EHVs are quite large loads, so to maintain the reliability of the grids, we need to exchange information and bi-directional energy flow between the EVs and grids. It can be enabled by use of power electronics devices.

### *C.* ENERGY SAVINGS POTENTIAL

The consumption pattern in city and highway for a mid-size Sedan passenger vehicle is provided in the fig. 3. Here a comparison is shown between diesel and petrol engines with corresponding hybrid vehicles are also presented in fig. 4. About 50% reduction in fuel consumption is achieved in city areas [1].

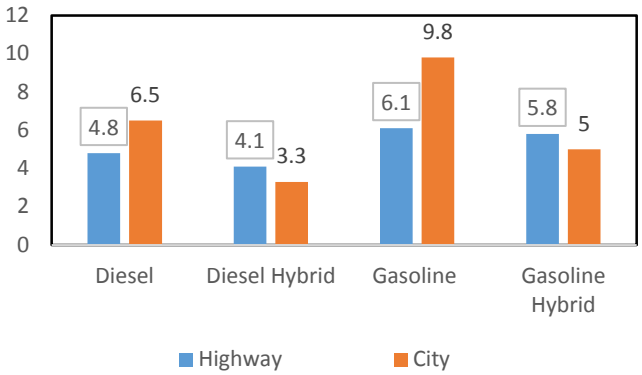


Fig. 3 Energy consumption pattern of vehicles in city and highway

The efficiency of ICE (Internal Combustion Engines) car is given only 12% as it uses inefficient mechanical motors. The ICE has an efficiency of 35% in case of highways and less than 20% in case of city. When It comes to clean source of energy, one will also side-line the convention mechanical vehicles and accepts electricity [1].

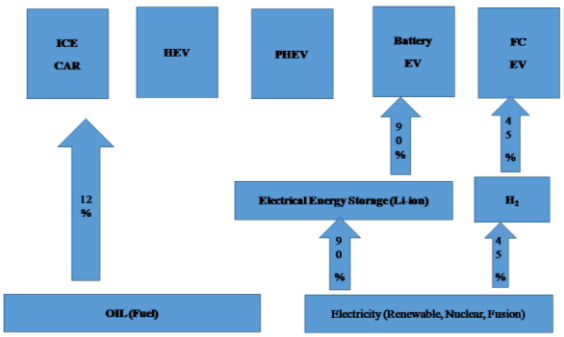


Fig. 4 Various transportation vehicles comparison

## V. INDUATRIAL DRIVES

### *A.* ENERGY CONSUMPTION PATTERN AND INTRODUCTION

The industrial drives are with electric motors with its control equipment and energy transmitting component is the backbone of our industrial development [1]. The low power industrial drives like fans, compressor and mixer, medium level industrial drives like traction and lift, large power rating drives used in cranes, trains and ships. It may be said that almost 65% of industrial electric energy is consumed by motors only. In residential sector, Industrial drives uses almost 13.2% of total energy and in commercial sector, it is about 11.3% which shows the importance.

### *B.* ENERGY SAVING TECHNOLOGIES

Use of variable speed drives will be more efficient if it replaces fixed speed drives according to load. Automation and advanced control system is now replacing the unintelligent drives. The main components in a variable speed drives are power electronic converters that is able to supply variable frequency input voltage to the motor to adjust or regulate its speed. These VSDs are economical as free maintenance, auto-adjustable and reduced operational cost (energy). In variable torque loads, if the speed is cut-down to 50%, the energy demand will go down to 12-15%.

*C.* ENERGY SAVINGS POTENTIAL

If VSDs will replace 40-50% of all motors used in industrial domain, the total energy saving potential is predicted is about 30-40% which is quite significant amount. As VSDs also reduce the operational energy costs, Its life cycle costs is also reduced. Energy saving potential for different segments have presented in table 1 [1].

Table 1: Energy saving potential across different segments

| Application | Electricity Consumption(in Terms of % of total) | Electrical Energy Saving Potential | Energy Saving Potential as % of total energy |
|---|---|---|---|
| Motor Control Industrial Application Appliances, Lifts Traction Drives | 50% | 30-40% | 5-6% |
| Lighting | 21 | >70% | >14% |
| ICT<br>Data Centers<br>Radio Base Station<br>Standby Consump | <br>2%<br>1%<br>4% | <br>50%<br>30%<br>80-90% | <br>1%<br>0.3%<br>3.6% |

## VI. CHALLENGES AND TECHNOLOGY GAPS

*A.* BUILDINGS AND LIGHTING

A number of solution and advancements are made in lighting systems but here are some barriers to which engineers should surpass to penetrate market for new efficient technology [1].

- The latest bulbs must be available at low price, so that people can afford them.
- LEDs are best among all lighting bulbs. People must be able to use them without cooling system.
- Building must be according to government policies or we should promote green building or smart buildings. Companies should reduce the maintenance and installation cost.
- We should promote high efficiency LEDs drivers, solid state lighting, and electric actuators.

*B.* POWER SUPPLIES

The main challenge in this case to develop technology such that it can adapt according to the mode of operation and should supply voltage and current level according to function of load.

- Try to develop chips in which local power management (power supply on the same chip) is possible.
- To reduce the standby losses, it requires to perform research work in the field of circuit and technologies which provide low leakage.
- The development cost associated with efficient power modules is quiet high. To follow the communication protocols and proper utilization of space, R&D should be engaged in this field.

• Automation should be applied in distribution field. Auto correction of system after detection of fault will be required for better reliability.

*C.* SMART GRIDS WITH ELECTRIC VEHICLE INTEGRATION

Replacement of unidirectional grids with centralized power system with bi-directional grids with distributed power system (renewable resources) needs a complex control facility as any components failure will assure the system failure. This is actually a step forward to smart grids but it will take long time as integration of large grids, thermal power plants, wind power generation farms, PV cells is not a handy task.

• As the number of intermittent renewable sources will added up to the existing system and there is no correlation between the load and generated power will create transmission and distribution problems.

• Load sharing, supplying surplus energy to batteries, demand response and balancing the load and generation will be a quite tough as number of loads is increasing.

• Integration of Electric vehicles and plug-in EVs will be an additional load to distribution systems. It will affect the reliability and power quality of the supply system.

The development of low loss transmission lines over long distance will be a challenge. Introduction of HVDC is a solution but we need further developments.

Bidirectional energy flow should need latest measuring equipment [1]. Management and control of super-grids and micro-grids, control of power flow from generating plants located remote and far from local population and loads. Electric vehicles charging management and integration to grids are also a big challenge. We require multi-level power conversion for HVAC systems and soft switching topologies (solid state transformers) for higher efficiency distribution purpose.

*D.* INDUSTRIAL DRIVES

• Development of new solid state materials like GaN, SiC that will allow less losses and are able to withstand higher temperatures. Development of new insulation materials and power capacitors goes with high operating temperatures. Thermal management leads to control over heating losses, cost.

• Development of wireless communication with self-powered sensors will help in identifying the load, intelligent control for drives.

• In industrial drives, avoiding the use of gears, transformers and filters are main challenges.

• Redundancy concepts and analyzing the system reliability and robustness including the design for reliability are under development and main challenges.

## VII. CONCLUSION

In this paper, we have dealt with the energy saving potential with the help of power electronics system in four key areas. As the application of power electronics devices goes wider, we will see the effect of these devices. In the area of renewable energy, we need power electronics devices for better control and enabling the maximum power extraction from source. The converters are quite important in the field of power system and should be replaced by efficient power electronics devices to save the energy. The new integration of control system with the help of microprocessor, digital sensors with power electronics is a major challenge to us. However, only by

implementation of these latest power electronics technologies, will not lead to sustainable energy. The economy, policy and customer acceptance will also require. The government and international agencies are working in formulation of standard and policies to reduce the environmental effects and preserve the ecological balance. The cost of purchasing and installation is also a major drawback in adaptation of latest technologies. The presence of economic barriers, still these technologies have shorter payback period. Public acceptance and attitude towards the utilities are crucial factors. Media campaign and effect of service will be able to change the mind-set of consumers.

## VIII. ACKNOWLEDGMENT

The paper was supported by Science and Engineering Research Board (SERB), Department of Science and Technology (DST).

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