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Energy Saving on Industrial Drive Technologies - Past, Present, and Future Perspective

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Abstract. Power is a crucial factor in sustainable economic development and growth, the world is facing the obstacles to pass towards a cleaner and more accessible route for utilization, a recent review of new developments in the energy-efficient sectors, concentrating on selected innovations instead. Efficiency of energy for various application, enhancing the productivity, performance and precision. At the same time, using the energy efficiently on any industrial applications reduces the operation cost, therefore adopting suitable energy efficiently to the system in a conventional profit. Also, there is no limit for innovation of new energy saving technologies. These technology is defined by in terms of their energy efficiency, economy and performance in the environment. This paper provides an overview of energy savings on industrial drive technologies, sustainable economy and the environment, are going to be running out of technologies in the future.

1. Introduction

Energy is the primary source of power to our lives. Power has an influence on the economic and social development of the nation in modern society. Due to instant availability, controllability, flexibility and cleanliness, electric power plays a prominent role in [1-2]. Over the last few decades, electrical energy has led to human well-being, growth and technological advances. Adequate generation of energy and proper use of electrical energy improves industrial investment in a country that results in gross domestic product (GDP) production [3-6]. The motor drives of modern global industry are the backbone that is well covered, but also play a major role in industries which often improve the world with our environment more sustainable. Electrical energy produced at any time must be used by the consumer within a small period of time. In figure 1 the sector wise energy consumption is mentioned, the Electric power transmits through grid, and current distribution is centered on line impedance [7-10].

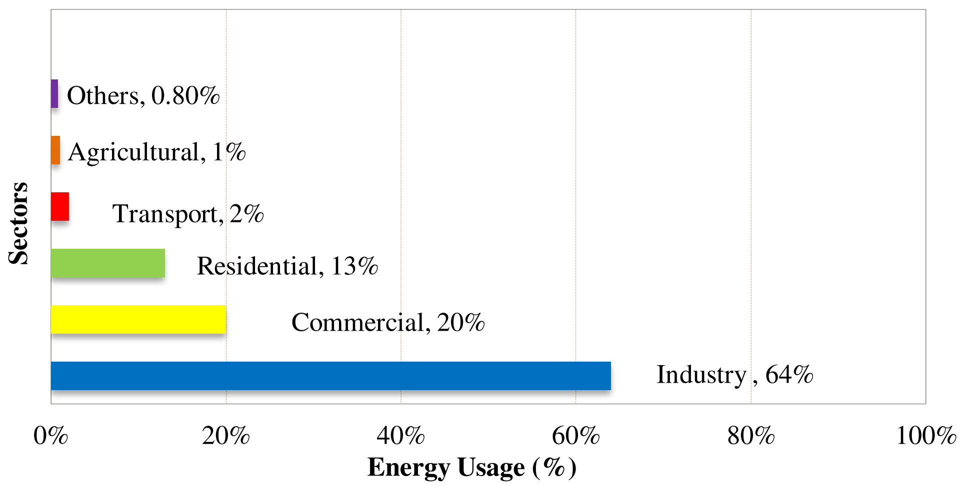

Figure 1. Sector wise energy consumption

In general, drives are commonly used for various application especially, fan, pump, compressor [11-12]. Similarly, the drives are adapted to perform any one of the function, speed control, process control in AC drives, high velocity drives, continuous frequency drives, VSD, frequency converters, power converters and inverters, By varying the frequencies and voltage of the power supply to an electric motor [13], drives can control the speed, enabling process control to be enhanced, reducing energy utilization and producing energy reliably or controlling the function of industrial applications based on electric motors [14-15].

1.1. Electric Drives for Industrial Application

Electrical drives are widely used in manufacturing industries and process industry to regulate the speed and to enhance the efficiency of the system. Such specifications are used to assess the demands for horsepower and torque. Owing to low starting torque requirements reduced voltage starters can be used [20].

Table 1. Industrial Drives Application

Industry	**Application of Drives**	**Motor Type**	**Year & Citation**
Petrochemical industry	Energy savings and process control optimization.	Three phase induction motor	2002 [5]
Pharmaceutical industry	Minor alterations in the Design stage and improve the energy efficiency	Brushless DC, AC squirrel cage, wound rotor, stepper and servo motors.	2003 [13]
Textile industry	Controllers in energy saving.	Induction motor	2007 [1][17]
Steel industry	Reduced maintenance costs and saved a considerable amount of electricity.	AC Synchronous motor	2008[2][18][19]
Petrochemical industry	Reduced Total Cost of Ownership and improve energy efficiency.	Three phase induction motor	2008 [4][21]
Cement plants	Compare the operational characteristics of the induction, synchronous and DC motors.	Squirrel cage induction motor	2009 [9]
Mineral products industry	Converting DC systems to AC systems	AC synchronous motor	2014 [8]
Garments industry	Reduce emissions for different energy-saving schemes.	Brushless DC/ induction motors	2016 [14][26]
Iron and steel industry	Improvement of performance and more energy-efficient	AC Synchronous motor	2017 [3]
Oil, petrochemical, pulp industry	Fans are using air exchange, drying / cleaning purposes.	Induction motors	2018 [6][22]
Paper industry	Reduce the energy input and improving energy efficiency	Induction motors	2019 [7][23]
Mining industry	Improving its sustainable and efficient industrial operating.	Induction motor	2019 [12][25]

1.2. Industrial Revolution

Industrial Revolution, in modern history, the trend of moving with an agriculture and economy driven by manufacturing industry and machinery. That process started in the 18th century in Britain and expanded to other regions of the world from everywhere.

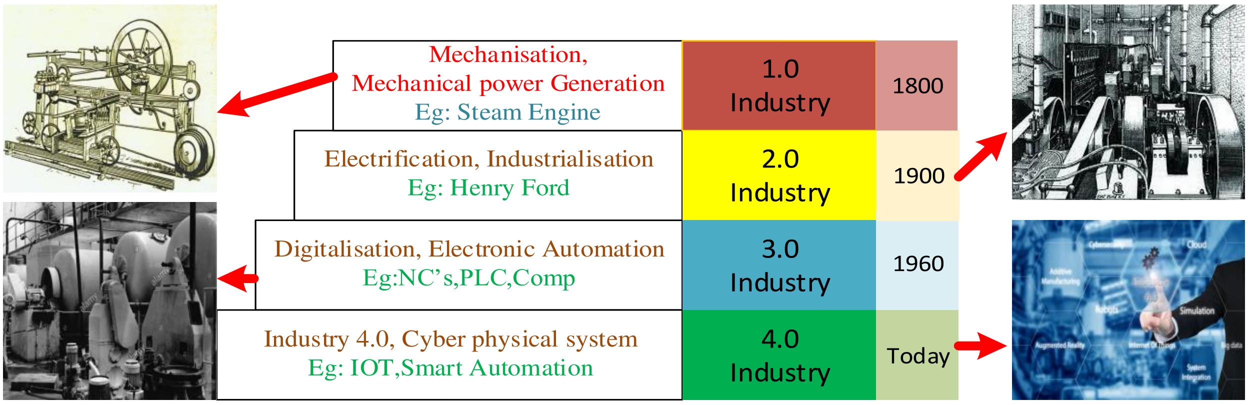

Figure 2. Stages of industrial revolutions

The main features of a four industrial revolutions are the first industrial revolution are transformed our economic and lives from the agricultural field and manufacturing economics to a production and machinery-dominated economy. The initial manufacturing revolution introduced in 1760 when the steam machine was invented. The second manufacturing revolution began in 1900 when the inner burning engine was invented. In 1960 the third industrial revolution began to be characterized by the use of microchip technology and IT for automating manufacture. The Fourth Industrial Revolution describes a future in the people turn from virtual worlds to offline reality using connected technologies to make life possible and controlled and also it includes computer-generated product design and 3D printing which can build up successive layers of materials to produce solid objects are shown in figure 2 [16].

Over the past few decades, public awareness of environmental concerns has led to a strong focus on topics such as resource-efficient, and energy-efficient development in both research and industrial applications. Numerous studies were performed, evaluating the energy usage of manufacturing environments from different perspectives. Among other things, the results showed substantial energy consumption during periods of non-value adding, i.e. during times when production equipment is stopped or idled, for almost every considerable way of classifying machinery and in almost all major manufacturing industries.

A method was designed to provide a standardized collection of possible energy-saving states for the production equipment, clustering these states according to the commonly applicable equipment behaviour. Improving energy efficiency and increasing demand for energy are commonly seen as the most promising, fastest, cheapest and safest means to mitigate climate change. Most incentives tend to be cost-effective at current levels of energy, and can provide additional benefits such as increased fuel poverty reduction and increased economic productivity. As a result, the International Energy Agency (IEA) and other organizations are placing their priority on reducing energy demand, the European Commission has set long-term targets to reduce energy demand, and countries around the world are implementing a range of policies to achieve those reductions.

1.3 Energy Conservation on Industrial Drives

Energy saving means by reducing energy demand by means of a smaller amount of an energy used. Although energy saving reductions vitality properties, it can contribute to improved quality of the climate, national security, individual financial protection and advanced savings. Energy saving is a significant element of vitality policy on a broader scale [24]. Vitality competence is also greatest economical approach to power losses. Energy saving is certainly of great position to us all, because its depend on energy for all the day [1]. Energy is generated – this is equal to 2 units of energy created its save one unit of energy. Saving energy to reduce pollution – generating and utilizing energy accounts for a large amount of air pollution and extra 83% of greenhouse gas emission productions [26-28]. If the highest of the ladder for renewable energy. It also reducing the energy costs and potential depletion of resources. Resource can be conserved by reducing waste and losses, increasing efficiency by technological changes, and improving the operation.

2. Energy Efficient Strategies on Electric Motor Drives

The manufacturing sector consumes more energy for all other end-use areas and this industry actually absorbs nearly 20% of the universe total energy supply. Energy is used in the manufacturing area by a diverse business population, including manufacturing, forestry, mining and construction, and for a wide range of activities, including production and assembly, room conditioning, and lighting [30]. The various energy efficient strategies are discussed in figure 3.

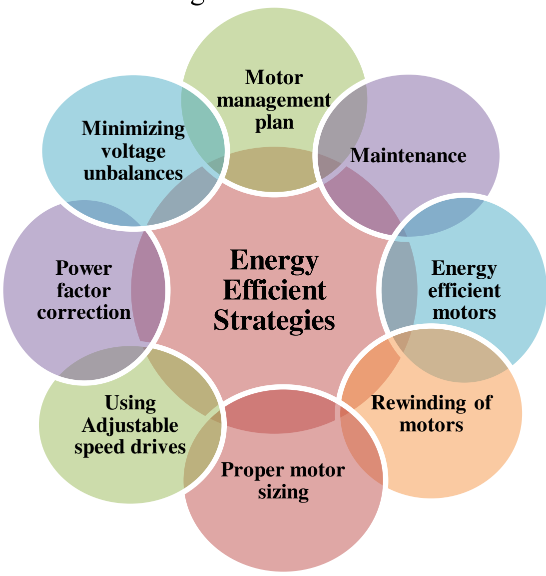

Figure 3. Energy efficient strategies

2.1. Management Plan of the Motor

An engine controlling system is the important share of a company's energy managing plan. The implementation of an engine management plan would help companies achieve long-term energy savings in the engine system, which will ensure efficient and cost-effective control of motor failures.

2.2. Maintenance

Motor preservation objectives remain to extend motor lifetime and anticipate a malfunction in the engine. Therefore, motor maintenance steps may be considered as either predictive or preventive. Preventive steps contain minimization of power inequity, awareness of weight, alignment of the motor, lubrication and ventilation of the engine.

2.3 Energy-Efficient Motors

Efficient power engines minimize the energy consumption by improved construction, improved products, tighter tolerances and advanced production techniques. Energy-efficient motors can also stay warmer with proper installation, can also decreasing heat loads on the facility and have extreme duty numbers, longer containing life, longer life span of insulation and much less noise.

2.4. Rewinding of Motors
For certain situations, rewinding a current, energy-efficient engine can be cost-effective, rather than purchasing a new engine. When repairing or rewinding an engine, it is critical to select an engine facility center that meets best preparation motor reversing standards to reduce possible losses to performance. The rewinding is applied efficiency losses are typically reduced less than 1%.

2.5. Proper Size of the Motor
Its common misconception that huge motors, particularly engines working less than 50 percent of the valued load, are not effective and must be directly changed by energy-efficient components of sufficient size. In fact, it takes many pieces of information to complete an accurate evaluation of energy saving.

2.6. Adjustable Speed Drives
Its ideally suited to load supplies for engine processes, thereby ensuring the engine energy usage for customized by particular uses. Because is motors' vitality consumption is about comparative flow rate cube, relatively small movement decreases, proportional to the pump speed, still result in significant energy savings.

2.7. Power Factor Correction
Energy metric is really the proportion of power delivered and work-time. That tests how power generation is being used properly. A high-power factor signifies a successful use of electric energy while a low-power factor implies inefficient use of electrical energy.

2.8. Minimizing Unbalances in Voltage
An imbalance in voltage reduces the presentation of three-phase engines and shortens their life. A voltage imbalance produces a current imbalance, resulting in rotation pulses, improved pulsation and mechanical strain, augmented losses, and motorized warmness, which container minimize the lifetime of the engine's winding protection.

3. Trends in Energy Saving
Energy efficiency has massive potential to boost financial growth and reduce greenhouse gas emissions, but a trend which has major impacts on people, companies and the environment is slowing the global rate of progress. The energy sector continues to turn its attention to energy efficiency with rising regulations. Industrial energy use remained roughly constant at EU level and since then has fallen rapidly twice as fast as industrial activity in figure 4[3].

Figure 4. Global renewable energy trends (source: https:www.deloitte.com)

3.1. Past Trends in Energy Saving

An analysis of these remarkable achievements helps explain both the factors its inspiring the combined motor drives and contemporary expansions in power electronics expertise that complete those induction motor drives (IMDs) possible. Such advancements are listed in a roughly sequential instruction to type it informal to classify the evolution of the expertise that has complete building more advanced IMDs technologically feasible [11].

3.1.1. Automotive Alternators

Moreover, the industrial inverter chosen for its first instance may not classify as an incorporated drive system but are included in this segment as it provides an essential reference to the following IMDs. Additional precisely, in an unregulated full-wave bridge configuration, the power electronics consists of 6 (or more) diodes short of any measured control buttons required to create variable-frequency ac power waveforms. The close connection with automotive generators and IMDs relates to the fact that the diode devices are mounted inside the alternator framework in areas close to the Lundell claw-pole synchronous alternator assembly, introducing both to a higher heat and vibration factors to follow this charging design.

3.1.2. Blower Fan Drive Electronically Commuted Motor (ECM)

Some of the initial main IMD devices designed for a residential usage in applications for boiler, ventilation and air preparing (HVAC), the Electronically-Commutated Engine, primary published as a creation in 1987. The ECM was intended aimed at usage in housing and bright profitable HVAC devices such as heater blowers anywhere they offered a way to improve the overall efficiency and comfort of the furnace system by in case adjustable-speed air flow to the active places rather than traditional on-off thermostat created regulator through a fixed-speed line.

3.1.3. Submersible Water Pump

Installing the motor and drive in the underground submersible pump unit enabled the control cabling essential in the well shaft to be reduced although using the impelled water as an abundant then efficient refrigerant for the motor and electronic drive.

3.1.4. Industrial-Grade Integrated Motor Drives

Modern motor drive manufacturers have produced combined motor drive product lines that are designed for overall industrial uses such as pumps and fans / blowers that result from adjustable speed operation in performance improvements and energy cost savings [31].

3.2. Present Trends in Energy Saving

By integrating solar energy systems for hot water and producing electricity, we achieve a further reduction in energy consumption. Recently there has been an increasing trend in the integration of solar photovoltaics in buildings.

3.2.1. Design of Energy Efficient Motors

Efficiency has a direct impact on energy consumption and the conservation of energy. Motor charging, relative to full load, affects the motor's efficiency and overall performance. The efficiency can be increased by reducing losses which can be a combined effect of decreasing the number of turns, increasing the size of the conductor and increasing the length of the core causing an increase in the efficiency [32].

3.2.2. The Generation IMMD with GaN-Based Power Electronics

Its benefit of GaN power devices benefit the third-generation IMMD prototype systems to reduce inverter form and capacity, with advanced changing frequencies then lesser conductive damages. The

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prototype IMMD unit also uses a 6-phase ac system like the aforementioned 2nd generation IMMD, except it is an induction system in this case. Another distinction between the two models is that the 3rd generation con- figures the sequence of 6 pole-drive elements into binary full-bridge 3-phase inverters, rather than parallel ones. It allows GaN devices to be used with lower voltage levels, raising the system's on-state resistance and conduction losses. Since this energy electronics package is placed on the outer external of the finish bell of the motor designed for easy watching short of disassembly, the energy electronics has remained suitably reduced towards be compatible by the inserting in the finish bell cavity of the motor short of at all alteration in the measurements of the housing an evaluation of the 2nd and 3rd group IMMD prototype elements therefore delivers substantial indication of the optimistic effect of elegant WBG established energy electronics on the forecasts of attaining fixed energy electronics in upcoming IMDs.

3.2.3. Current Source Inverters enabled by WBG

A stated in Unit V.A, new WBG control semiconductors made from silicon carbide(SiC) and gallium nitride (GaN) are attractive accessible which can turn additional 10 times earlier than their silicone equivalents. The research communal is highly optimistic that these new WBG control switches that bring significant benefits to the uses such as IMDs, which urgently need breakthroughs leading to smaller , lighter, and more powerful electronics.

3.3. Future Trends in Energy Saving

Evaluates or findings that suggest an operator change and to analyse driver patterns to have a sense of where the industry is going, EPRI will track developments on a routine basis, finding significant changes that may suggest a major effect on scenarios, drivers, global perspectives, or the Interconnected Energy Network.

3.3.1 Ultra-efficient Heat Pumps

Stepping up energy efficiency will be needed as global demand for energy continues to rise. The technology chances are endless and possible real investments, but so far customers and values have remained measured to capitalize in the maximum economical, energy-efficient machineries. In-use houses, electrical equipment, and devices' energy efficiency is well short of what is theoretically achievable.

3.3.2 Variable Speed Drives

The AC induction motors translate the electrical energy into mechanical and other types of usage. Therefore, about two-thirds of the electrical energy is fed to the world's motors for this reason. And the

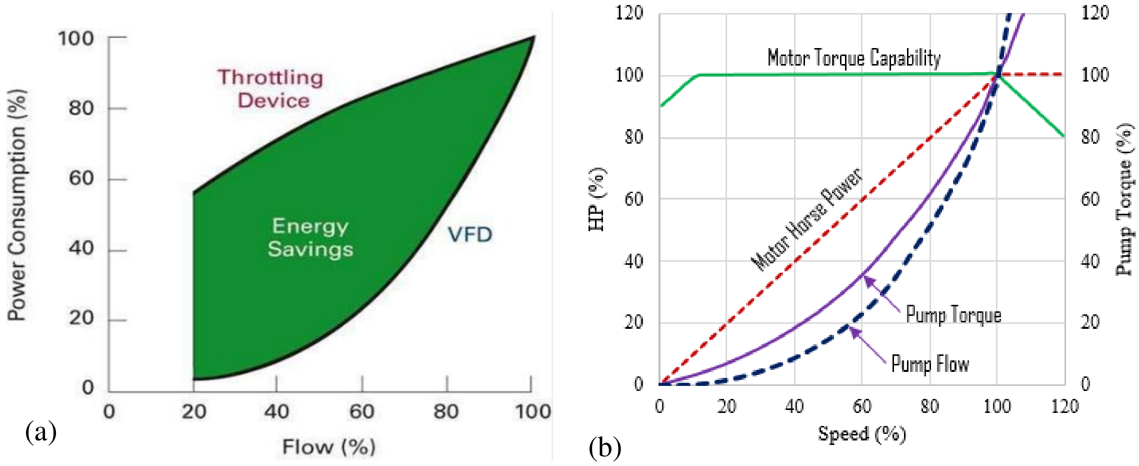

Figure 5. Pump energy curves (a) Power savings using VFD, (b) Pump Affinity Laws

big restriction is energy efficiency for motors. And this energy saving is accomplished largely by the use of variable frequency power. In general, three types of major load applications are classified as variable torque type load, constant torque type load and constant Horsepower type load [29]. VSD control, using inverter technology, it allows the regulation of starting inrush currents, the management of specific fixed speeds, quick change of speed and the reversal of AC motors. Such types of electric motors are responsible for a significant part of energy usage in manufacturing, operating in combination with fluid-moving machinery such as pumps, fans, compressors etc [33]. Most variable torque drives have Proportional Integral Differential (PID) capability for fan and pump an application, which allows the drive to hold the set point based on actual feedback from the process, rather than relying on estimation. High levels of accuracy for other applications can also be achieved through drives that offer closed-loop operation. Closed-loop operation can be accomplished with either a field-oriented vector drive, or a sensor less vector drive. The field-oriented vector drive obtains process feedback from an encoder, which measures and transmits to the drive the speed and/or rate of the process, such as a conveyor, machine tool, or extruder. The drive then adjusts itself accordingly to sustain the programmed speed, rate, torque, and/or position Variable speed drives, on the other hand, gradually ramp the motor up to operating speed to lessen mechanical and electrical stress, reducing maintenance and repair costs, and extending the life of the motor and the driven equipment[6].In variable torque applications, the torque required varies with the square of the speed, and the horsepower required varies with the cube of the speed, resulting in a large reduction of horsepower for even a small reduction in speed[7] [8].The motor will consume only 12.5% as much energy at 50% speed than at 100% speed as shown in Figure 5 (a) and (b).

3.3.3 *Energy Efficient Motors*

IE3 & IE4 Motors have high efficiency at any ambient temperature. Hence these are costly than IE2 Motors. The materials cost of the motor is increased by a few percent. While trying to reduce copper losses, we end up increasing core loss. Hence the starting current of motor is high, it may increase fault levels and in turn cable size. The disadvantages are overcome as the payback period for the customer can be as little as six months for a continuously loaded motor. Through improving architecture, improving materials and improving production techniques, the energy-efficient electrical motors decrease energy losses. Replacing an engine may be defensible based on the fuel cost savings resulting from an energy-efficient model. It is correct if the engine is constantly running, the power levels are great, the engine is overweight for the mission, or damage or past rewinds have reduced its nominal performance.

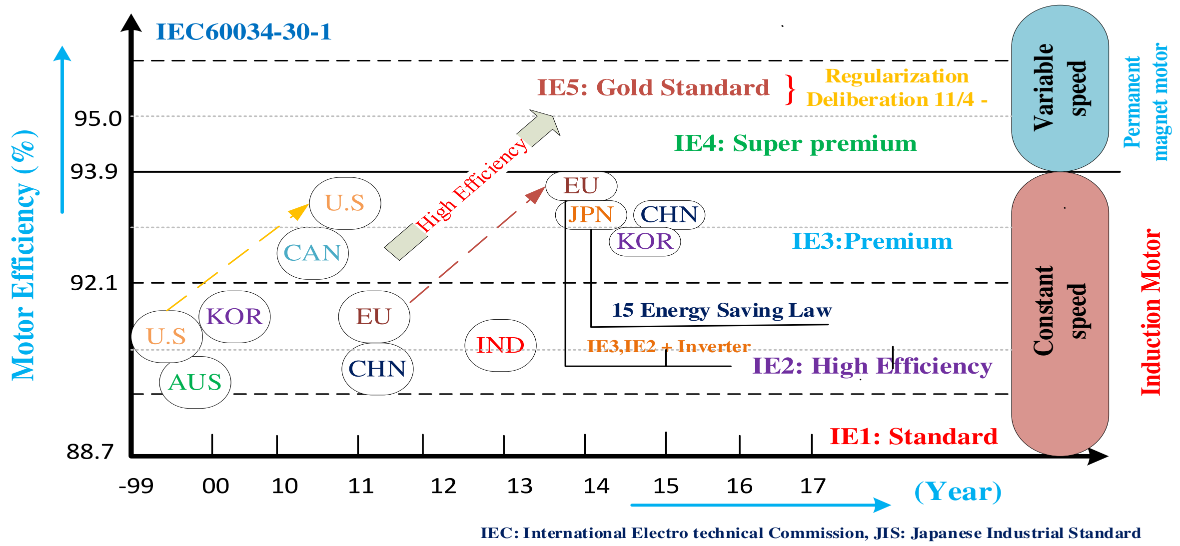

Figure 6. Movement of regulation of motor efficiency

It also has good performance as under loaded as compared with the IM, and has higher torque density and overload capacities the movement of regulation of motor efficiency are shown in figure 6. When less heat is produced inside, it is easier to refrigerate. Syncrel has another important benefit when it is required to substitute the normal motors with energy efficient ones. Since the high efficiency IMs at the same parameters are larger than the regular ones, the high efficiency SyncRels have the same height of the centerline shaft as those to be replaced. The upgrade is therefore simple and quick, without the need for mechanical modifications [35]. SynRel and PMSM engines it can be provided as a possible additional to the induction engines in applications where speed variation is required, realizing in consistency and outstanding in performance. Such machines run at synchronous speed, minimizing rotor losses and are thus able to achieve very high performance levels, often reaching IE5 standards. The better assets of these machineries be able to similarly remain used to greatly decrease the complete size and mass of the engine, meaning that the design of the engine needs less materials.

3.3.4 Soft Starter with Energy Savers
The Soft Starter offers a consistent and cost-effective solution to these difficulties by supplying the motor with a measured power issue, resulting in phase smooth, less acceleration and deceleration. As damage to the windings and rollers decreases, motor life will increase. In 3 step units, Soft Start & Soft Stop offers guided start and stop with a range of ramp times and current limit settings to match all applications [34].

3.3.5 Bidirectional Converter for Energy Recovery
Most applications driven by electric drive, such as lifts, tooling machines, packaging machines, etc., are branded by frequent stops / starts with erratic duty rounds; thus, significant energy-saving capacity exists through the recovery of extreme kinetic energy during braking intermissions. Though, modern variable frequency drives do not support regenerative braking, since they are normally provided by bridge diode rectifiers. The renewed kinetic energy is thus degenerate in case of assistance of decelerating devices. It can result in a considerable amount of vitality wastages, particularly once there are frequent stops / starts.

3.3.6 Internet of Things (IOT)
Energy management system for commercial and industrial spaces through the Internet of Things. Using the data that comes from a network of on-site sensors and meters, the system offers saving steps to minimize energy usage and increase productivity. IoT can help to improve the various processes to be more quantifiable and measurable by the large amount of data collected and processed. IoT could potentially improve quality of life in various spheres including medical services, smart cities, construction, Agriculture, water, and the energy sector [36].

3.3.7 Digital Twin Technology
Digital twins are used in the energy sector to optimize the functioning and maintenance of physical assets, systems, and manufacturing processes. The digital twin is used through the visualization of change over time to track construction and identify problems. This capability helps the team to immediately respond to changes on-site.

Table 2. Comparison of past, present and future energy saving techniques of industrial drive

Components	Past	Present	Future
Motor	Normal motor	Energy efficiency motor	Light weight motor
Converter	Power electronics switches	Advanced power electronics switches	Silicon carbide switch
Drives	Industrial-Grade IMD	Adjustable speed drive	VSD with digital twin technology
Load	Normal load	Pump and fan load	IOT based connected load

4. Conclusion

Most developed countries have adopted legislation close to those of the European Union on energy efficiency. Motors representing 40–50 per cent of total global energy usage are becoming the largest appliance requiring high-efficiency standards. Currently the most common program in the motor industry is the research and technological production of DC brushless motors. Certain R&D products include refining motor design, enhancing silicon steel sheets electromagnetically, encouraging the advantages of permanent magnetic fields, adjusting wire-winding technology, and developing the electronic control system. The emerging energy saving and carbon cuts issues as well as the high-energy price age approach have led to the rapid production and popularization of high-efficiency engines. There is a trend towards increasing efficiency inside the electrical machine itself, but the greatest system-level improvements occur when the machine is coupled with an electronic power converter to produce a variable speed drive. The key drawbacks to this lie in the initial expense of a variable-speed motor, but the payback period is very limited in many situations. Future technological developments will reduce the cost of capital of the drive and thus existing markets will expand and new markets will open up[10].The motor is the sector's most energy-using part. Promoting high-efficiency motors is conducive not only to improving industrial productivity but also to reducing greenhouse gases. Several countries have thus been discussing the enhancement of motor-efficiency requirements in their energy and industrial policies in recent years.

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