SPARK INSIGHTS

VOLUME 01 SEPTEMBER 2023

UNLEASH THE CURIOSITY, GETTING INTO ELECTRIFYING WORLD

UNVEILING THE WONDERS OF ELECTRICAL ENGINEERING

PRECISION AND PROGRESS

EESoc

PUBLISHED BY ELECTRICAL ENGINEERING SOCIETY

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MESSAGE FROM THE HEAD OF THE DEPARTMENT

Dear Readers,

It gives me great pleasure to welcome you to the inaugural edition of "Spark Insights," the e-magazine proudly presented by the Electrical Engineering Society (EESoc) of University of Moratuwa. As the head of the department, I am delighted to witness the fruition of this ambitious endeavor that showcases the remarkable ingenuity and enthusiasm of our budding electrical engineering undergraduates ably guided by its leaders.

"Spark Insights" is not just a collection of articles; it is a testament to the innovation and dedication that characterize our esteemed institution. In these pages, you will find a treasure trove of knowledge encompassing diverse facets of electrical engineering.

Our vibrant undergraduate community has poured their energy into crafting articles that span the spectrum of our field: from Power and Energy, Power Electronics, Electrical Installations and Electrical Safety to Intelligent Automation with AI, where the boundary between human ingenuity and machine intelligence is ever more intriguing.

One of the hallmarks of "Spark Insights" is its reflection of the dynamic activities organized by EESoc throughout the year. Our society, a hub of collaboration and innovation, has consistently orchestrated events that foster learning beyond the classroom. From workshops that push the boundaries of conventional thought to seminars that bring luminaries from the industry, EESoc has been instrumental in nurturing the holistic development of our students.

As we stand at the intersection of tradition and progress, it is imperative to acknowledge the unwavering support of our faculty and staff, whose guidance propels our students toward excellence. The collaboration between mentors and mentees creates an environment where creativity flourishes and ideas find expression.

I extend my heartfelt appreciation to the dedicated team behind the conception and execution of this e-magazine. Their passion and perseverance have translated into a platform that encapsulates the spirit of EESoc and the vibrancy of our department.

In closing, I invite you to delve into the pages of "Spark Insights" with curiosity and enthusiasm. May this magazine ignite not only sparks of knowledge but also a fervor for exploration and innovation. Together, we illuminate the path towards a brighter future, powered by the intellect and imagination of the next generation of electrical engineers.

Warm regards,
Professor Anura Wijayapala
Head of the Department
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World's largest energy storage system, Pumped Storage Hydro Power Plants

The problem – Why we need energy systems and what are its advantages

The world is stepping towards renewable energy systems such as solar energy, wind energy, tidal energy etc. But the problem with these energy generation systems is, their output fluctuates with time. For example, if the sky suddenly becomes cloudy on a cloudless day and the light intensity drops by 80%, a 100MW solar power plant can turn in to a 20MW solar power plant in just a few minutes. This creates an imbalance in the grid. So, we need to turn on extra generators to meet that demand. Another problem we incur is, some renewable energy sources depend on climate. For example, strong winds and large waves are experienced during the monsoon season. Due to that, there should be a method to store excess energy during these seasons and supply the energy gap to the grid during non-monsoon periods.

Another importance of energy storage systems is, during peak demand hours, we can use the energy stored in storage systems other than turning on generators which run consuming fossil fuels and inefficient generators. This has a huge impact on greenhouse gas emissions also. Sometimes using energy in energy systems is more cost effective than turning on generators that run by consuming fossil fuels. . So, it has an impact on the economy also. Furthermore, if the demand increases suddenly with time, we can use energy stored in the energy storage systems so that the reliability of the grid is not affected. Another example for reliability is Fossil fuel and nuclear power plants have a single capacity that they run most efficiently. So that we can store the excess energy without slowing down thermal power plants.

Examples for energy storage systems

There are various modes of energy storage systems. One method is using battery systems. That is, using large lithium-ion batteries to store excess electricity. Due to their small storage and declining price, they are getting more popular these days. Another mode is using thermal storage systems. That means melting salt to store solar energy, using chilled water etc. Moreover, mechanical storage systems are also used more often. That means compressing air using the excess energy and using that compressed air to turn a flywheel to regenerate energy, using pumped storage power plants. In this article our focus will be on pumped storage hydro power plants.

What is a pumped storage hydro power plant?

In ordinary hydro power plants, basically a dam is built across a river and then water is taken out from the reservoir through a penstock. Then the potential energy in water is used to turn the turbine and then the rotational kinetic energy in the turbine is used to generate electricity. After this process, water is released back to the river.

A pumped storage power plant is not just a single reservoir but a combination of two. Significant amount of energy can be stored by having a large water body relatively close but located as high above as possible to the second water body. These reservoirs may or may not be connected to an actively flowing river.

Reservoirs are geographically situated at two altitudes. In simple words, water in the reservoir at high altitude is used to generate electricity during peak hours. Water in the reservoir at the lower altitude is pumped back to the higher altitude during low demand hours for energy. As of 2020 this is the largest capacity energy storage system available in the grid. The energy efficiency of pumped storage hydro power plants is between 70% -80%, which is the most cost-effective way of storing energy at large scale.

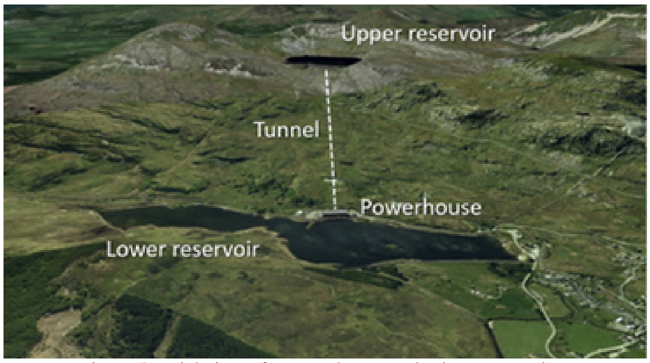
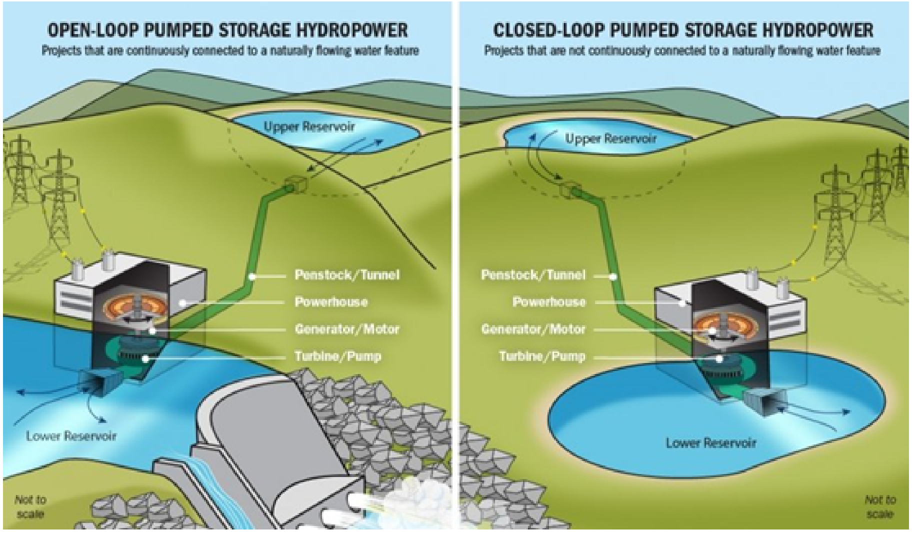


Figure 3 -ariel view of pumped storage hydro power plant

How it works

As stated above, for a pumped storage hydro power plant, we need two reservoirs. In large scale pumped storage hydro power plants, reversible turbine act as the combined pump and the generator unit while in small scale pumped storage hydro power plants, a set of large motors do the same job.

There are 2 main types of pumped storage plants namely open loop and closed loop.



In the open loop method, pure pumped-storage plants use this upper reservoir exclusively for storing water, with no natural inflows from streams or rivers. On the other hand, pump-back plants use a combination of pumped storage and conventional hydroelectric plants with an upper reservoir that is replenished partially by natural inflows from a stream or river.

In closed loop pumped storage systems, the reservoirs are not connected to an outside water body. The main difference between closed-loop and open-loop pumped storage hydro power plants is that closed-loop systems use the same water repeatedly, with no natural inflows or outflows. The water is pumped back and forth between the two reservoirs, so there is no need for a natural water source. One of the main advantages of closed-loop systems is, upper reservoir can be constructed near a hilltop rather than in a river valley, which drastically increases the height difference between the reservoirs, increasing the potential energy stored in water.

A pumped storage hydro power plant operates much like conventional hydropower plants, it can use the same water multiple times. When power from the plant is needed, water flows from the upper reservoir spinning turbines that produce electricity. The water is collected to the lower reservoir until electricity demand lowers. When this occurs, the turbines spin backward to pump the water back into the upper reservoir so it can be used again to generate electricity during peak hours.

Advantages of pumped storage hydropower

The main advantage of this system is storing energy in low demand hours. It provides a reliable way to store excess energy generated by other sources, such as wind and solar power and release them back during peak demand hours.

·This system is an efficient mode of storing energy. The energy conversion efficiency lies in between 70%-80%.

Unlike other energy storing methods, pumped storage hydropower facilities can operate for many decades, with a lifespan of 50-100 years or more, making it a long-term investment in energy infrastructure.

Pumped storage hydropower can be used to respond to changes in demand for electricity quickly. It can be used to generate electricity in short period of time, making it an ideal backup for varying energy sources such as wind and solar power.

Disadvantages of pumped storage hydropower

Pumped storage hydropower facilities have large capital costs, including the construction of two large reservoirs and a pipeline or tunnel system to transport water between them.

Pumped storage hydropower facilities require a specific topography with two bodies of water at different elevations, which can limit the availability of suitable sites for construction.

Pumped storage hydropower facilities consume water during operation, which can have implications for water availability in regions with water scarcity since portion of water is not released to the natural water body again.

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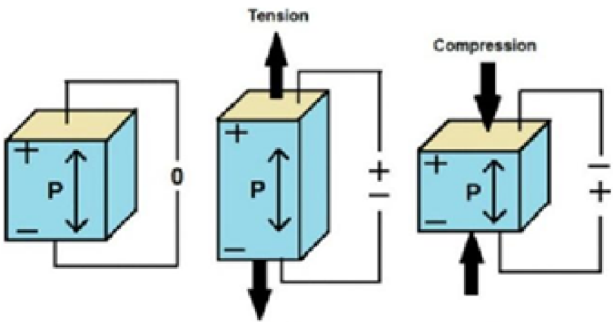
21 batch

Piezoelectric Energy Harvesting

What is Piezoelectricity?



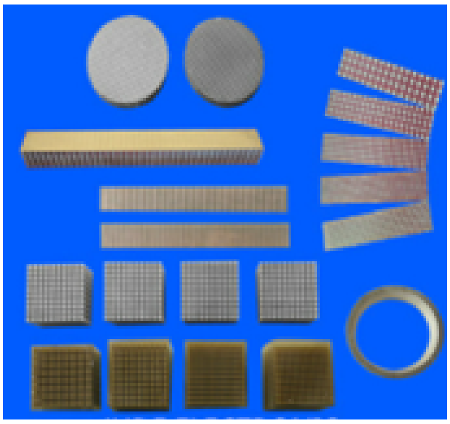
Briscoe and Dunn defined piezoelectricity as "electrical charge that accumulates in response to applied mechanical stress in materials that have non-centrosymmetric crystal structures", while Erturk and Inman came up with a definition as "a form of coupling between the mechanical and electrical behaviors of ceramics and crystals belonging to certain classes". Basically, this is a mechanism of capturing mechanical energy and converting into useful electrical energy. This is done with the use of piezoelectric materials.

What are Piezoelectric materials?

In simple terms, a piezoelectric material is a type of material that can produce an electrical field in response to the application of mechanical force. Some of the naturally occurring piezoelectric materials are Quartz, Sucrose, Topaz and Lead titanate. Piezoelectric materials can be mainly divided into 4 main categories: polymers, ceramics, single crystals and composites. Piezoelectric ceramics is the mostly used one due to low cost and ease of integration into energy harvesting devices. Ex: lead zirconate titanate (PZT) and barium titanate. Though single crystals show piezoelectric properties, they are rarely used due to high cost and lower mechanical strength. Flexible piezoelectric materials are increasingly appealing due to their capability to endure significant levels of strain without losing functionality.

Piezoelectric ceramics

Piezoelectric Crystals



Piezoelectric Polymers

Why Piezoelectricity?

With the higher levels of human activities, energy sources are overconsumed. Since most of this energy comes from non-renewable energy sources, this had led to an energy crisis. With this, attention is given to renewable energy sources and research are also done on eco-friendly energy harvesting. Piezoelectricity is both green and renewable energy. Though it doesn't come from natural environment, there is no harm like hazardous emissions. Since we can make use of all kind of vibrations which results from human activities, this will exist until the last human being on Earth and therefore can be considered as renewable energy.

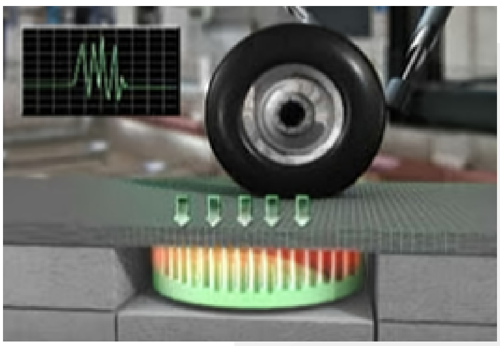
Following are more advantages of piezoelectricity over other energy generating methods

1. This has a simple structure and also do not need an external voltage source
2. By combining piezoelectric materials with other materials, it is possible to create hybrid materials that can generate a broad range of voltages.
3. Good scalability
4. Piezoelectric transducers are available in variety of shapes, making them adaptable to a wide range of applications.
5. It can be fabricated at both major and minor scales.
6. The Curie temperature, which is the temperature at which piezoelectric materials lose their piezoelectric properties, is relatively high in many such materials.

Piezoelectric Energy Harvesting Methods

1. Piezoelectric Energy Harvesting Methods

At present we use asphalt roads. Whenever a vehicle passes over, the road vibrates and heat energy is produced, but wasted.



By using piezoelectric devices, we can convert this into usable energy. These devices will be placed about 5 centimeters below the surface of the road. When a vehicle travels, the wheels exert a force into the piezoelectric device which leads to deformation in the piezoelectric material. With this mechanical stress applied there will be a change in electric polarization inside the material which will be helpful in power generation. On busy roads, the movement of vehicles are mostly constant, so that constant power can be generated. We can use it for street lights and small scale purposes.

2. Power generating sidewalks

This is somewhat similar to roads, but instead of vehicle wheels, vibrations created by footsteps are used. Research is also done on power generating boots which also includes an attempt to power battlefield equipment with the energy generated by piezoelectric generators embedded in soldier's boots

3. Gyms and workplaces

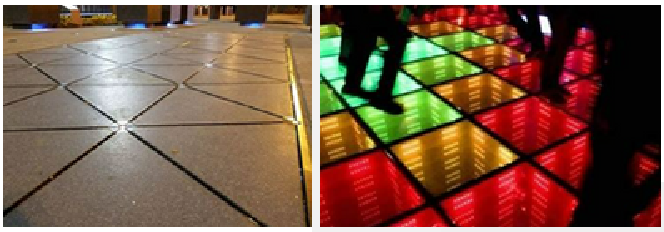
There are lots of machines working at the same time inside a gym. This results in lot of vibrations. Even a chair in a workplace will generate vibrations when a person is seated on. If we can lay piezoelectric crystals beneath these machines and chairs, piezoelectric energy will be generated which then can be stored on batteries.

4. Keyboards

Keyboards are widely used nowadays. With each press of every key vibrations will be created. By laying piezoelectric crystals under the keys, these vibrations can be utilized in energy harvesting. This can then be used for charging purposes.

5. Public places

Another potential application of piezoelectric devices is to install them beneath frequently used floor coverings such as mats, tiles and carpets in public places. For example, some night clubs in Europe have already begun to generate power by installing piezoelectric crystals underneath the dance floor.



Drawbacks

- When we install piezoelectric generators on roads the maintenance of the roads will be difficult and constant inspections will have to be made.

- Piezoelectric crystals might damage if overstressed and might get affected after long usage at high temperatures. Suitable precautions have to be made before installing.

- Piezoelectric devices may not be efficient enough to provide a continuous power supply because the power generation process relies on mechanical stress, which can vary in intensity and therefore lead to inconsistent power output.

- The cost of piezoelectric materials is relatively high, which may cause a hindrance to their widespread use.

- Piezoelectric devices may not be suitable for rural and semi-urban areas, as there may not be enough commuters or other sources of mechanical stress available to consistently generate power using these devices.

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Wireless electricity evolution

Introduction to Wireless Electricity

Just a century ago, the idea of transmitting electricity through the air without the need for physical connections seemed like pure science fiction. However, thanks to the relentless pursuit of innovation, wireless electricity is now a reality that is poised to revolutionise the way we think about power. Imagine a world where your smartphone charges effortlessly while sitting on your desk, where electric vehicles charge simply by parking in designated areas, and where smart homes are powered seamlessly without the need for numerous power outlets. This is the future that wireless electricity promises to deliver. Welcome to this exciting exploration of wireless electricity, where we will witness the power of technology unbound by wires, paving the way for a more connected and energy-efficient world.

Historical Background

To understand the development of wireless electricity, we must journey back to the late 19th and early 20th centuries when the visionary inventor Nikola Tesla played a significant role. Tesla, often regarded as one of history's greatest electrical engineers, was fascinated by the possibilities of wireless power transmission. Tesla's experiments with wireless electricity began in the 1890s, as he explored the concept of transmitting electrical energy through the air without the need for traditional wiring. He envisioned a world where power could be transmitted over vast distances, providing energy to remote locations without the limitations of physical connections. One of Tesla's most notable accomplishments in wireless electricity was his development of the Tesla coil, a high-voltage resonant transformer. The Tesla coil allowed for the creation of high-frequency, high-voltage alternating currents, which were essential for wireless power transmission experiments. In 1891, Tesla demonstrated wireless power transmission by lighting a series of phosphorescent bulbs wirelessly in his laboratory. He continued to refine his wireless electricity experiments, envisioning the construction of a global wireless power distribution system called the Wardenclyffe Tower. Unfortunately, due to funding challenges and technical setbacks, Tesla was unable to fully realise its grand vision.

How Wireless Electricity Works

Wireless electricity, also known as wireless power transfer, operates on the principle of electromagnetic fields and induction. It enables the transmission of electrical energy from a power source to a receiving device without the need for direct physical contact Let's explore how wireless electricity works

Power Generation: The process begins with the generation of electrical power. This can be through traditional means, such as a power plant, or through renewable sources like solar panels or wind turbines. The power generated is typically in the form of alternating current (AC).

Conversion to High Frequency: The alternating current is then converted to high-frequency alternating current using an inverter. This high-frequency AC allows for more efficient wireless power transfer.

Transmitter and Receiver Coils: The next crucial components are the transmitter and receiver coils. These are typically copper coils that are designed to resonate at the same frequency. The transmitter coil is connected to the power source, while the receiver coil is integrated into the device or system that needs to be powered.

Inductive Coupling: Inductive coupling is the key principle behind wireless electricity. When an alternating current passes through the transmitter coil, it generates an oscillating magnetic field around it. This magnetic field induces an alternating current in the receiver coil, which is nearby and resonates at the same frequency.

Energy Transfer: The induced alternating current in the receiver coil is then converted back to a usable form of electrical power using a rectifier and conditioning circuitry. This power is then used to operate or charge the receiving device.

Efficiency Considerations: Efficiency is a critical factor in wireless power transfer. Various factors can affect the efficiency of the system, such as the distance between the transmitter and receiver coils, the alignment between them, and the quality of the components used. Techniques like resonant coupling and optimization of the coil design help maximise the efficiency of wireless electricity transmission.

It's important to note that there are different methods of wireless power transfer, each with its principles and techniques. These include magnetic resonance, radio waves, and even laser-based systems. Each method has its advantages and applications, such as short-range charging for consumer electronics or long-range wireless power transmission for electric vehicles.

Applications of Wireless Electricity

One of the most common applications of wireless electricity is in consumer electronics. Wireless charging pads or docks based on standards like Qi enable convenient charging of smartphones, smartwatches, tablets, and other portable devices. This eliminates the need for multiple cables and connectors, providing a more streamlined and user-friendly charging experience. Wireless electricity has the potential to revolutionise the electric vehicle industry. Wireless charging systems for EVs allow for convenient and efficient charging without the need to physically plug in the vehicle. By integrating wireless charging technology into roads or parking spots, electric vehicles can charge automatically while stationary or in motion, reducing the need for traditional charging infrastructure. Wireless electricity offers significant benefits in the medical field. Implantable medical devices, such as pacemakers and neurostimulators, can be powered wirelessly, eliminating the need for frequent surgeries to replace batteries. Wireless power transfer also enables the development of wearable medical devices, remote monitoring systems, and smart implants that can continuously and wirelessly receive power and transmit data. Wireless electricity has applications in military and defence sectors, where the ability to transfer power without physical connections is highly valuable. It can power unmanned aerial vehicles (UAVs), surveillance systems, and remote sensors in remote or inaccessible areas. These are just a few examples of the wide-ranging applications of wireless electricity. As the technology continues to advance, we can expect to see its implementation in various other fields, including aerospace, robotics, telecommunications, and more. Wireless electricity has the potential to reshape our world, offering convenience, efficiency, and new possibilities in how we access and utilise electrical power.

Challenges and Limitations

While wireless electricity holds great potential, several challenges and limitations need to be addressed for its widespread adoption. Let's explore some of the key challenges associated with wireless electricity:

Wireless power transfer systems often experience efficiency losses compared to traditional wired connections. Factors such as distance between the transmitter and receiver, alignment, and power losses during transmission can impact efficiency. Improving efficiency is crucial to minimise energy wastage and maximise the effectiveness of wireless electricity.

The effective range of wireless power transfer is typically limited. In most cases, the distance between the transmitter and receiver needs to be relatively close for efficient power transfer. Extending the range for practical applications, such as wireless charging for electric vehicles or large-scale power transmission, remains a challenge. Safety is a significant consideration when it comes to wireless electricity. The generation and transmission of electromagnetic fields raise concerns regarding potential health effects. Research and regulations are necessary to ensure that wireless power transfer systems are safe for human health and the environment. Despite these challenges, ongoing research and development are addressing these limitations and pushing the boundaries of wireless electricity. As technology advances and innovative solutions emerge, many of these challenges are expected to be overcome, leading to a more efficient, reliable, and widespread implementation of wireless electricity in the future.

Future Trends and Implications

The future of wireless electricity holds exciting possibilities and potential implications across various sectors. Let's explore some of the future trends and implications of this transformative technology: Researchers and engineers are actively working to improve the efficiency of wireless power transfer systems. Through innovative designs, optimised resonant coupling, and better materials, higher efficiency levels are being achieved. Increased efficiency will lead to reduced energy wastage, improved power transmission over longer distances, and enhanced overall performance of wireless electricity systems. Future developments in wireless electricity aim to extend the range of power transfer. This includes technologies like magnetic resonance coupling, which enables power transmission over greater distances. This could have significant implications for charging electric vehicles wirelessly while in motion, providing seamless power transfer in a variety of environments and applications.

In conclusion, the era of wireless electricity is dawning upon us. With ongoing advancements and innovation, we are witnessing a transformative revolution that will shape how we access and utilise electrical power. As wireless electricity becomes more prevalent, its impact will be felt across industries, bringing us closer to a future where power is wirelessly transmitted, accessible, and sustainable.

Vaishnavi Shanmugam
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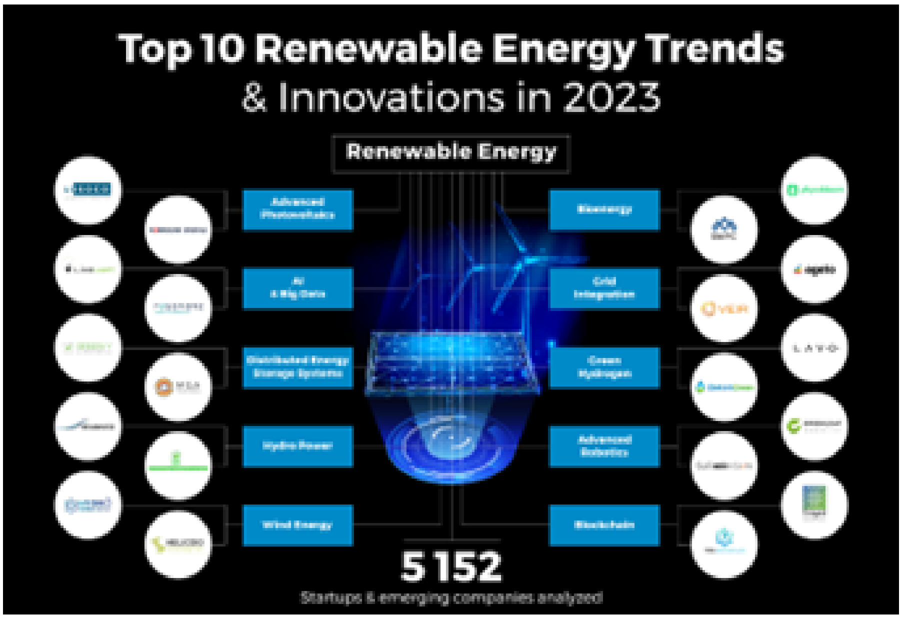
New trends in energy sector



One of the major issues dominating political debate, social and government policy making is the need to develop sustainable alternatives to fossil fuels to meet the global energy crisis and global warming. Demand for energy increased starting from the industrial revolution and it keeps on increasing with the advancement of civilization and technologies. Most used energy sources to generate daily energy need are fossil fuels like oil and coal, nuclear energy, and renewable energies like wind, geothermal, solar and hydropower. Due to high emission of greenhouse gases and limitation of fossil fuels countries tend to prioritize renewable energy.

With the advancement of technology there are upcoming trends in the energy sector Shifting to renewable energy, decarbonisation, electric cars, AI and big data in the energy industry, sustainable biomass and use of green hydrogen energy are few emerging trends.

Coal has been dominating the energy sector for a long time. Rystad energy estimates total consumption of China expected for the year 2022 was 7400 TWh, of which coal generated 4922 TWh. Due to the release of carbon dioxide to the environment which has caused lots of deaths, governments show preference for the use of other energy sources with net-zero carbon emission. The major topic of discussion currently is shifting to renewable energy sources, use of green hydrogen energy. Although it was known to have basic technologies in generating and storing renewable energy, research and developers have found new ways for efficient energy production and storage. Use of Grid Renewable Storage Power Supply (GRES) to store energy produced by solar power plants, offshore wind power plants over Onshore and Nearshore wind power plants, using solid hydrogen storage are some of the upcoming technologies. Although the underlying process is complicated, countries have already begun to use these technologies.

The concept Decarbonisation came along with the increase of carbon dioxide levels in the atmosphere which caused numerous deaths during past years. Governments have already taken steps for decarbonization as it helps in sustainable development of the country. There are four key technological pillars in decarbonation. Energy efficiency, Industrial Electrification, Low carbon fuels, Feedstocks, and energy sources (LCFFES), Carbon Capture, Utilization and Storage (CCUS). Optimizing performance of industrial processes at system level, using machine learning and advanced technologies in data analysis makes the manufacturing processes more efficient. Advancement of using low-carbon electricity generating sources will be critical to decarbonisation efforts.

Since governments are adapting to new technologies to reduce gas emissions and develop ecological economical model, companies and institutes are in the process of implementing technologies and methodologies such as Artificial Intelligence (AI) and Big Data improvement alternatives. We as human beings are constant generators of information. We analyse data and make decisions in our life. Big data systems analyse this information, which makes our work easier. Constant use of data and analysing processing continuously trigger for AI. Due to this excellent application in energy management through data collection, analysis and autonomous optimization, artificial intelligence and big data has gained prominence not only performance optimization but predictive maintenance systems, efficient process management using cloud, alerts and proactivity on production lines are fewer applications of them. The 'Smart building' concept of which a smart city or intelligent city is created using intelligence systems in the building which collects and analyse data and lead to decision making on energy demand and supply through the city is a rising concept in energy industry.

"Electric vehicles are one of the driving forces in the new global energy economy that is rapidly emerging, and they are bringing about a historic transformation of the car manufacturing industry worldwide." IEA Executive Director Fatih Birol said in a statement.

One of the sources of environmental pollution is transportation. Many countries over the world fight against environmental pollution since it causes many effects on human and plant lives. Emissions from vehicles contain not only carbon dioxide, but also unburned carbon particles, toxic sulfur dioxide. So, the environment is a key motivator for the auto industry's strong momentum towards electrification when compared with gasoline or fuel vehicles. Electric vehicles have a very small carbon footprint. This increases the demand for electric vehicles. The use of the electric vehicle has become a new trend in many countries due to low carbon footprints, but how does the electric car engine work? It is simple. Electric cars function by plugging into a charge point in order to charge it's battery and taking electricity from the grid. This energy is stored in rechargeable batteries that power up the electric motor which turns the wheels. One of the key advantages of electric vehicles is that they can accelerate faster than traditional fuel engines. Moreover, these electric vehicles can be charged by plugging into public charging stations or into a home charger.

There are three main categories in electrical vehicles. Battery electric vehicles which are powered by a battery pack runs purely on electricity and this type doesn't need petrol or diesel to run so zero emissions while operating, plug in hybrid which is a combination of fuel engine and an electric motor mainly run on electricity but also have a traditional fuel engine which can be used when ran out of charge and fuel cell vehicles which splits electrons from hydrogen molecules to produce electricity to run the motor.

In recent publications by the European Environment Agency (EEA), electric vehicles are clearly preferable over traditional petrol and diesel vehicles when it comes to environmental changes but there are drawbacks in adapting to electric vehicles. The electricity supply must be from renewable energy sources to make it more eco-friendly. Recycling of vehicle parts after use is a key factor that must be considered since the disposal of vehicle parts without recycling can cause harm to the environment. Even the electricity bill can go up, but the cost is less when compared to the use of traditional fuel powered vehicles.

In conclusion, the energy sector is experiencing rapid transformation. Using renewable energy with advanced technologies for energy storage, use of machine learning algorithms and AI in energy management, using electric vehicles with advanced technology as mentioned above. These new trends present exciting opportunities for the energy sector to create a more equitable, sustainable, and resilient energy system for the future.

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Solar Panel Degradation

Solar panels convert the sun rays into heat or energy. They generate electricity with photovoltaic cells using the photovoltaic effect. Since Sri Lanka having a higher potential of solar radiation, solar powered electricity has been using for a long time in wide range. By the end of 2021, Sri Lanka has rooftop solar PV systems in operation in total capacity of 284MW and generated 389.50GWh and grid connected solar has 100.36MW and generated 156.02GWh. As in generation expansion plan, that has planned to increase the total PV capacity up to 10,739 MW by the end of 2042. But with time there is a degradation in the capacity of the solar panels which needed to be considered. Normally the solar panels' performance is guaranteed for 25 to 30 years by the manufacturers, where the output of the panel falls below 80% of the full capacity. But the solar panels can last longer than that period and generate electricity. This can be proven that the world's first modern solar panel is providing power for 60 years. First let's consider what is degradation in solar panels.

What Is Degradation?

Each and every equipment does not perform 100% in their life span. Likewise, the average life span of the solar panel is 25 years. Within this period of time, the electricity generation of solar panels will be reduced gradually. .

This process can be identified as degradation. The average degradation rate will be 1% per year. There are several factors which affect degradation.

Light Induced Degradation (LID)

In the first exposure of the solar panel to sunlight, the phenomenon called power stabilization will occur. Here the crystalline silicon cells on panel are interacting with the outside environment. Furthermore, the electronic items in cells are wrapped or buckled by heat due to direct exposure to sunlight. More than that the crystalline silicon oxide layer forms a boron dioxide on the surface which reduces efficiency. Due to these effects, a solar panel will lose 2 to 3 percent of the rated output within the first hundred hours of operation. After that initial stage Light Induced Degradation rate will be reduced to the range of 0.3 to 0.7 percent per year for next operation years. These rates will depend on the high purity of N-type silicon cells.

Potential Induced Degradation (PID)

This will occur due to voltage leak from the cells to the frame of the panel, which will reduce the power output. This cannot be identified at the very first time. It will be progressively worse when identifying the problem. This degradation will become apparent after 4 to 10 years of use. High

Voltage, elevated temperatures, and high humidity, faster the degradation rate. The large solar farms are in operation at 1000 to 1500 volts. So, the panels have a much greater chance of PID. If this PID issue does not consider more than 10 years, the effect could be more adverse. It could be occurring a 50% loss in power. By using high quality materials, this degradation can be reduced. Moreover, some advanced large scale solar inverters can reduce the effect of PID by running a small reverse current overnight.

General Degradation

The protective layer and encapsulation, which are used as the protection of cells can be damaged over the time period. This could be a significant issue within the time due to water, humidity, and other damages. This degradation can lead to serious issues like moisture ingress, corrosion, and earth leakage over the period of time. Most common failure is the back sheet failure as shown in figure 01. The rate of this degradation can be reduced by using high quality materials and proper maintenance.

Figure 01 : Back sheet cracked solar panel

Light & Elevated Temperature Induced Degradation(LETID

Most of the solar panel manufacturers are using the PERC (Passivated Emitter and Rear Contact) solar cell technology is being used due to higher efficiency. This LETID occurs due to P-type PEREC cells. Even though the LETID and LID are similar, the LETID records a higher degradation rate around 6% in the first year. As in LID, this phenomenon can be reduced by using N-type silicon cells instead of P-type or by using P-type poly and mono PEREC.

Mico-cracks and hot spots

Modern solar cells are made using ultra-thin (around 0.16mm) silicon wafers. So, panels are made using a series of these cells. These cells and wafers are made from brittle materials which means they can easily crack or fracture under high mechanical stress under conditions like mishandling during installation. Moreover, extreme wind loads can also cause damage. More than that unusual load applies by humans in maintenance or installation, or transportation can also damage the cells. These micro cracks can cause hot spots formation over the years and then cause a panel failure.

Figure 02 : Minor micro cracks in a solar cell

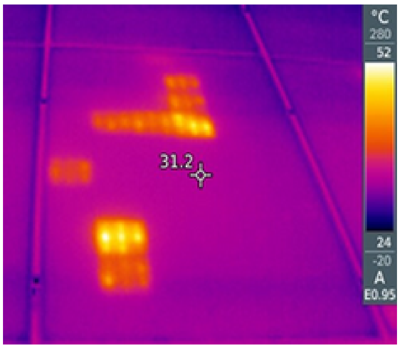


Figure 03 : Thermal image of a solar panel with hot spots due to severe micro-cracks

At first stage, these micro cracks are invisible and hard to detect. The cracks are visible as snail trails when the panels are getting older. The panel can still generate electricity for many years after cracks are placed. The case will be significant with increasing the internal resistance and breaking the current flow. The higher resistance in the cracks generated the heat. Then the heat will increase the resistance furthermore and it will keep generating the heat and makes the hotspot. The failure will become much worse when the cracks are significant or are formed in entire cell. This could also be burning the cell. These hot spots are not visible for human eye and can only captured by a thermal imaging camera as in figure 03 where the hot spots are highlighted according to temperature differences.

How to reduce the degradation rates?

Mainly the degradation rate can be reduced by using good quality products, panel assembles in a compatible manner. By using a backup battery, the lifetime of solar panel can be increased by lessening the burden on solar panels. Regular inspection is required for fault detection and identifying potential issues. With the proper maintenance of panels can solve the minor issues before becoming more serious. These minor errors can be identified with proper inspection. More than that, the damage can be reduced by keeping the panel clean regularly.

P. Nipun Madhushan
19 batch

Power Over Ethernet

Introduction

In today's digitally connected world, where the demand for seamless communication and reliable network infrastructure continues to surge, technological advancements are constantly reshaping how we deploy and power our devices. Among these innovations, Power over Ethernet (PoE) is a unique solution that has revolutionized the landscape of data transmission and power delivery.

PoE technology has emerged as a game-changer, enabling data and electrical power to traverse a single Ethernet cable. This ingenious integration has significantly simplified the installation and operation of network devices, eliminating the need for separate power cords, and offering newfound freedom in device placement.

In this article, we delve into Power over Ethernet, exploring its principles, applications, and the remarkable advantages it brings to various industries. From enhancing network flexibility to streamlining installation processes, PoE has proven to catalyze efficiency and innovation.

PoE is a technology which allows twisted pair ethernet network cables carry electrical current required to operate each electrical device rather than using standard cables to supply electricity. PoE can be easily adapted for smart home applications and business premises. Since both power and data is sent through the Ethernet cables, less wiring is required for this technology, and it is a cost-effective option as well. Since the invention of the Power over Ethernet in 2000's for low-power IP phone (7 W) it has now evolved such that, it can transmit power up to 100 W over the network cables.

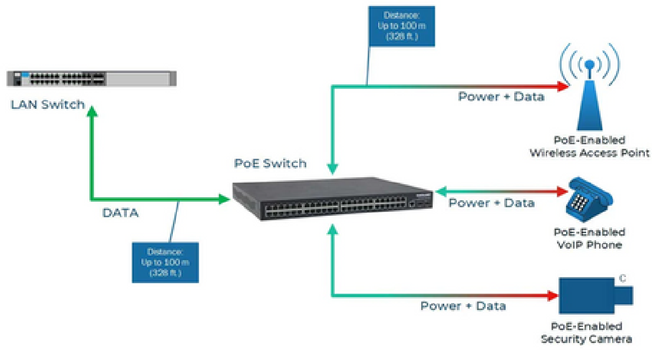


Fig1: An overview of Power over Ethernet connection

Why Power over Ethernet?

A straightforward answer to this question is that it eliminates the need for electrical sockets or power cables near network connected devices, so that these devices are not restricted by the location. In the future, these network-connected devices are not limited to switches, modems, routers. They can also be power devices such as,

- IP Cameras/Phones – devices connected via Internet Protocol (These devices can communicate with each other)
- Remote computer terminals
- Computer monitors
- Laptops
- Large TV's and LCD display screens
- LED lighting
- WiMAX devices, (which stands for Worldwide Interoperability for Microwave Access) , AP devices or nodes.

Another advantage is that it can largely reduce the cost of using separate power cables since both power and ethernet uses the same network cable. A network switch with built-in Power over Ethernet injection is known as a POE switch. When you connect other network devices to this switch in the usual manner, it will automatically detect their compatibility with POE and activate power accordingly.

A midspan, also known as a POE injector, is utilized to incorporate Power over Ethernet functionality into standard non-POE network connections. It serves to upgrade existing LAN setups to support POE, offering a flexible solution when fewer POE ports are needed. The process of upgrading each network connection to POE involves seamlessly routing it through the midspan. Like POE switches, the power injection is managed automatically and with precision. Midspans come in various options, including multi-port rack-mounted units or budget-friendly single-port injectors.

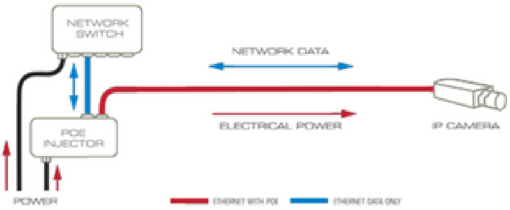


Fig2: Upgrading to a PoE connection.

It is possible to upgrade powered devices such as, Monitors, Laptops, IP cameras, also into PoE by using PoE injectors, PoE splitters and similar methods.
Furthermore, ethernet cables used for PoE is already installed in commercial and residential buildings. Although you still need to replace the old network switches with PoE enabled ports, the saving of not having to install copper wires can be significant. This leads to reducing the cost of electricians and labor charges thus saving energy by centralizing power distribution and allowing for more efficient power management.

If we consider the safety, the POE devices are designed to comply with safety standards and have built-in safeguards against overloads, short circuits, and under voltage conditions. Since this technology uses lower voltages, it reduces the risk of electrical hazards and improves overall safety in the deployment of network devices. Even though PoE uses low voltages you might be still wondering if our devices are safe to connect to the PoE. PoE technology is compliant with IEEE 802.3af/at/bt standards and are designed to ensure safety. Both PoE injectors and switches are designed to prevent any damage to equipment, even if the equipment is not specifically built for PoE applications. Before transmitting power to a connected Powered Device (PD), the Power Sourcing Equipment (PSE) initiates a handshake procedure to determine the power requirements of the device. This handshake procedure utilizes low voltage and poses no harm to any connected device, regardless of whether it supports PoE or not. Once the handshake is successfully completed, the PoE injector or switch proceeds to deliver power, activating the PD. However, if the handshake fails to establish, for any reason, the PSE refrains from sending any power. This inherent feature found in all IEEE 802.3af/at/bt-compliant devices ensures the inherent safety of PoE technology.

The Power over Ethernet (PoE) Class designation is exclusively assigned to Powered Devices (PDs) and indicates the specific power requirements needed for their operation. Currently, nine PoE classes exist, each denoted by a numeric value ranging from 0 to 8. The PoE classes are defined as follows:

Class	Usage	Wattage required at PD
0	Valid for Type 1 (802.3af) devices	0.44–12.94W
1	Valid for Type 1 (802.3af) devices	0.44–3.84W
2	Valid for Type 1 (802.3af) devices	3.84–6.49W
3	Valid for Type 1 (802.3af) devices	6.49–12.95W
4	Valid for Type 2 (802.3at) devices, not allowed for 802.3af devices	12.95–25.50W
5	Valid for Type 3 (802.3bt) devices	40W (4-pair)
6	Valid for Type 3 (802.3bt) devices	51W (4-pair)
7	Valid for Type 4 (802.3bt) devices	62W (4-pair)

Limitations of PoE

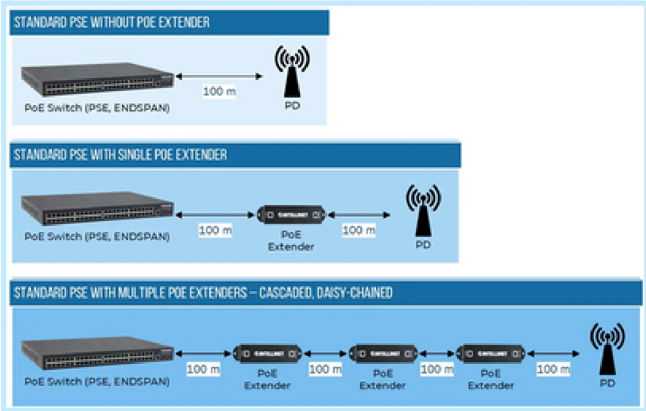
The effective power delivery range of PoE is constrained by the cable length. Generally, Cat5e or superior Ethernet cables can reliably support PoE up to 100 meters (328 feet). If the cable length surpasses this limit, power loss can transpire, potentially resulting in inadequate power levels for connected devices.

Power over Ethernet (PoE) has inherent power restrictions, and the maximum power output varies based on the specific PoE standard employed. For instance, IEEE 802.3af permits a maximum power delivery of 15.4 watts per port, while IEEE 802.3at (PoE+) can provide up to 30 watts. If you have devices with higher power requirements, you may need to explore alternative power solutions or utilize multiple PoE ports to adequately meet their power needs.

If we need to extend the PoE transmission distance, one can utilize a PoE extender or PoE repeater, appropriately named for this purpose. A PoE extender is installed between the Power Sourcing Equipment (PSE) and the Powered Device (PD) in a sequential manner. On each side of the extender, the connection distance can reach up to 100 meters (328 ft.). Some PoE extenders even allow for daisy-chaining multiple units, extending the total connection distance beyond 500 meters (1640 ft.).

When a PoE extender is connected to a PSE, it receives both power and data. It consumes a portion of the power for its own operation and passes the remaining power to the subsequent PoE device. A Gigabit PoE extender consumes around 4 to 5 watts of power. If it is connected to an IEEE 802.3at PSE, which can deliver approximately 25 watts to the extender, approximately 20-21 watts remain available for the connected PoE device.

As you cascade PoE extenders, each extender consumes an additional 4 to 5 watts of power. Consequently, the available power for the subsequent PD decreases. For instance, the next PD would have approximately 15 watts available, the one after that would have around 10 watts, and so forth.



Conclusion

Power over Ethernet (PoE) technology provides a simple and effective way for powering network devices over Ethernet connections. It eliminates the need for separate power lines and allows for flexible device placement, making installation easier and less expensive. PoE enables a safe power transmission mechanism through a handshake procedure with IEEE 802.3af/at/bt compliance, preventing damage to connected devices. However, the power restrictions of PoE standards, cable length constraints, and device compatibility must all be considered. Furthermore, using PoE extenders or repeaters can extend the connection distance even further, offering greater flexibility in network deployments. Despite its restrictions, PoE is still evolving, with improved power capability and management functions. As technology advances, PoE is likely to play an increasingly significant role in powering diverse network devices, contributing to streamlined installations and improved network efficiency.

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19 batch

Autonomous Power Systems

Autonomy

Autonomous systems are those systems that can act on their own without any human intervention. Often confused with automation, the two terms possess different meanings even though both processes do not require a human hand.

Automation is defined as a process that occurs according to the data and instructions fed into the system, making it a more prescribed process. Here, generally the user takes trouble in learning the various circumstances and formulating the results. In contrast, autonomy is where the system is intelligent enough to act according to the situation, however unexpected it could be. In this regard, the system itself identifies change without user formulated parameters and has the ability of learning from an outcome.

This scenario is most common in the automobile industry, where the engineers work upon building self-driving cars with a more autonomous approach. Similarly, Autonomous power systems also follow a similar trail.

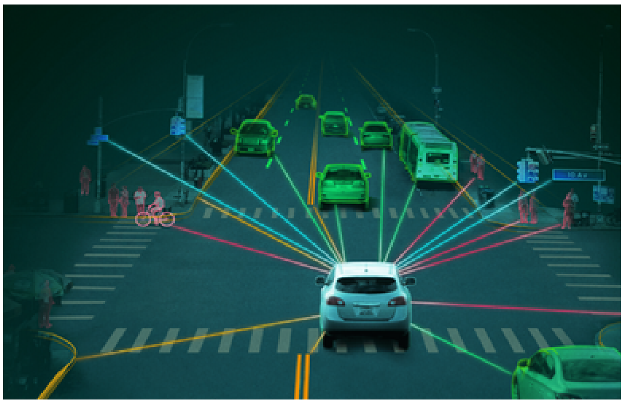

Figure 1 : (2022). Researchleap.com. https://researchleap.com/wp-content/uploads/2021/12/AI_Drive_Reasoning-002.png

Introduction to Autonomous Power Systems

A power system is responsible for generating, converting, transmitting, and distributing electrical energy. Most power systems in the world allow unidirectional energy flow only, from large power plants to consumer points. Yet, with the advancement of different power generation systems like solar and wind, the power flow is more bidirectional which in turn, demands heavy control, and system operation. Hence, small scale Autonomous power systems come into play. These systems behave in isolation to the grid and are more reliable than the traditional power systems along with the intelligence and smartness of an autonomous system as mentioned above.

Figure 2: (n.d.). Towards more autonomous and optimized operations [Review of Towards more autonomous and optimized operations]. https://www.valmet.com/contentassets/f1bb40bbbc964d64bc2a11b877fc8b14/building-blocks-hands-435x277.png

Artificial intelligence, being an arena focused upon forming algorithms that predict human behavior, is a must in the autonomous industry coupled with Machine learning which analyzes past and present data sets to recognize patterns and make accurate forecasts for the future. In addition, in AI systems, the decisions are fed back to the system, enabling the system to learn and improve at an increasing rate.

Furthermore, technologies like Supervisory Control and Data Acquisition (SCADA) can be utilized in this aspect. SCADA also allows operators to monitor and control from anywhere over the world. These can be further advanced to suit the autonomous system we expect to acquire.

Components of an Autonomous Power System

A small-scale autonomous system consists of several definite components for standalone performance such as generators, controllers, and energy storage devices. Generators convert energy from a renewable or non-renewable energy source to electrical energy and Eenergy storage devices such as batteries and cells store the energy for future use. This helps in balancing the demand and supply even when the generators are not producing electricity.

The controller is the central administration unit of the system which monitors and controls both the input and the output efficiently and safely. Most of all, the autonomous action is established by this component as a typical Real Time Operating system (RTOS) is used to control tasks in a timely manner.

Advantages and Challenges

Autonomous systems are intelligent and flexible to optimize according to the generation and conditions pertaining to variations in function. This subsequently avoids unnecessary resource utilization as well, hence, could be considered a cost-effective approach. Conversely, initial installation costs and maintenance costs of such a system are greater.

The reliability of autonomous power systems is greater as they are not liable for outages caused by variations in weather conditions, or any other disruptions caused to the grid. Therefore, to start with, institutions like hospitals, data centers and remote locations like military bases and research stations might benefit from such a system. Moreover, they can be scaled to suit the application as well, even though it becomes complex when promoted to a larger scale. These can be integrated to operate millions of resources in and out of the grid.

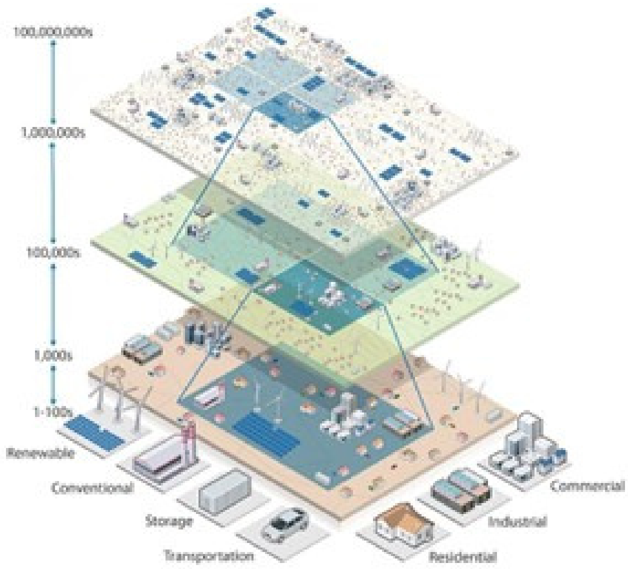

Figure 3: (n.d.). Control Algorithms for Autonomous Energy Systems [Review of Control Algorithms for Autonomous Energy Systems]. https://www.nrel.gov/grid/assets/images/aes-scale-final-v2.jpg

One of the biggest challenges encountered by an Autonomous power system is providing the level of real time optimization it demands. The setting is viable to vary at a sub second timescale, which puts the system in a whole lot of multi-tasking and system coordination confined to a minute timespan. This can even exacerbate if the power system is grid connected which would claim a more synchronous process rather than functioning isolated systems.

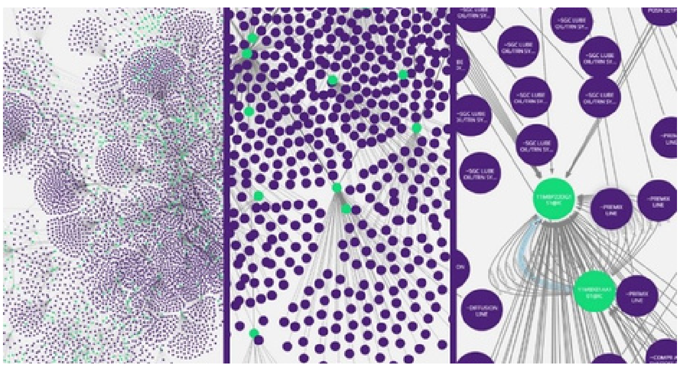

Figure 4: (2021). Autonomous power plants are ready to launch https://assets.siemens-energy.com/siemens/assets/api/uuid:fb7ffc71-00c6-4c6d-8295-e38989548c4e/width:1266/quality:high/knowledge-graph-of-data-

Furthermore, since the amount of data coming in by different sensors, meters and appliances are huge, collecting and managing them to make faster decisions is vulnerable. This inevitably needs efficient big data analytic techniques as the data streams are complex up to the extent of a neural network in the human brain. Figure 2 shows a knowledge graph of such data streams between components in a power plant.

Since autonomous systems are under research and construction, there is a fair risk whether these systems would work and ease the process or otherwise.

Future

Autonomous power systems are in use in countries like Ukraine, Nepal, and Japan in small scale renewable power systems. Sources even show that energy security is established in using such systems which has been evident during the Russia-Ukraine war where Ukraine has maintained a steady power supply.

Even though fully autonomous power plants are not implemented as of now, ambitious research is in progress. Scientists and engineers forecast this to be a triumph for the whole of mankind, which will benefit economically and technologically.

H.D. Niyumi Nethmanthi
21 batch

High Voltage Direct Current (HVDC) Transmission in Sri Lanka: A Key to a More Reliable and Efficient Energy System

Sri Lanka is heavily dependent on its energy industry, which generates electricity using a mix of fossil fuels and renewable energy sources. The country's energy infrastructure, particularly in the area of high-voltage direct current (HVDC) transmission, has a lot of potential for expansion. Higher efficiency and lower transmission losses are only two advantages that HVDC transmission technology provides over conventional AC transmission. In this article, we will examine the potential advantages potential outcomes of HVDC transmission in Sri Lanka.

The potential benefits of HVDC transmission

Transmission of high-voltage direct current (HVDC) has been under development for over a century. In 1888, the concept of the HVDC gearbox was patented in the United States. The first commercial HVDC transmission line, however, was installed in Sweden in 1954. HVDC transmission has grown in popularity since then due to its capacity to carry power across vast distances with low losses. [1]

HVDC transmission was developed to answer the demand for efficient power transmission across large distances.

Traditional alternating current transmission lines suffer high resistive losses over long distances, making them inefficient for transmitting large quantities of electricity. HVDC transmission, on the other hand, is more efficient and can carry power over vast distances with reduced losses. As a result, HVDC transmission has become an appealing method for transferring power from remote places to populous areas. [1], [2]

The growing popularity of renewable energy sources like wind and solar energy has facilitated the expansion of HVDC transmission. The majority of these sustainable energy sources are located in rural locations far from population centers. HVDC transmission may transport power from remote sites to more populous areas, where it can be utilized to generate energy or keep the system stable.

Today, over 100 HVDC transmission lines with a total capacity of more than 200,000 MW are in operation across the world. HVDC transmission is expected to become more crucial in energy transfer as electricity demand grows.

HVDC transmission has emerged as a crucial technology for creating a more effective and ecologically friendly energy system due to its capacity to distribute electricity across great distances.

High-voltage direct current (HVDC) transmission techniques offer the potential to increase the grid's sustainability and efficiency. Its ability to transport electricity over great distances with low loss is its key benefit. Alternating current (AC) produced by power plants is transformed into direct current (DC). The DC power is converted back to AC at the other end. The gearbox system is therefore more efficient and uses less energy. High-voltage direct current (HVDC) transmission has the ability to radically transform the electrical grid. It offers several advantages over traditional alternating current (AC) transmission, including the following according to [2], [3]:

Higher efficiency: Compared to AC transmission, HVDC transmission can carry power over longer distances with fewer losses. This is because DC electricity does not sustain the same level of resistive losses as AC power.

Reduced transmission losses: HVDC transmission can reduce transmission losses by up to 50% compared to AC transmission. This can save money on electricity costs and help to reduce greenhouse gas emissions.

Increased power capacity: HVDC transmission can carry more power over longer distances than AC transmission. This is because DC power does not experience the same voltage drop as AC power.

Enhanced system flexibility: HVDC transmission can provide greater flexibility in the operation and control of power systems. This is because HVDC transmission can be used to connect different AC systems and to balance power supply and demand.

Easy renewable integration: HVDC transmission has the ability to integrate remote renewable energy sources, particularly offshore wind farms, into the grid. Offshore wind resources are often located far from onshore grids, and transmitting their power to the grid can be challenging. However, HVDC transmission can transport large amounts of power over long distances with minimal losses, making it a viable solution for offshore wind power integration.

Successful implementations of HVDC transmission turnarounds around the world:

North Sea Link: The North Sea Link is a 500 kV HVDC undersea cable that connects Norway's and the United Kingdom's electricity systems. The project, which has a capacity of 1,400 MW, was finished in 2021. The North Sea Link has increased the dependability of power systems in both Norway and the United Kingdom while also lowering electricity costs. The North Sea Link is a critical component of the European Union's effort to connect its electricity systems.

The project has contributed to the development of a more robust and efficient European energy grid. [4]

Baltic Cable: The Baltic Cable is a 400 kV HVDC undersea cable that connects Germany and Sweden's electricity networks. The project, which has a capacity of 700 MW, was completed in 2015. The Baltic Cable has aided in increasing the dependability of power networks in both Germany and Sweden, as well as in lowering electricity costs. The Baltic Cable is an important component of the Nordic-Baltic energy market. The project has contributed to the development of a more integrated and efficient Nordic-Baltic energy system. [3], [4]

Hydro Quebec – New England HVDC Interconnection: This is a 230 kV HVDC transmission line that connects the power networks of Quebec and New England. The project, with a capacity of 2,000 MW, was finished in 2009. The Hydro Quebec - New England HVDC Interconnection has increased the reliability of power networks in both Quebec and New England while cutting costs related to electricity. The Hydro Quebec-New England HVDC Interconnection is an important component of the North American electricity system. The initiative has contributed to the development of a more robust and efficient North American energy grid.

West African Power Pool: The West African Power Pool is a regional power system that links the electricity networks of 15 West African nations. The project, which has a capacity of 4,000 MW, was completed in 2017. The West African Power Pool has helped to strengthen the dependability of power systems in all 15 nations while also lowering electricity costs. This is an important component of the West African energy sector. The initiative has contributed to the development of a more integrated and efficient West African energy grid.

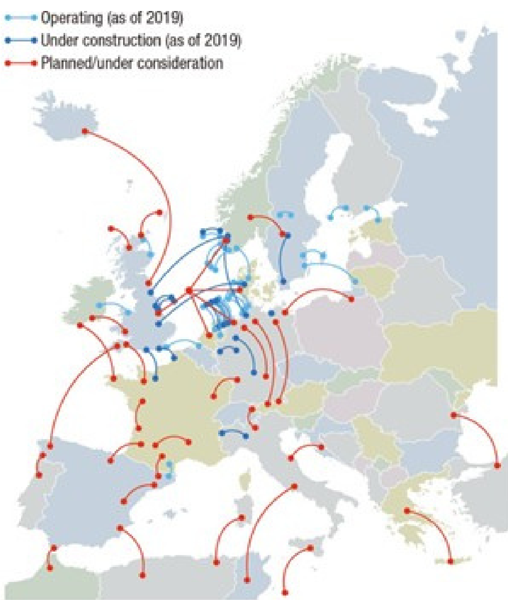

Fig 1- Construction of VSC HVDC in Europe [5]

West African Power Pool: The West African Power Pool is a regional power system that links the electricity networks of 15 West African nations. The project, which has a capacity of 4,000 MW, was completed in 2017. The West African Power Pool has helped to strengthen the dependability of power systems in all 15 nations while also lowering electricity costs. This is an important component of the West African energy sector. The initiative has contributed to the development of a more integrated and efficient West African energy grid.

East African Power Pool: The East African Power Pool is a regional power grid that connects the electricity systems of six East African nations. The project is presently being built and is scheduled to be finished in 2025. The East African Power Pool will help strengthen the dependability of power networks in all six nations while also lowering electricity costs. It has become an important component of the East African energy sector. The project has the potential to produce a more integrated and efficient energy system in East Africa.

HVDC Transmission Projects in Sri Lanka:

The proposed India-Sri Lanka HVDC Grid Interconnection project has the potential to bring about a range of benefits to both countries. One of the main advantages is the increased reliability of the electricity supply, which is especially crucial given the current power crisis in Sri Lanka. By connecting their grids, both countries will be able to share resources and help each other meet their energy needs, thereby reducing the risk of blackouts and power cuts. This could lead to increased productivity and economic growth in both countries, as businesses and households alike will be able to rely on a more stable supply of electricity.

In addition to increased reliability, the project could also increase the flexibility of the electricity grids in both India and Sri Lanka. With a more interconnected grid, it becomes easier to balance the supply and demand of electricity and respond to fluctuations in renewable energy generation. This could be especially important in the long term as both countries seek to increase the amount of renewable energy in their respective grids.

Moreover, the India-Sri Lanka HVDC Grid Interconnection Project could help reduce the environmental impact of electricity generation. By sharing resources and balancing their grids, both countries could potentially reduce their reliance on fossil fuel-based power generation. This could help mitigate the negative environmental impacts associated with the burning of fossil fuels, such as air pollution and greenhouse gas emissions.

The project's first phase would enable the transmission of 500 MW of electricity between the two countries. The second phase is aimed at increasing the transmission capacity to 1,000 MW. This project is viewed as an alternative stopgap solution to the existing power crisis in Sri Lanka and is expected to provide import opportunities for Sri Lanka with minimal or no export opportunities in the studied scenario. It is also expected to enhance system flexibility to integrate a large amount of renewable energy in the long term and save valuable resources [6].

However, the project is not without its challenges. One of the main obstacles is the high cost of the project, which is expected to reach approximately $800 million. The technical complexity of the project is another challenge, as it involves the construction of a 285-

kilometer-long HVDC link, including 50 kilometers of undersea cables. The environmental impact of the project is also a concern, as it could potentially affect marine life in the Palk Strait. Finally, there are political risks associated with the project, as it involves the cooperation of two sovereign nations with differing political systems and priorities [7].

Despite these challenges, the India-Sri Lanka HVDC Grid Interconnection project has the potential to be a major boon for both India and Sri Lanka. It is still under discussion, and nothing has been finalized yet, but if the project does move forward, it could have significant positive impacts on both countries

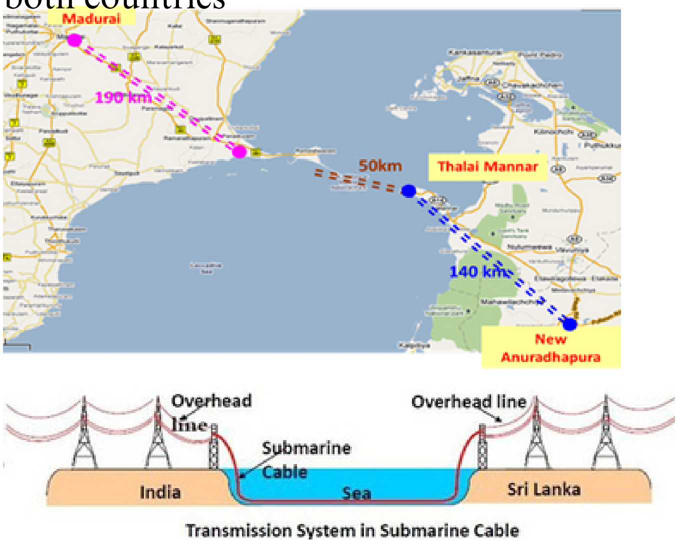

Fig 2: Proposed HVDC transmission System between The transmission system between India and Sri Lanka [7]

Final thoughts:

In conclusion, the adoption of HVDC transmission technology in Sri Lanka has the potential to bring significant benefits to the country's energy sector. However, there are a number of challenges that need to be addressed in order to realize these benefits, including technical, financial, and regulatory barriers. By exploring these issues and developing effective strategies to address them, Sri Lanka can unlock the full potential of HVDC transmission and move towards a more efficient, sustainable, and reliable energy future.

L. R. S. De Silva
18 batch

"Breaking the Mold: The Promise of Grid-Forming Inverters in Enabling high Penetration of Variable Renewable Energy in Electrical Systems"

In recent years there has been a growing shift towards renewable energy sources such as solar, wind, biomass, tidal power, and geothermal. This is driven by a variety of factors including concerns about climate change, energy security, economic benefits, and public health. Therefore, most countries are more focused on implementing these renewable energy sources into the system. The main goal is to replace fossil fuels with abundant renewable energy.

Renewable energy sources also can be classified into two broad categories as dispatchable and variable renewable energy. Dispatchable sources are the ones that can be controlled and scheduled to produce power according to demand. Examples of dispatchable renewable energy sources include hydropower (with reservoir storage), biomass power plants, geothermal power plants, and concentrated solar power (CSP) with thermal storage.

Variable renewable energy sources include solar photovoltaic systems, wind turbines, and tidal energy converters which the generation of power depends on external factors such as weather conditions and cannot be controlled or scheduled as per the demand.

The significant increase in the adoption of power electronic interfaced renewable energy sources like solar and wind presents several key challenges which need to be addressed.

When these sources are more prevalent in the power system, they are gradually replacing the synchronous generators (SG) in the generation mix. This transition has a significant impact on the structure and the operation of the electrical system. One notable effect is the reduction in system inertia.

In traditional power systems, SGs provide stability and help regulate frequency by utilizing their stored kinetic energy. However, inverter-interfaced RESs lack this stored mechanical energy, leading to a decrease in system inertia which means it reduces the ability of the power system to resist and dampen frequency deviations caused by sudden disturbances. This phenomenon can cause substantial fluctuations in the frequency of the power system, resulting in reliability concerns such as load and generation disruptions.

Resource adequacy: as mentioned previously, VRE sources are intermittent by nature. Therefore, there must be a way to have dispatchable power sources to balance supply and demand to maintain a reliable electricity supply.

Voltage stability: System voltage should be maintained within the acceptable range. Voltage stability is affected by several factors such as reactive power balance, sudden system load variations, transmission and distribution line impedance, faults and contingencies, etc.

System Protection: Integration of VRE sources requires appropriate protection mechanisms to ensure the safety of the grid and connected devices. This includes managing fault currents, coordinating protection schemes for bidirectional power flow, and addressing potential issues related to grid stability and protection coordination.

To address these challenges, additional measures and technologies need to be implemented.

Advanced control strategies and grid-forming inverters are being developed to address these issues along with energy storage systems.

What is a grid-forming inverter?

As mentioned above, Solar and wind are inverter-based power sources. These inverters can be categorized into three groups based on their implemented control strategies or operation modes as Grid following inverter (GFL), Grid forming inverter (GFM), and Grid supporting inverter (GS).

Grid-following inverter: Grid-following inverters are designed with power and current control loops as their primary mechanism, enabling them to function as adjustable providers of both active and reactive power. The frequency is set by phase locking to the existing grid which means these rely on the presence of a stable grid to regulate their output voltage and frequency.

Grid-forming inverter: These inverters have the capability to establish and control the voltage and frequency of the grid independently, without requiring a stable grid connection. These operate as an AC voltage source with a fixed frequency, providing a stable and reliable power supply to the connected loads within the grid.

Grid-supporting inverters: Also known as grid conditioning inverters. These inverters collaborate with the grid to support the stability and reliability of the grid's voltage and frequency, functioning as both a voltage source and a current source.

When forming an all-inverter system (100% inverter-based system), Grid-forming inverters have a significant role in establishing and regulating the grid's voltage and frequency, making them an essential asset for the power system. Additionally, GFM inverters have the capability to actively contribute to primary frequency control, which is not achievable with grid-following inverters.

Existing grid-forming controllers can be categorized into different types based on their control strategies and operation. A few commonly known categories are droop control, virtual synchronous machine, and virtual oscillator controller.

Droop control: Droop control was first proposed in the early 1990s and since then it is extensively studied and applied in various grid-forming inverters. This is the most adopted control strategy, and the key characteristic is its linear relationship between frequency and real power, as well as voltage and reactive power resembling the behavior of synchronous machines.

In conventional droop control for grid-forming inverters, the droop gains (Kp and Kq) are determined based on the characteristics of the system. In the case of a predominantly inductive grid, the equations for conventional droop control can be expressed as:

$\omega = \omega ref - kp(P - Pref)$

$V = Vref - kq(Q - Qref)$

Here ω represents the output frequency of the inverter, ωref is the reference frequency (typically the nominal grid frequency), P is the measured active power feedback signal after passing through a low-pass filter, Pref is the reference active power, V represents the output voltage amplitude of the inverter, Vref is the reference voltage (rated inverter output voltage during no load conditions), Q is the measured reactive power feedback signal after passing through a low-pass filter, and Qref is the reference reactive power.

The presence of a low-pass filter in the active power droop and reactive power droop serves two primary objectives. Firstly, they help filter out measurement noise, ensuring a more accurate feedback signal. Secondly, in the case of the active power droop, it emulates the inertia effect of a synchronous machine. This is significant as it provides a similar response to sudden changes in power demand, contributing to grid stability.

By adjusting the droop gains Kp and Kq, the inverter can regulate its output frequency and voltage based on the difference between the measured feedback signals (P and Q) and their respective references (Pref and Qref). This enables the inverter to participate in system-wide synchronization and power sharing, as discussed earlier.

Virtual Synchronous Machine: VSMs are another approach to grid forming control in inverters. This entails replicating the functionality of a synchronous machine within the control system of the inverter. In the VSM approach measurements taken at the terminals of the inverter are used as inputs to a digital model of a synchronous machine. The dynamics of the emulated machine are then mapped to the output of the inverter in real-time. The level of complexity in the virtual machine can vary, ranging from intricate electromechanical models that closely resemble the characteristics of a physical synchronous machine to simplified swing dynamics.

VSM implementations that closely resemble the characteristics of a synchronous machine, including both Q-V (reactive power-voltage) and P-omega (real power-frequency) characteristics, are often referred to as "synchronverters." These synchronverters replicate not only the droop response but also the voltage and current dynamics of a synchronous machine, potentially even including virtual flux dynamics.

In contrast, less complex Virtual Synchronous Machine (VSM) approaches concentrate on capturing solely the dynamics of a simulated rotor and its steady-state-P-Omega droop. These methods, often referred to as virtual inertia methods, provide a simplified emulation of the inertia effect of a synchronous machine.

Therefore, VSM-based control strategies enable the inverter to operate in a way that enhances the grid stability and provides features such as system-wide synchronization and power sharing.

Dispatchable Virtual oscillator control (dVOC): This is based on the concept of virtual oscillator control. The key requirement for a grid-forming control strategy to be dispatchable is that it can be adjusted according to the system's demand. In dispatchable systems, there is no fixed system reference, and the control parameters need to be adaptable based on the desired generation dispatch.

The original VOC, while effective, lacks the dispatchability feature and does not explicitly calculate real and reactive power at the inverter terminal. Conversely, dVOC is designed to be dispatchable and only relies on local measurements to enable grid-forming behavior with adjustable droop characteristics. It allows for the variation of frequency and voltage in generating units based on active and reactive power generation.

Unlike droop control, which often relies on phasor approximation, dVOC operates as a nonlinear time domain controller. It does not rely on phasor-based approximations and offers a different approach to achieving grid-forming control. The use of VOC in grid forming control has advantages over traditional droop control.

To ensure the dependable performance of these inverters, it is necessary to have access to a controllable and dispatchable energy source. As mentioned earlier, since VRE sources are non-dispatchable, GFM inverters are commonly coupled with Energy storage systems. The size and location of the ESS unit have a direct impact on the GFM inverter's ability to regulate frequency and voltage.

Although grid-forming inverters combined with energy storage systems seem to answer all the challenges which arise with the high penetration of inverter-based sources, when it comes to system protection things get a bit complicated.

Power system protection focuses on maintaining the stability of the power system and minimizing the extent of network disconnections. The primary objective is to reduce the geographical and temporal impact of network outages resulting from abnormal situations by effectively operating and coordinating protection devices across various grid regions.

As the development of inverter-based resources increases and replaces synchronous generators, there is a shift in the evaluation of transmission level protection. Presently, the primary focus is on identifying weak grids with low short-circuit currents and further advancing the protection and relaying techniques (IEEE/NERC 2018). Since the inverter-based resources exhibit different magnitude and phase characteristics compared to synchronous generators, the focus has changed to facilitate necessary improved protection strategies for the implementation of these sources. Even with the recent increase of grid following resources have challenged the traditional protection system, with bidirectional power flow as one example. From the studies done on integrating grid following inverters, it has been determined that integration of higher levels of these sources will result in incorrect operation of traditional protection systems. And yet for grid-forming inverters, studies have not been extensively done. Therefore, adaptive protection is suggested due to the lack of studies.

However, there are small islands including Ta'u (American Samoa), King Island (Australia), and Maui (Hawaii USA) that are already operating at or near 100% wind and solar by including grid-forming inverters supported with energy storage systems. With more research, the integration of these systems can be implied at a larger scale.

In conclusion, grid-forming inverters combined with energy storage systems technically have the potential to replace traditional power systems with solar and wind at or near 100% in the future. Due to a lack of research and studies on protection systems, efficient and reliable energy storage systems, and mainly due to the higher level of initial costs, implementing those on a larger scale seems to be practically impossible but, with the necessary research and infrastructure, hopefully, this will be viable in the near future.

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Power Electronics and Control System in Aerospace Industry

1.0) Introduction

Space power electronics plays a crucial role in the field of aerospace technology. Space power electronics, a key component of aerospace technology, enables the control and conversion of electric power in a number of applications, including satellites, spacecraft, launch vehicles, space stations, and rovers. In this area of electronics, high voltages and currents are processed to produce power that meets a variety of purposes. A modular power electronic subsystem (PESS), coupled to a power source and a load at its input and output power ports, is the basic building block of a power electronic system, according to NASA. The third port of the PESS is connected to the control system, enabling effective power management. This article will examine various noteworthy power electronics applications that are becoming more common in the aerospace sector. The power systems for the International Space Station, satellites, possible starter/generators, flywheel technology, electric airplanes, and reusable launch vehicles are some of these uses. By spotlighting these developments, we may learn more about how power electronics is influencing aircraft technology in the future.

2.0) Space Station Power System

The International Space Station's Electric Power System (EPS) is divided into two main segments: a Russian and an American one, both of which operate at 28 and 120 volts respectively. Dc converters connect these systems, enabling the transmission of electricity based on supply and demand. With contributions from numerous partners in the form of interchangeable hardware elements known as Orbital Replacement Units that offer power generation, distribution, and energy storage, the EPS marks a successful international integration effort.

2.1) DDCU

The Direct Current-to-Direct Current Converter Unit plays a crucial role in regulating voltage for NASA's Space Station power system. The DDCU ensures a constant voltage output of 124.5 ± 1.5V by regulating the widely varying voltage from the solar arrays (ranging from 115V to 173V). It is capable of handling loads ranging from less than 1A to more than 50A, with an overload condition at 80A. The DDCU is designed to be short circuit proof and communicates its status with other modules in the power system via a Mil-Std-1553-type bus.

As NASA plans for future space travel, power electronics technology must continue to evolve. Advancements in areas such as wide bandgap semiconductors, packaging, manufacturing, electromagnetic and physical impact, and converter control technology will drive the development of more efficient and compact power management systems. These advancements will be crucial for achieving NASA's objectives in space exploration, including missions to Mars, the moon, and beyond.

3.0) Starter or Generator Technologies

3.1) VSCF

Variable-speed constant frequency (VSCF) functioning has become a potential solution to get past these limitations and provide more advanced starter-generator systems for aerospace applications. Aircraft power systems based on VSCF technology exhibit longer mean-time between failures and speedier mission turnaround times than CSD-based systems used in existing aircraft. By developing VSCF-based electric power systems that can be integrated within the confines of current CSD-based systems, existing aircraft can benefit from increased dependability, lower costs, and quicker mission cycles.

In the VSCF system, an interface power converter transfers power from the constant frequency mode to the electric machine that serves as a starter for loads like aircraft engines. In the generating mode, an electric machine uses a variable speed prime mover, such as a gas turbine or a wind turbine, to produce variable frequency electricity.

In the VSCF system, an interface power converter transfers power from the constant frequency mode to the electric machine that serves as a starter for loads like aircraft engines. In the generating mode, an electric machine uses a variable speed prime mover, such as a gas turbine or a wind turbine, to produce variable frequency electricity. This power is transmitted to the system at a steady frequency by the interface converter.

Aerospace applications can be gained from higher power generation, improved control, and increased operational flexibility by implementing VSCF technology. To fulfill the changing needs of contemporary aircraft and spacecraft, the integration of VSCF systems has the potential to revolutionize electric power generation in the aerospace industry.

3.2) The Doubly-Fed Brushless Machines

Double-fed machines, including wound-rotor induction machines, have been utilized frequently in slip power recovery techniques for wind energy production. This method uses the power source to recover or supply energy when the rotor slips below or above synchronous speed. In a VSCF doubly fed wound-rotor induction machine system, excitation occurs at the stator and rotor terminals, and bidirectional variable frequency converters control slip power in both directions. To balance the power flow in this system, the rotor terminals act as the energy regulating port. Harmonic currents are transmitted to the rotor windings because of the power electronic converter regulation, which changes the frequency of the stator windings.

Another strategy is the brushless doubly fed induction machine, which has two sets of windings in the stator and a special design. One set is directly excited from the utility supply and is referred to as the "power windings," while the other set, the "control winding," functions as an equivalent set of rotor windings. A bidirectional frequency converter's control winding is used to manage the energy flow through it. The type of rotor is a cage-or-reluctance one.

4.0) Future Trends and Conclusion

Power electronic converters are essential to the functionality of on-board electric propulsion systems and aeronautical power systems. For the greater integration of power electronics in flight systems, it is imperative that the compatibility issues between standard 400Hz operating equipment and the variable frequency requirements of the "more electric" technology be resolved.

The usage of multi-voltage level converters is essential as future aeronautical systems demand different voltage levels and flexible load requirements. Incorporating electronic modules with dual-use capabilities and hardware that is compatible with both spacecraft and aircraft can also dramatically save development costs, maximize system reusability, and improve the reliability and performance of the entire system. To keep up with the rapidly changing needs of the aerospace industry, this survey emphasizes the crucial role that power electronics play in advancing aircraft technologies

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SriLankan 70% Renewable Energy Dream

Climate change and global warming has become a buzzworthy topic which is increasingly important to discuss in recent years, as the world has seen the effects of rising temperatures and extreme weather events. As a result, there has been a growing interest in renewable energy sources to reduce greenhouse gas emissions and combat climate change. However, the transition to renewable energy is not without its challenges. One of the key issues is the intermittent of renewable energy sources such as solar and wind power, which can lead to fluctuations in energy supply and demand.

In the 2023–2042 Sri Lankan Long Term Generation Expansion Plan (LTGEP), some methodologies have been mentioned based on the latest Sri Lankan government policy guidelines for the electricity industry to implement 70% of electricity generation from renewable energy sources such as wind power, solar power, biomass, hydropower and maintain it beyond 2030 as well as reach carbon neutrality from the electricity sector by 2050.

Sri Lanka (SL) has given the commitment to United Nations Framework Convention on Climate Change (UNCCC), reach carbon neutrality by 2050, cease building coal power plants and to generate 70% of electricity using renewable energy sources by 2030.

The term 'Carbon Neutrality' differs from zero emission and net-zero emission. Zero emission means no emissions. Net-zero means you can emit but should have emission absorption technologies to make the net impact zero within the country boundary. Carbon neutrality means you can emit, and you can purchase carbon credits from other countries to balance off the emissions and make net-zero. In our country commitment we have focused on carbon neutrality, it is not zero emission or net-zero emission. This commitment was given in 2021 through updated Nationally Determined Contributions (NDC) to the Paris Agreement (PA). The ambition of Paris Agreement is adopted under the UNFCCC to limit global warming. Global emissions need to be reduced by nearly 43% by 2030 for the world to achieve PA's goal. To achieve targets, the Paris Agreement requires all the parties to submit their NDCs, which outline their targets and actions to reduce greenhouse gas emissions and adapt to the impacts of climate change. The Agreement also requires countries to regularly report on their progress and to strengthen their targets over the time, with a view to reaching global peaking of greenhouse gas emissions as soon as possible and achieving a balance between anthropogenic emissions and removals of greenhouse gases in the second half of this century. Therefore, our ministry of Power and Energy has released the latest policy guidelines for the electricity industry which complied with these commitments. So, SL electrical engineers are evaluating future generation plans based on these policies and guidelines.

LTGEP is made once every 2 years because the plan needs to be changed with the country's economy, demand variation, policy, technology development and actual implementing timelines and other practical issues etc.

Now let's go to the latest plan 2023–2042 which was approved by Public Utility Commission of Sri Lanka (PUCSL) after a several years.

4 scenarios based on government policies have been mentioned there and the lowest present value cost scenario among above 4 scenarios has been considered as the base case. And they have suggested more 3 scenarios that are unconstrained by policies and guidelines but more cost-effective than the above 4 scenarios. Scenario 6 is the lowest present value cost case among all the scenarios, and it is operationally feasible, so it is considered the reference case in the plan.

7 scenarios has been analyzed economically and technically including the base case.

The reason to compare 7 scenarios is, then it will be more convenient to take right decisions along the path to achieving the goal and then accredited officers may tend to a more practical and economic scenario to implement.

Scenario 1 (base case): Achieving 70 % RE by 2030, maintaining 70% RE beyond 2030, and no coal-fired plant additions throughout the horizon.

Scenario 2: Achieving 70 % RE by 2030, attempt to further increase RE share up to 80% by 2040, and no coal-fired plant additions throughout the horizon

Scenario 3: Achieving 70 % RE by 2030, maintaining 70% RE beyond 2030, no coal-fired plant additions throughout the horizon, and considering cross-border interconnection with India.

Scenario 4: Achieving 70 % RE by 2030, maintaining 70% RE beyond 2030, no coal-fired plant additions throughout the horizon, and considering nuclear power development beyond 2040.

Scenario 5: Achieving 50 % RE by 2030, maintaining 50% RE beyond 2030, and no coal-fired plant additions beyond 2030.

Scenario 6 (reference case): Achieving 60 % RE by 2030, maintaining 60% RE beyond 2030, and no coal-fired plant additions beyond 2030.

Scenario 7: Achieving 60 % RE by 2030, maintaining 60% RE beyond 2030, and no coal-fired plant additions throughout the horizon.

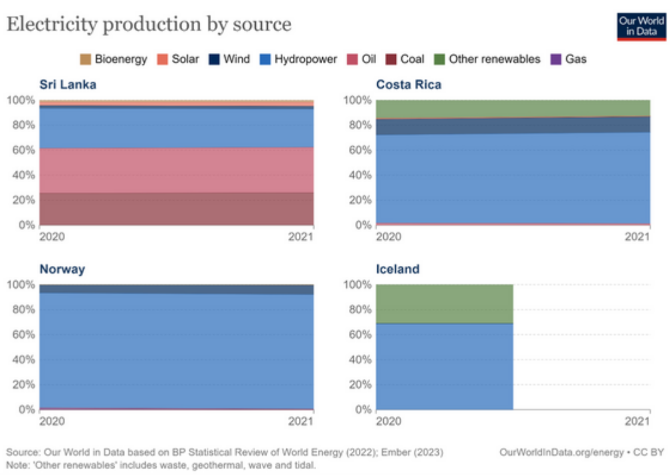
Below table shows energy share and capacity share in electricity generation in 2042 according to the base case.

Source	Base case	
	Energy share (%)	Installed capacity share (%)
Solar	31	42
Natural gas	22	12
Wind	20	14
Major hydro	10	6
Coal	8	2
Biomass	5	2
Mini hydro	4	3
Battery storage		13
Pumped storage		6

So, Sri Lanka is trying to generate electricity using solar power more than other sources. The number of large hydropower plants are already saturated, some mini hydro projects are going to be initiated, but it is not a large capacity. After achieving the maximum and possible biomass capability and wind power, we have to go with high energy share in solar power to achieve the targets. By the way there are some clues to getting geothermal in the Mannar basin, so the Sustainable Energy Authority is working on that to make it possible to contribute to electricity generation. As it is not proved yet, geothermal is not considered as an energy source in the latest generation plan. Going for a high energy share in solar power may be more challenging. See why in later paragraphs. It will be good to see the status of some countries who have achieved almost 100% renewable energy share in generating electricity.

According to the data in 2021, there are some countries such as Iceland (99.99%), Costa Rica (98.74%), Norway (99.54%) reached almost 100% of generating electricity using renewable energy sources. In below table represents energy share between renewable energy sources of each country in 2021.

	Sri Lanka	Iceland	Norway	Costa Rica
Geothermal (%)	-	26.3	-	9.4
Hydro power (%)	50.5	74.5	93.4	78.9
Wind (%)	2.2	0.5	4.4	10.6
Solar (%)	1.4	0.1	-	0.6
Other renewable (Biomass, tidal, wave) (%)	0.4	<0.1	2.2	0.5
Total renewable energy share (%)	54.5	100	100	100



fair to say, Iceland and Costa Rica can achieve a reliable power system.

Costa Rica uses grid connections from the Central American electrical interconnection system, and adding energy storage such as pumped storage and battery system as well as diversification of renewable energy sources helps to improve system reliability with large hydro power percentage.

Norway has been maintaining its system reliability by diversification of renewable energy sources, reservoir management, and energy storage systems.

Any above-mentioned countries have not gone for more than 1% of energy share of solar power. It is too much fair of they have not gone for solar because they have other renewable resources which are more reliable than solar power.

As a country that is trying to go for a 70% renewable energy share, we have a challenge of keeping the power system reliable and stable. To achieve that, conventional technologies which can provide cyclic operations with faster ramping and frequent start-ups should be added to the power system for reaching the power supply by adjusting the output of power plants quickly according to the change in energy demand. When a fault happens which can cause for a system blackout by tripping off some major power plants, high inertia machines should be there to keep system frequency for several seconds without dropping it low suddenly, then the system will not go for a blackout if the fault can be cleared within seconds. Pump storages for hydro plants, advanced control systems, flexible fuel sources, and battery systems can be considered as the technologies which support to provide cyclic operation with faster ramping to initiate in black starts, frequency dropouts and emergency cases.

What do you think about the future of the Sri Lankan power system which is trying to generate 31% of electricity using solar power?

We are going for the most challenging energy source, solar power. Why solar power generation is more challenging was discussed in the next section.

Considering the reliability level of electricity generation from each renewable energy source, it can be shown as follows.

Geothermal > Hydropower > Biomass > Wind > Solar

From the side of Sri Lanka, we can agree with our weather patterns, it will be stipulated by electricity generation using solar. Lanka Electricity Company (LECO) and Ceylon Electricity Board (CEB) have been facing a major problem of increasing line end voltages in distribution level when solar electricity generation is high, occurring from many on-grid household solar Photovoltaic (PV) systems.

On sunny days daytime, solar energy generation is high, and many people are not at home in urban areas, they are at workplaces, so the line-end voltage can be high at the inverter in the household PV systems. If people are consuming enough power generated by the self-solar PV system, this problem may not happen, or it may be controllable. But it has been happening in urban areas where excess power is generated from solar panels in their homes during the daytime and there are many solar PV systems in that area. Then due to the high voltage from home solar PV system, power-connected appliances in that home and other near homes can be damaged due to overvoltage.

The problem is solar electricity generation passes its voltage limits in the end that connects to the distribution line in the distribution network. So how to prevent this situation?

We must stop the overvoltage from solar PV systems.

Solution 01 — Limit the number of solar PV systems and capacities for each that can be installed within an area to a reliable value that can be handled by the grid within the maximum generation from solar PVs.

This value should be calculated after collecting existing solar PV systems capacities in the relevant area and the grid capability of that area. If some areas already exceed that limit, then the following solutions should be tried. Otherwise, a big problem can be stopped at the beginning by limiting the capacities like mentioned above.

Solution 02 — Transformers with on load tap changers

By the transformer tap changers in the distribution level, the network voltage can be maintained within the allowed limit (-6%/+6%). But this voltage range can be changed from tapping windings in a transformer. The voltage variation that can be handled from tapping is also limited. In Sri Lanka, this infrastructure should be developed by replacing distribution transformers with on-load tap changers which are working automatically. And new cables of more current carrying capacity are required to apply to the network to hold more currents. Additionally in Sri Lanka, many factories are working at nighttime. Therefore, in the daytime, there are no big machines (motors, transformers) working to consume reactive power in the lines. This also mainly causes to increase the line voltages. So, our system should be more developed to regulate line voltages.

Solution 03 — Battery storage

The excess energy can be stored in batteries while controlling the output voltage to the grid within the allowed limits or moving towards off-grid solar systems will solve this problem, but it is not suitable for house levels that are having medium/ less demand. Storing excess energy in battery storage, the home can use it at nighttime and can supply it to the network when the system has low production and high demand.

Solution 04 — Smart inverters, Smart meters

Smart inverters can be programmed to trip off when the PV system voltage is not within its allowed limits. And using smart meters, LECO/ CEB can control it remotely when voltage is going to exceed in household PV systems. If a battery system is not involved in the system, these options will limit electricity generation whether solar power is accessible.

Solution 05 – Static var compensators

Installing these in grid substations along the lines, line voltages can be controlled. They consist of a set of capacitors and reactors that can be switched on or off as needed to control the voltage and power factor of the system. Normally they are used in transmission lines, but at least using small scale inductors which absorbs reactive power, this problem can be controlled in considerable manner.

Not only solar, considering the high level of variable renewable energy (VRE) integration into an electrical system, they are some key challenges to be faced, including above discussed one. System demand and supply should be balanced in every case. But the system of high VRE energy share may face the challenge of system adequacy which can occur due to VRE droughts, seasonal imbalances, steeper demand ramps.

System frequency should be maintained within its limits, that is essential to balance supply and demand instantly. This may be a big challenge because of the reduction of system inertia due to the inverter-based generation.

Voltage stability is the other thing which can be a challenge because the reduction of reactive power capabilities due to decrement of conventional, dispatchable generation and increment of inverter-coupled generation.

Energy storages, increasing grid capacity, curtailing VRE, operating grid forming inverters and synchronous condensers may be solutions for some of above challenges.

These all solutions have their own limits, specially economic issues.

Therefore, as a country, to achieve this much high percentage of electricity generation from solar power, we should have the economic strength first and the availability of land (as a good solution to this, they have suggested floating solar PV systems also) and suitable and developed infrastructure to maintain the system stability, reliability, and sustainability with a large amount of solar, wind energy generation. Developed countries may support financially to the developing countries in this case of fighting against climate changes all together.

We have to wait to see what will happen in the future… Will all countries implement their NDCs as they promised or will the world face disasters due to climate change? Anyway, this is a hot topic.

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Propelling Intelligent Automation in Customer Service with Natural Language Processing (NLP)

There is no doubt that humans are the most advanced creatures on the Planet Earth. This is because of our ability to communicate and understand each other. And, this is what differentiates humans from other animals. Natural Language Processing is being able to understand human's languages. In the modern era, automation has become a vital part of business operations. Intelligent automation has revolutionized the way businesses operate, especially in the customer service industry. Customer service teams are expected to be available 24/7 to assist customers and ensure their satisfaction. However, it can be difficult to maintain a high level of customer service with limited human resources. That's where natural language processing (NLP) comes in.

NLP is a branch of artificial intelligence (AI) that allows machines to understand, interpret, and respond to human language. By leveraging NLP, customer service teams can automate several tasks, making their operations more efficient and cost-effective. In this article, we will discuss how NLP is propelling intelligent automation in customer service

Chatbots

One of the most significant applications of NLP in customer service is chatbots. Chatbots are automated tools that communicate with customers through a chat interface. They use NLP to understand and interpret customer inquiries and respond appropriately. Chatbots can handle routine inquiries, freeing up customer service teams to focus on more complex issues. Chatbots can be integrated into websites, mobile applications, and social media platforms, making them easily accessible to customers. They can provide personalized responses, ensuring that customers receive the assistance they need. Additionally, chatbots can handle multiple conversations simultaneously, reducing wait times and increasing customer satisfaction. With the help of machine learning, chatbots experience can be improved. Here is an example:

This is a machine learning model, running on jaseci and following information are given to the model.


```
{
  "question": "What is Tesla Inc.?",
  "answer": "Tesla, Inc. is an American electric vehicle and clean energy company based in Palo Alto, California.
},
```

```
"question": "What are the specifications of Tesla Model S?",
"answer": "The Tesla Model S is a full-sized all-electric five-door liftback car, produced by Tesla, Inc. and
introduced on June 22, 2012. The EPA official range for the 2019 Model S Long Range RWD is 370 miles (600 km), while
the Long Range AWD is 348 miles (560 km). The EPA official range for the 2019 Model S Long Range RWD is 370 miles (600 km),
while the Long Range AWD is 348 miles (560 km)."
```

When the user asks information, the question can be different to one another. But, with a machine learning model, it can actually find out the meaning of the question asked and give the relevant answer to that question.

These are questions asked by customers relevant to above details.

```
User > whats Tesla?
Tesla, Inc. is an American electric vehicle and clean energy company based in Palo Alto, Californi
a.
User >
```

```
User > specs of model S?
The Tesla Model S is a full-sized all-electric five-door liftback car, produced by Tesla, Inc. and
 introduced on June 22, 2012. The EPA official range for the 2019 Model S Long Range RWD is 370 mi
les (600 km), while the Long Range AWD is 348 miles (560 km). The EPA official range for the 2019
Model S Long Range RWD is 370 miles (600 km), while the Long Range AWD is 348 miles (560 km).
User >
```

As you can see the questions asked by the customers can be quite different. But model was able to give accurate information for their inquiries.

Sentiment Analysis

Sentiment analysis is another application of NLP that is propelling intelligent automation in customer service. Sentiment analysis uses machine learning algorithms to identify and interpret human emotions from text. This enables customer service teams to understand customer feedback and improve their services accordingly. By leveraging sentiment analysis, customer service teams can quickly identify issues that are affecting customer satisfaction. They can then take appropriate action to address those issues, reducing the number of customers.

complaints and improving customer loyalty. Additionally, sentiment analysis can be used to monitor brand reputation and identify trends in customer feedback. For an example, here are some reviews done by some

0 - "Great coffee and vibe. That's all you need. Crab was outstanding but not good finger food like a taco should be. Really want to try the pork belly sandwich - looked excellent. This became my go to breakfast place in Darling harbor. Had the avocado salmon salad breakfast and it was excellent. Service has been excellent."

1 - "Great coffee and vibe. That's all you need. Crab was outstanding but not good finger food like a taco should be. Really want to try the pork belly sandwich - looked excellent."

2 - 'Great food amazing coffee and tea. Short walk from the harbor. Staff was very friendly'

3 - "It was ok. Had coffee with my friends. I'm new in the area, still need to discover new places."
4 - "Ricotta hot cakes! These were so yummy. I ate them pretty fast and didn't share with anyone because they were that good ;). I ordered a green smoothie to balance it all out. Smoothie was a nice way to end my brekkie at this restaurant. Others with me ordered the salmon Benedict and the smoked salmon flatbread. They were all delicious and all plates were empty. Cheers!"
5 - 'Great staff and food. Must try is the pan-fried Gnocchi! The staff were really friendly and the coffee was good as well'
5 - 'Great staff and food. Must try is the pan-fried Gnocchi! The staff were really friendly and the coffee was good as well'

	review	sentiment
0	Great coffee and vibe. That's all you need. C...	5
1	Great coffee and vibe. That's all you need. C...	4
2	Great food amazing coffee and tea. Short walk ...	5
3	It was ok. Had coffee with my friends. I'm new...	3
4	Ricotta hot cakes! These were so yummy. I ate ...	5
5	Great staff and food. Must try is the pan fri...	5

This is a simulation conducted using the pre-trained BERT model for the aforementioned reviews, which performed sentiment scoring within a range of 0 to 5, with 5 indicating the most positive sentiment.https://github.com/udithishanka/Sentimental_Analysis.git

Key word searching

In keyword searching within search engines, NLP plays a crucial role in providing customers with accurate results for their inquiries. NLP algorithms and techniques are employed to understand the intent and meaning behind the keywords entered by the users. One of the significant advantages of NLP in keyword searching is its ability to handle spelling mistakes. Search engines equipped with NLP models can identify and correct misspelled words, ensuring that the user's query is interpreted correctly. This makes the user gets the relevant results even though the inquiry is grammatically incorrect. By employing techniques like fuzzy matching and phonetic algorithms, the search engine can suggest alternative spellings or automatically correct the misspelled words to improve the search accuracy.
Furthermore, NLP enables search engines to go beyond literal keyword matching. It incorporates sentiment analysis, which helps understand the user's emotional context or intent. By analyzing the sentiment associated with the keywords used in the search query, search engines can deliver more relevant results tailored to the user's needs. For example, if a user searches for "best budget-friendly smartphones," sentiment analysis can help prioritize results that emphasize positive reviews or recommendations for affordable devices.

Knowledge Management

NLP can also be used to automate knowledge management in customer service. Knowledge management involves organizing and storing information that can be used to assist customers. NLP algorithms can analyze customer inquiries and identify relevant information from a knowledge base. By automating knowledge management, customer service teams can provide faster and more accurate responses to customer inquiries. This can improve customer satisfaction and reduce the workload on customer service agents. Additionally, it alleviates the workload on customer service agents, enabling them to focus on more complex or specialized customer needs. By harnessing the power of NLP in automating knowledge management, organizations can enhance their customer support processes and deliver a seamless and efficient customer experience. This automation of knowledge management empowers customer service teams to provide faster and more accurate responses to customer inquiries, resulting in improved customer satisfaction.

Voice Assistants

Voice assistants have revolutionized the way businesses interact with their customers. With advancements in NLP technology, voice assistants have become increasingly sophisticated in understanding and responding to customer inquiries. These assistants have the ability to recognize and interpret spoken language, enabling them to navigate complex conversations and provide accurate and relevant information. By incorporating speech recognition technology, voice assistants can understand the spoken word and convert it into text. This text is then processed using NLP algorithms, which analyze the customer's intent and extract key information from their query. This allows voice assistants to comprehend the meaning behind the customer's words and provide appropriate responses or actions.

The benefits of voice assistants extend beyond just understanding customer inquiries. They can also provide personalized responses by leveraging customer data and preferences. By accessing relevant information about the customer, such as their purchase history or previous interactions, voice assistants can tailor their responses to meet individual needs. This level of personalization enhances the customer experience and builds stronger relationships between businesses and their clientele. Furthermore, voice assistants have the ability to handle multiple conversations simultaneously, greatly reducing wait times and increasing efficiency. Traditional phone-based customer support often involves long wait times and repetitive menu navigation, leading to frustration and dissatisfaction. With voice assistants, customers can have their inquiries addressed promptly without the need to wait in a queue or navigate complex phone menus. This not only improves customer satisfaction but also frees up human support agents to focus on more complex or specialized tasks.

In conclusion, NLP is a powerful technology that is propelling intelligent automation in customer service. By leveraging NLP, customer service teams can automate several tasks, making their operations more efficient and cost-effective. Chatbots, sentiment analysis, keyword searching, knowledge management, and voice assistants are just a few examples of how NLP is transforming customer service.

Udith Ishanka
20 batch

A JOURNEY WITH EESOC EVENTS

Tech Talk

Tech Talk, a discussion organized by the EESoc of University of Moratuwa on The Safety Related Challenges of Using Lithium Ion Batteries took place on January 4th, 2023 at the civil auditorium. The guest speaker, Prof Michael Pecht, (45,000+ citations, 95 H-Index) (BS in Physics,MS in Electrical Engineering, MS and PhD in Engineering Mechanics from the University of Wisconsin) shared his expertise on the topic giving undergraduates the opportunity to widen their knowledge. Following his speech a special session was conducted by the representative Mr. Jaliya Chinthaka from VEGA Innovations (Pvt) Ltd. on battery technologies the industry is working with.

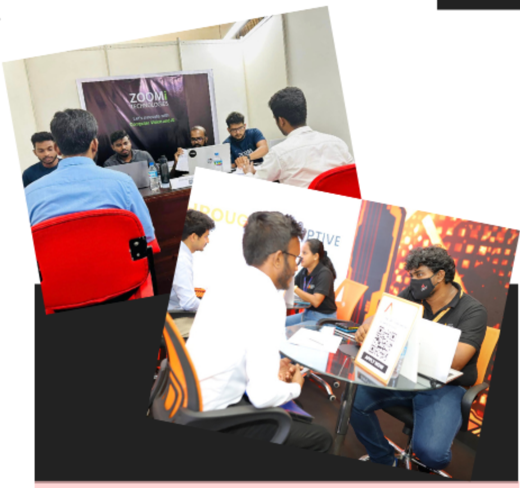
AI workshop

The Electrical Engineering Society of the University of Moratuwa organized a lecture series on "Conversational Artificial Intelligence." The first session, held on March 16, 2023, featured a keynote address by Professor Jason Mars from the University of Michigan. Prof. Mars, a prominent figure in Conversational AI, shared insights from his experience as the founder of Jaseci Labs and author of "Breaking Bots." The event attracted undergraduates and all AI enthusiasts, fostering discussion and networking opportunities. This marked the start of an enlightening lecture series aimed at enhancing understanding of Conversational AI's advancements and applications.

Measurements Lab Opening

The newly renovated Measurements Lab of the Electrical Engineering department was opened by the vice-chancellor of University of Moratuwa on 30th of November 2022. The Electrical Engineering Society of University of Moratuwa had the privilege of organising the opening ceremony with the guidance of the academic staff. This renovation will benefit students to engage in inclass activities and encourage peer learning.

EESpire '22



EESpire'22 ,official career fair of the Department of Electrical Engineering, University of Moratuwa was successfully concluded on 25th of May 2022 with the virtual participation of more than 20 companies. This year, it was organized for its third consecutive year giving the opportunity for another batch of undergraduates to set their first step on the career ladder.

The career fair consisted of several webinars, which were focused on preparing the undergraduates to face industry confidently. The webinar series was conducted by several distinguished speakers. Dr. Ravi Wijesiriwardhana, a former lecturer at the department, currently the senior Vibro-Acoustic Engineer at SUBPAC, USA, conducted the first webinar of the series, guiding undergraduates on the topic of Successful Interaction and How to Face an Interview optimistically. Professor Joseph Rohan Lukas, a former lecturer at the department, and Mr.Lalith Kahatapitiya, founder and the chairman of K.I.K group were also joined with the webinar series, to give undergraduates valuable tips and tricks on the career development and engineering entrepreneurship.

Prakampana

ALBUM

On the first day of December 2022, the halls of the University of Moratuwa came alive with the electrifying "Prakampana" event, organized by the undergraduates of the Department of Electrical Engineering, University of Moratuwa, in collaboration with EESOC. The 18th, 19th, and 20th batches had joined forces to create a spectacle like no other, and the audience was amazed.

As the curtains opened, the audience was transported to a world of adventure, as the theme for the concert was none other than Captain Jack Sparrow. The atmosphere was electric, as the students poured their hearts and souls into every performance, leaving the audience completely captivated.

The concert was a true feast for the senses, with drama, music, and dance performances that showcased the incredible talents of the undergraduates. From soulful songs to breathtaking instrumental performances, the students brought their A-game to every act. The medley performances were particularly noteworthy, as the students seamlessly blended multiple genres to create something truly unique.

But it wasn't just the students who shone that night. The staff also put on a show-stopping performance, proving that talent knows no age limit. The concert was a true collaborative effort, with everyone working together to create something truly special.

The decorations were best, transforming the hall into a pirate's paradise. The attention to detail was remarkable, and it was clear that the students had poured their hearts and souls into every aspect of the event.

The cherry on top was the chief guest, the one and only Captain Jack Sparrow, who had graced the event with his presence. His mere presence electrified the already charged atmosphere, and he couldn't help but be impressed by the sheer talent and creativity on display.

In the end, the Prakampana event was a resounding success, the very first and best concert from the Department of Electrical Engineering in the history of the university. The beginning was dramatical, and the flow of the event was flawless. The concert was a true testament to the creativity and passion of the Electrical Engineering students, who had once again proven that they were a force to be reckoned with.

Symposium

The National Symposium on Power Sector Reforms in Sri Lanka, organized by the Electrical Engineering Society of the University of Moratuwa (EESoc), took place on May 31, 2023, at Waters Edge Hotel in Colombo. The symposium aimed to provide a platform for experts, researchers, and professionals to discuss and promote sustainable solutions for power sector reforms in Sri Lanka. Covering a wide array of topics such as power generation, transmission, distribution, energy efficiency, renewable energy, and regulatory frameworks, the symposium facilitated significant discussions on the challenges and opportunities within Sri Lanka's power sector. The event allowed participants to engage in meaningful conversations about the future of the sector and fostered valuable networking opportunities

Sip-Darana

Sip-Darana, a mathematical tutorial session organized by the Electrical Engineering Society at University of Moratuwa took place on April 1st, 2023, at Kalagama Kanista Vidyalaya. The program was initiated aiming to provide learning opportunities for the students with limited resources. In concert with the program a lab opening also took place in the premises, intending to provide the best learning experience to the students. The facility was renovated by the support of EESoc, equipping with modern equipment, to support students in their academic pursuits. Through Sip-Darana, EESoc aims to provide quality education to underprivileged students and empower them to reach their full potential. EESoc remains committed to supporting and guiding students in need and will continue to organize similar initiatives in the future.


Gathered knowledge from a specific sector is a treasure for enthuastics.....
EESoc