ENERGY DAY 2024 ABSTRACTS

Academic Presentations

1. Advanced Combustion and Energy Conversion & Storage Technologies
2. Power Electronics and Smart Grids
3. Renewable Energy and Sustainability

A. Advanced Combustion and Energy Conversion & Storage Technologies

1. Low Calorific Value Fuel Based Burner Design for Industrial Applications

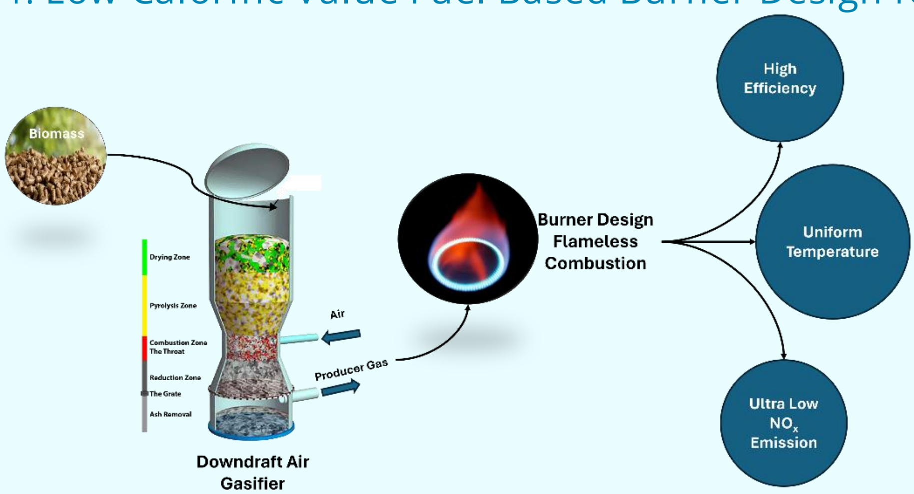


Figure 1 Representation of whole project

In the current global context, nations like India and China are shifting towards renewable energy sources, particularly biomass, to enhance energy security, waste management and address environmental concerns. This study focuses on the utilization of biomass-derived producer gas by biomass gasification through novel flameless combustion technology achieving ultra-low NOx emissions. By employing advanced simulation tools like ANSYS Chemkin and Computational Fluid Dynamics (CFD), the research identifies key parameters such as lean air/fuel mixtures and exhaust gas recirculation for minimizing NO_x emissions (below 20 ppm). Experimental validation confirms the feasibility of flameless combustion, although adjustments are necessary for integration with existing gasifier setups. Despite initial challenges, the study underscores the potential of flameless combustion in enhancing energy efficiency and reducing environmental impact. By bridging theoretical insights, computational simulations, and experimental validation, this research contributes to the ongoing discourse on sustainable energy utilization.

Keywords: Producer gas, Flameless Combustion, Premixed Burner, CFD, Ultra-low NOx emissions.

2. Battery Thermal Management: Generalized Thermal Modelling via ECM Approach

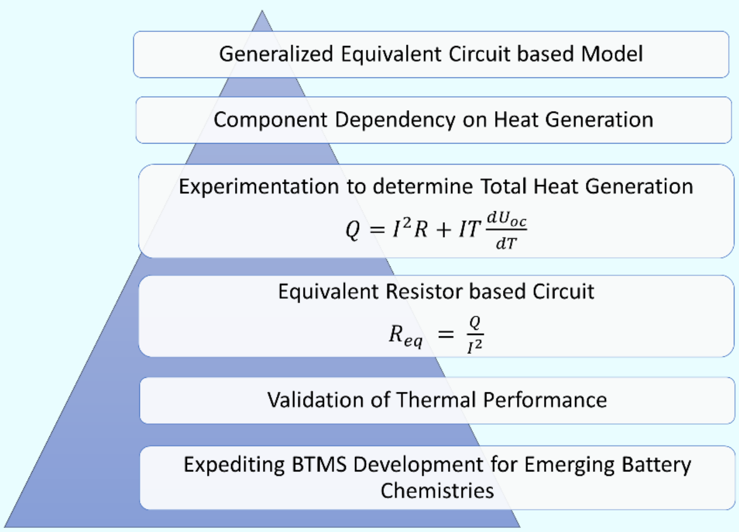


Figure 2 Workflow

The transition from fossil-based fuels to renewables, including the EV sector, highlights the significance of batteries. Thermal issues underscore the critical importance of Battery Thermal Management Systems (BTMS) for ensuring battery safety and performance. This Master's project proposes a generalized methodology for developing an Equivalent Circuit Model (ECM) to replicate battery heat generation rates, expediting BTMS development for emerging battery chemistries. Feasibility assessments of equivalent circuits across various battery chemistries from literature led to the selection of the 2-RC-Thévenin model for the ECM approach. PLECS software was utilized to assess component dependency on heat generation rates, while CFD simulations evaluated thermal severity across different cell geometries. Experimental procedures involving Electrochemical Impedance Spectroscopy (EIS) and Open Circuit Voltage (OCV) tests are designed to determine internal resistance and the Entropy coefficient, respectively in order to calculate total heat generation rate. The cylindrical 18650 cell for NMC and LCO are selected for the experimentation. Validation of the thermal performance of the ECM-based circuit against actual battery cells at specific C- rates constitutes the final step. This research facilitates rapid prototyping and optimization of BTMS, crucial for advancing novel battery technologies.

Keywords: Battery Thermal Management, Equivalent Circuit Model, Heat Generation rate, CFD analysis.

3. Development of electrolyzer system for household application

The world's growing concern over the environmental impact of traditional cooking fuels has triggered a search for cleaner and more sustainable alternatives. Hydrogen, as a versatile and efficient energy source, has emerged as a promising candidate for cooking fuel, offering numerous advantages over conventional fuels. Exploring the current energy scenario, particularly in India, delves into the potential of hydrogen as a substitute for traditional cooking fuels. In this study, system sizing is done based on the daily demand and then modelled in MATLAB-SIMULINK. It shows that a system with direct coupling of Solar PV and electrolyzer generated 4% less hydrogen than when connected with MPPT. There are five cooking scenarios and various lifetimes of the electrolyzer considered in this study, which shows that a system with direct coupling is economically feasible in various cases. In whole life, the proposed system can save 3.8-8.5 tonne CO_2 depending on the cooking scenarios. However, none of the proposed systems was found to be economic if completely relies on firewood for cooking.

4. Copelletisation of biomass and plastic wastes

As the issues of energy security and waste management worsen, it is imperative to use renewable energy resources along with wastes with calorific values, viz. biomass and plastic wastes, for the benefits of energy extraction and waste management. Pelletisation, as a feed densification strategy, is an important aspect for uniformity in the feed properties and increased bulk density for efficient usage in thermochemical energy harnessing such as combustion, incineration etc. In the present study, the co-pelletisation of biomass and plastic wastes has been investigated. Poor adhesion between biomass and plastics necessitates the use of additional binders or preheating of the feeds. Hence, in the present study, wheat flour has been used as a binder and the plastic content in the feed was changed from 0 to 30 % with a step of 5 %. The influence of plastic addition on the pelletisation performance parameters has been analysed.

The increase in feed plastic content adversely affected pellet durability and hardness. However, favourable pelletisation was obtained up to feed plastic content of 25 % such that durability and hardness values were greater than 96 % and 22 kgf, respectively. The calculated and measured pellet gross calorific values were also in close agreement.

Keywords: Biomass; Plastic wastes, Co-pelletisation

5. Hydrodynamic Instability in Single Media Thermocline Storage System

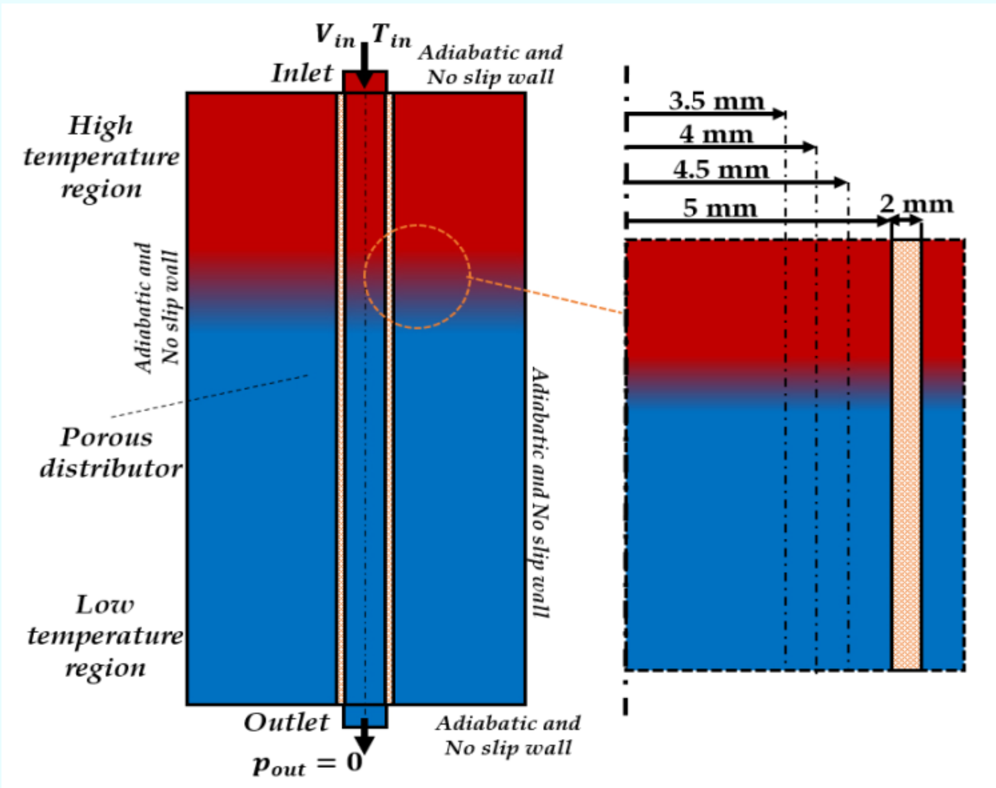


Figure 3 Schematic illustration of single media storage tank with porous flow distributor

Thermal Energy Storage systems play a crucial role in mitigating the intermittent nature of renewable energy sources, particularly solar energy. Sensible single media thermocline storage tanks have emerged as a promising solution. However, studies have revealed instabilities induced by thermal disturbances, potentially impacting the performance of TES systems. This work focuses on examining hydrodynamic instability induced by thermal disturbance in single media thermocline storage tanks equipped with a porous flow distributor. Numerical simulations are conducted to investigate instability characteristics during the charging process under various operating conditions. The study delves into the interplay between TES and hydrodynamic instabilities arising from viscosity stratification within the system. A critical stability boundary, on the Atwood number and Peclet number plane, is also derived to differentiate between stable and unstable regions.

Keywords: Thermal Energy Storage (TES), Thermocline, Hydrodynamic Instability, Viscous Stratification, Thermal Disturbance

6. Low-cost and high cycle life cathode for Lithium-ion batteries

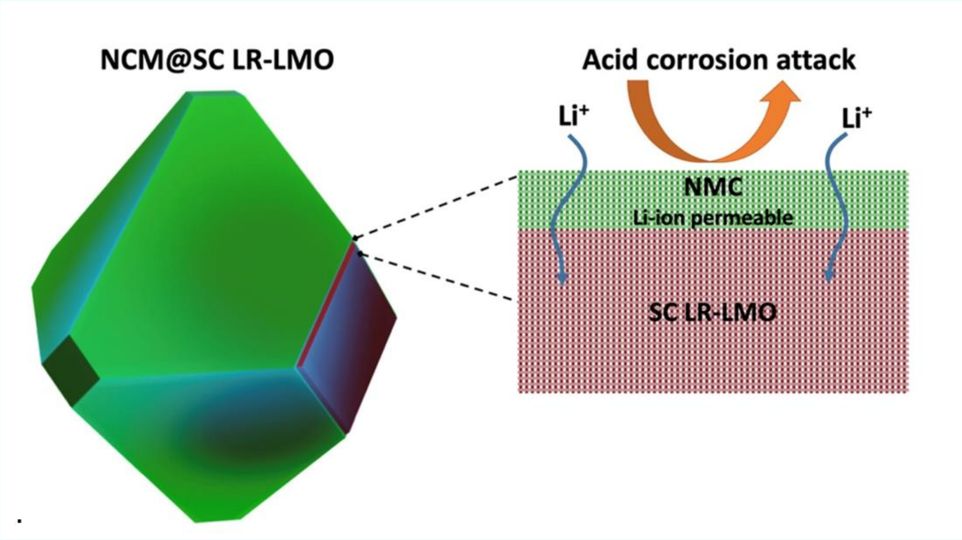


Figure 4 Schematic representing the NMC@SC-LRLMO coating

Spinel LiMn2O4 is considered as the most promising cathode for next-generation Li-ion batteries due to its high operating voltage, environmentally-friendliness, and abundance. However, there are some challenges associated to this cathode inhibiting its practical usage are: Jahn-teller distortion followed by Mn2+ dissolution and acid corrosion under electrolyte contact which destabilises the cathode structure.

Herein, we report a novel heterostructure design; NMC layered Li-ion permeable phase grown on the Lithium-rich LiMn2O4 octahedra surface that protects the host spinel from being directly exposed to the acidic electrolyte during electrochemical cycling. In addition, it provides an efficient path for the ionic and electronic mobility resulting in improved kinetics due to its Li-ion permeability. The excess Li in LMO contributes to the structural enhancement during cycling to accommodate anisotropic volume changes, thus resulting in a robust cathode for high-voltage Li-ion batteries. The uniquely developed LiMn2O4 phase surface coated with layered structure demonstrated discharge capacity of 120 mA h g-1 at 20 °C temperature while retaining >97% of its initial capacity after 300 cycles at 0.5C. Further, The cathode was tested at 60 °C in half-cell format along with full cell testing against MCMB anode.

Keywords: Li-ion permeable robust coating; single crystal LR-LMO cathode; low-strain; lattice matching concept; manganese dissolution; high temperature study

7. Modelling of Reversible Solid Oxide Cells

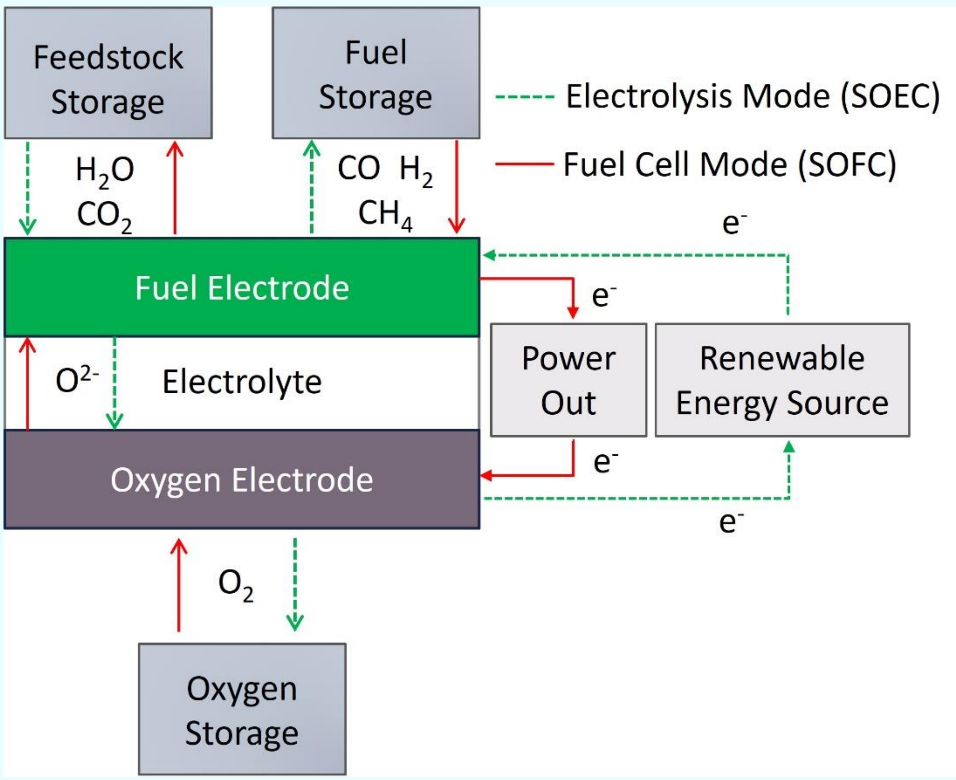


Figure 5 A Schematic of a Reversible Solid Oxide Cell (ReSOC) System

The integration of renewable energy sources into power grids presents significant challenges due to their intermittency and unpredictability. Addressing these challenges, large-scale energy storage and highly efficient conversion systems, such as reversible solid oxide cells (ReSOCs), emerge as pivotal solutions. In fuel cell mode (SOFC), a ReSOC can utilize H2 to generate energy, while in electrolysis mode (SOEC), it consumes energy to produce H2. The round-trip efficiency of such a system is of prime interest, which can be enhanced by reducing temperature or increasing pressure. Moreover, ReSOCs offer the advantage of utilizing carbonaceous fuels such as reformed methane and syngas, further improving round-trip efficiencies.

To accurately predict ReSOC performance, a fast and efficient quasi-2-D cell model has been developed using Python. This model can simulate both modes of operation and predict local variations of cell variables. It can incorporate both humidified hydrogen and carbonaceous gases as fuels, providing insights into performance under both isothermal and non-isothermal conditions. This predictive capability is invaluable for designing and optimizing ReSOC systems for real-world applications.

Keywords: Reversible solid oxide cell (ReSOC), Round-trip efficiency, Fuel Cells, Electrolysis, Thermoneutral Voltage, Cell Modelling

8. Enhancing Sodium Sulfur Batteries with 3D Current Collectors and Sulfur Hosts

This research delves into the recent advancements in room temperature sodium-sulfur (Na-S) batteries, aiming to overcome key challenges hindering their practical use. Focusing on enhancing performance and scalability, novel approaches like 3D current collector architectures and efficient sulfur host designs are explored. The study underscores the significance of materials with high electrical conductivity and flexibility, with nitrogen doping playing a crucial role. Innovative designs such as double-carbon-shell architectures and catalytic sulfur hosts are investigated for their potential in addressing battery-related issues. Additionally, the introduction of a groundbreaking 3D current collector, MGF, is highlighted for its promising benefits in energy density and stability. The research also examines the deposition of Ni_3Sn_4 intermetallic alloys on various substrates, showcasing their remarkable discharge capacity and cycle performance. Moreover, the utilization of polyaniline-coated carbon cloth as a 3D current collector is discussed, offering improved energy storage capabilities due to its high specific capacitance and binder less assembly strategy. These findings collectively signify significant progress toward achieving efficient and sustainable energy storage solutions, propelling us towards a greener future.

Keywords: Polyaniline-coated carbon cloth, Sulfur host, Cycle life, Free standing cathode, Catholyte

9 . Thermal Management of High Energy Density Batteries

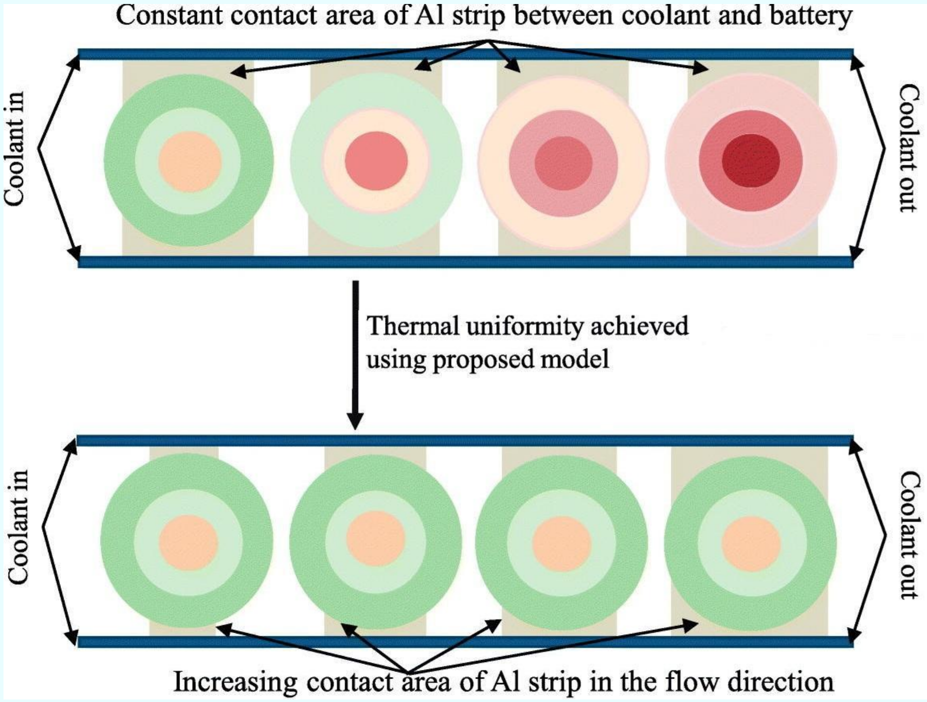


Figure 6 Constant contact area and increasing contact area temperature contour

The role of Li-ion batteries in vehicle electrification is significant, owing to their long lifespan, high energy density, and low self-discharge rates. These advantages make Li-ion batteries a preferred choice for electric vehicles (EVs). However, to ensure optimal operation, certain conditions must be met, such as maintaining a maximum temperature limit of 40°C and a maximum temperature difference limit of 5°C. To maintain these temperature conditions, proper cooling of the battery module is essential. While increasing the flow rate of the coolant can help regulate the maximum temperature of the battery, achieving thermal uniformity across the module presents a challenge. To address this issue, a unique relationship between the contact area of the battery and coolant is proposed in the study.

This relationship involves increasing the contact area in the direction of flow to ensure uniform heat transfer from all batteries. Aluminum strip between battery and the coolant channel is introduced for providing the varying contact area. The study compares the effectiveness of straight and serpentine coolant flow channels. Results show a 74% improvement in thermal uniformity with straight channels and a 71.7% improvement with serpentine channels.

Keywords: Battery Thermal Management System, Li-ion Battery, Liquid Cooling, Electric Vehicle(EV), Variable Contact Area

10. Oxy-steam gasification of biomass for hydrogen-rich syngas generation

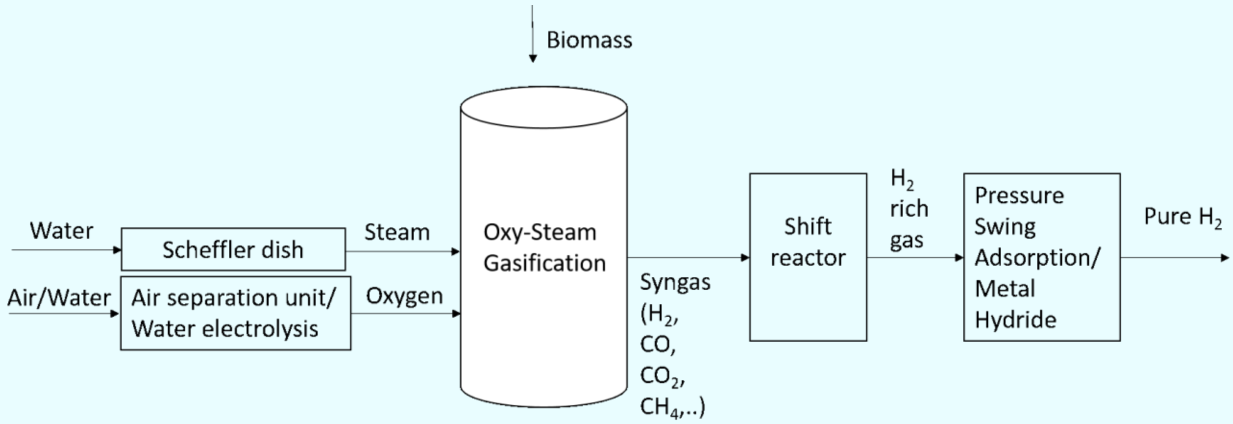


Figure 7 Block diagram for hydrogen generation through oxy-steam gasification

Green hydrogen is one of the emerging sustainable fuel which can be produced from easily available biomass through gasification. The use of steam in oxy-steam gasification as an oxidizer with oxygen enhances hydrogen content in produced syngas. System-level analysis is performed to check feasibility and energy efficiency. A comprehensive equilibrium model for oxy-steam gasification of biomass for H_2-rich syngas production has been developed using Aspen PLUS process simulation software and validated with experimental data available in the literature. Increased gasification temperature from 700 °C to 1000 °C resulted in a monotonic reduction in H_2 and CO_2 content in syngas with a subsequent increase in CO content. This increase in gasification temperature also results in an increase in syngas lower heating value (LHV) and cold gas efficiency (CGE) from 7.55 to 8.34 MJ/Nm^3 and 63.5 to 64.85 %, respectively. The increase in equivalence ratio has an opposing trend, both on syngas LHV and CGE. An increase in steam to biomass ratio increases syngas H_2 content by about 8 % at an expense of approximately 21.5 % in CGE.

Keywords: Biomass, Hydrogen, Gasification, Syngas, Aspen plus

11. Effect of NaI on the morphology, composition and thickness of Al-Mg electrodeposits from molten salts

Aluminium (Al) - Magnesium (Mg) alloys are key materials for several industrial applications such as the automotive industry, aviation, household applications, and heat exchangers because of their lightweight, mechanical and chemical properties, corrosion resistance, and aesthetics. Electrodeposition is the most versatile method for the preparation of Al-Mg films due to the reduced thermal stress on the core material, time, and economic feasibility. Electrodeposition also has the advantage of the controllable thickness of Al-films deposited and continuous uniform film deposition.
The Al-Mg alloy electrodeposition reported previously aimed at depositing powders and dendrites of Al-Mg with a higher percentage of Mg. The current work electrodeposition of Al-Mg alloys was deposited using chloride-based molten salt electrolyte system. A maximum of 3.50 wt. % of Mg was achieved using this electrolyte. To improve the morphology and Mg content in the deposit, an additive NaI was used. Addition of 2 % NaI was found to improve the conductivity of the electrolyte. Hence, it offered a wider range of current densities when compared to electrolyte without NaI for galvanostatic depositions. The use of NaI was found to improve the deposit morphology, composition and thickness.
Keywords: Al-Mg alloys, Morphology, Alloy composition

B. Power Electronics and Smart Grids

1. Battery Charger for Electric Vehicle Applications

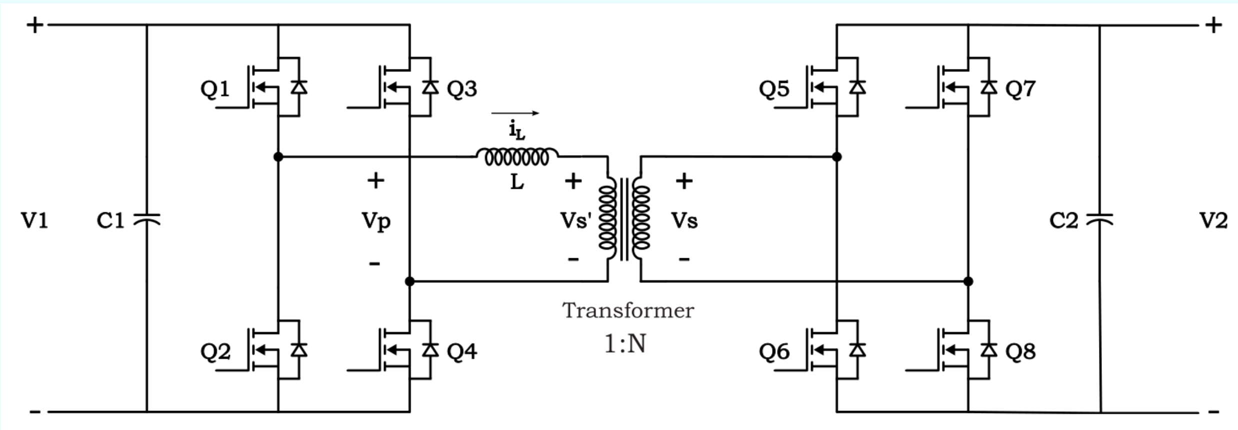


Figure 8 Dual Active Bridge Converter

With the need for cleaner technologies growing globally, the electric vehicle (EV) industry received an enormous boost, increasing global interest significantly. As EV adoption increases, the need for better charging topologies arises. Increasing the performance of modern EVs brings about weight and size constraints, which necessitate high efficiency and high power density chargers. One such topology involves a DC-DC Dual Active Bridge power converter, which achieves high efficiency through Zero Voltage turn-on, reducing switching loss significantly. Another application of this converter is in DC fast chargers, where converters are stacked in parallel to achieve high power. This study discusses the design and operation of a Dual Active Bridge converter in single phase-shift modulation, the impact of design variables on soft-switching range and hardware design for a 1kW system in open loop control.

Keywords: Electric Vehicles, Power Electronics, EV Charging, Soft Switching, Dual Active Bridge

2. Direct Torque Control of Induction Motor Drives

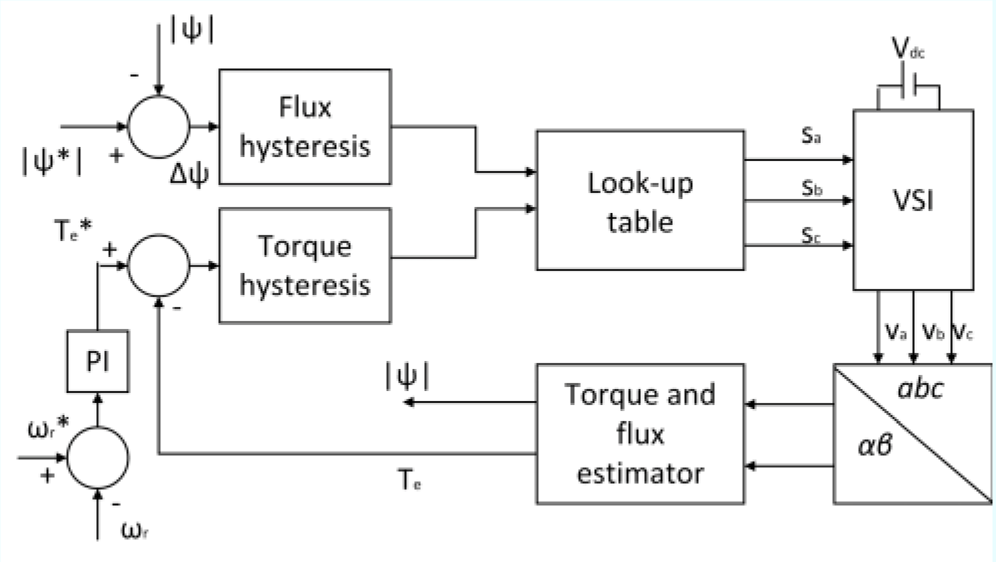
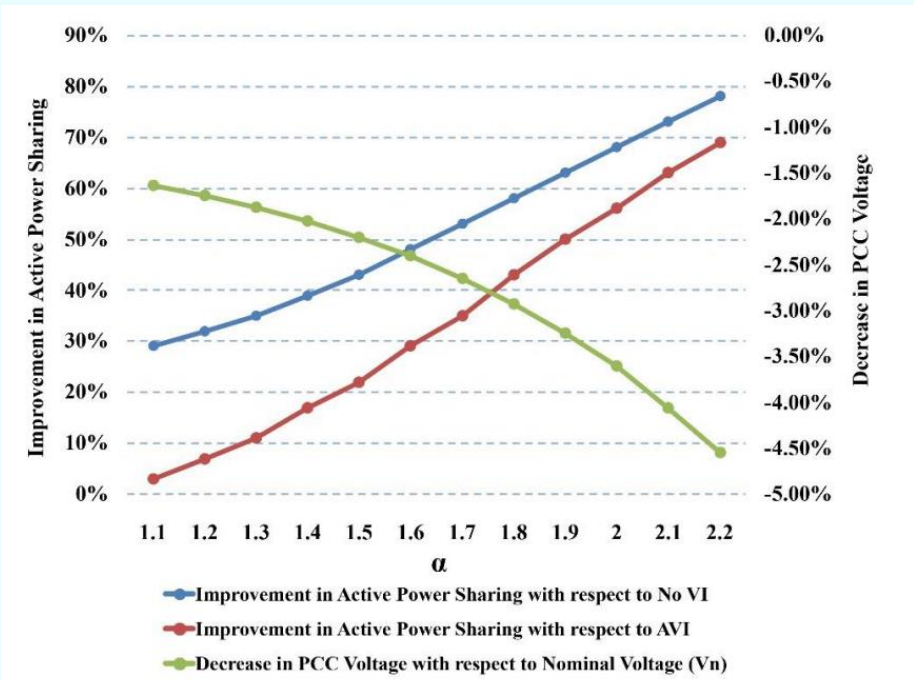


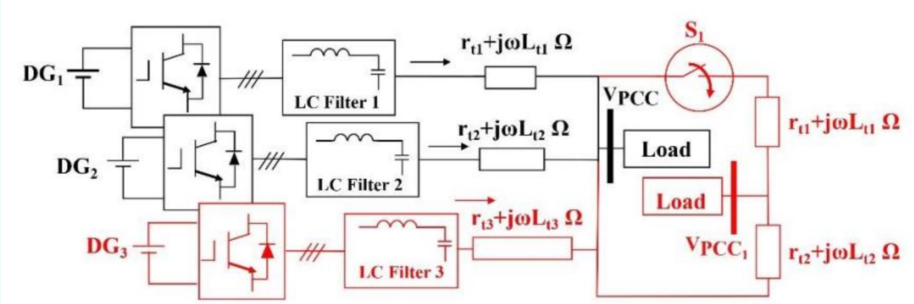
Figure 9 Block Diagram for DTC Implementation

Induction motors (IM) are widely used due to their simple, rugged, and reliable construction. The control of IM speed can be broadly categorized into two types: scalar control and vector control. Scalar control is based on the steady-state relationship of the motor where the magnitude and frequency of current and voltage can be controlled. On the other hand, vector control takes care of the transient and steady-state behavior of the machine using state space vectors. It can determine not only voltage and frequency but also the instantaneous value of quantities. Recently, more advanced control methods like Field-oriented control (FOC) and Direct torque control (DTC) have been developed and are widely used in industrial applications. However, FOC requires speed sensors and complex transformation algorithms for control. Conventional DTC schemes are used to directly control the torque and flux of inverter-fed induction motors. This project aims to demonstrate direct torque control on an induction machine and study its improvements using SVM-DTC.

Keywords: Electric drives, Induction machine, Motor control, Space-Vector Modulation

3. Non-linear virtual impedance shaping strategy for predominantly resistive islanded power networks

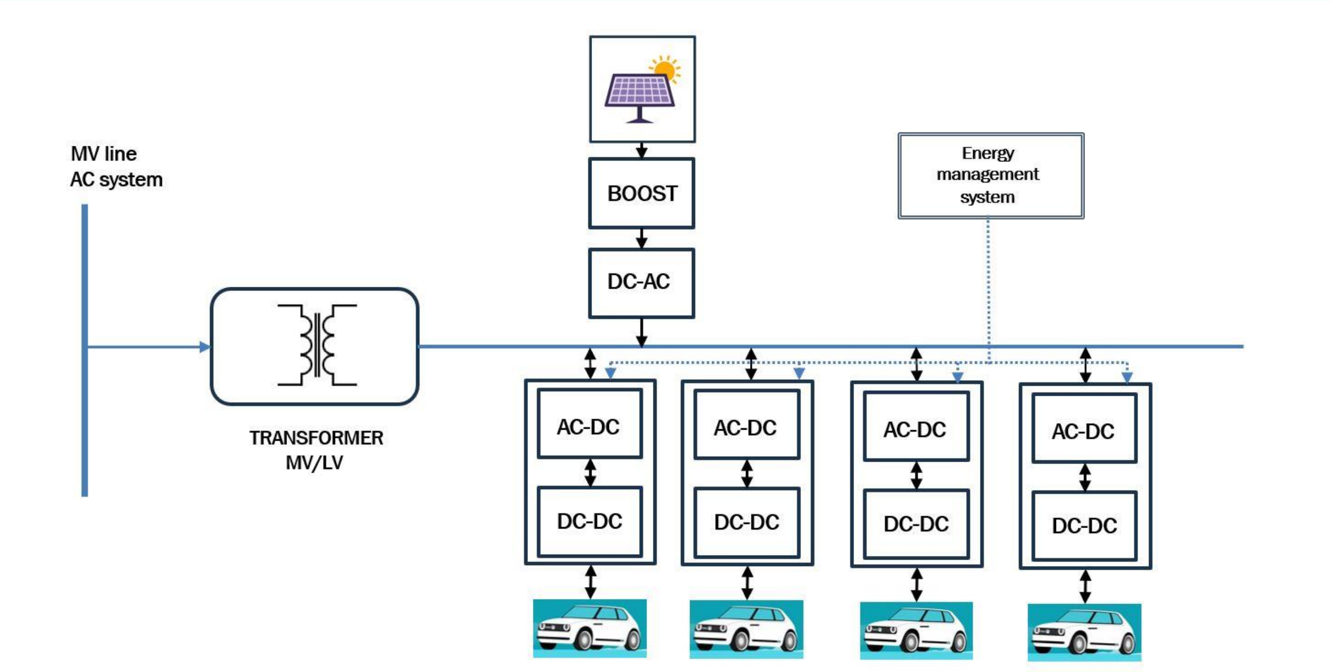




In contemporary distribution networks, converter-based distributed generators (DGs) are increasingly utilized to harness power from renewable sources. A prominent challenge in employing decentralized control for this purpose is the inaccurate distribution of real power among these DGs due to voltage drops caused by feeder/line impedances. To address this issue, many turn to employing virtual voltage drop within the controllers of these DGs, which helps mitigate impedance mismatches and improves power sharing. However, determining the appropriate value for this virtual voltage drop presents a significant challenge. This paper delves into a droop-based VI shaping technique tailored for converter-based DGs, particularly focusing on nonlinear variations for predominantly resistive islanded networks. The effectiveness of this technique is evaluated across a broad spectrum of loads, encompassing balanced (constant impedance), constant power, unbalanced, nonlinear, and induction motor loads, through comprehensive simulations. Furthermore, the proposed method is tested in a mesh network setting. The performance of DG plug-and-play functionality and the impact of load variations are examined on a modified 13-bus network using the proposed control scheme. The stability range for control parameters is validated through modelling and eigenvalue analysis. Experimental validation on a laboratory setup further corroborates the efficacy of the proposed strategy. Additionally, the technique is extended to achieve closer-to-proportional sharing of unbalanced currents, enhancing its applicability in diverse scenarios.

Key words: Impedance-based-droop, Non-linear droop, Renewable integration, Inverse droop control, Power sharing, Virtual impedance, Negative Sequence

4. Development of smart charging solution for EV charging station



The electricity and transportation sectors contribute to majority of the total global carbon dioxide (CO_2) emissions, posing an escalating environmental challenge. To address this issue effectively, the adoption of electric vehicles (EVs) and renewable energy sources offers a promising solution to significantly decrease emissions from transportation and power generation. However, to maximize environmental and economic advantages, integrating EVs and renewable energy sources within a smart grid infrastructure is essential. One possible strategy to reduce CO_2 emissions is to use renewable energy as a complete or partial source of power for EV charging stations (CSs). This project introduces a novel approach by designing a photovoltaic (PV)-based charging station that aims for independence from the grid. Leveraging smart charging technologies and incorporating vehicle-to-grid (V2G) capabilities, the charging station offers a sustainable and cost-effective solution for EV owners and charging station operators alike. Key components of the project include the PV system for renewable energy generation, intelligent charging algorithms to optimize charging schedules and minimize operating costs, and V2G functionality allowing EVs to feed surplus energy back to the grid during peak demand periods.

The integration of these technologies not only reduces the environmental footprint of EV charging but also contributes to grid stability and resilience.

Keywords: Electric vehicles (EVs), Renewable energy integration, CO2 emissions reduction, Smart grid technology, Photovoltaic (PV) charging station, Grid independence, Smart charging algorithm

5. Development of 4-Quadrant Power Amplifier for Power Hardware-in-the-Loop Validations

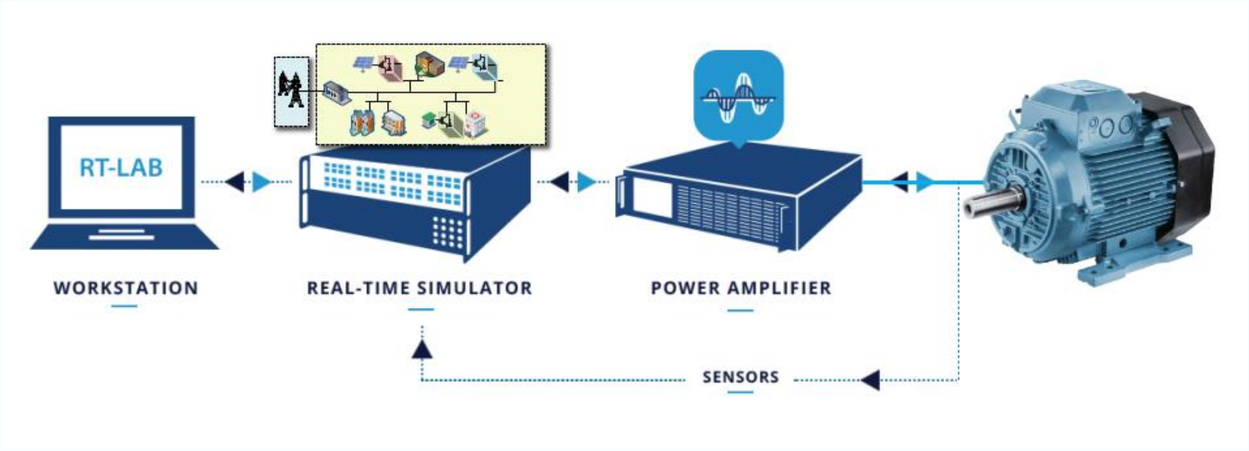


Figure 10 Typical PHIL test scheme

Power Hardware-in-the-Loop (PHIL) can be used as a powerful tool for testing and validation of hardware before being deployed in the field since full-fledged hardware testing may not be feasible in a lab environment. PHIL provides a balance between cost and fidelity and can have an important role in renewable energy integration. The power amplifier is one of the main components which facilitates these tests. Commercially available power amplifiers are black boxes in terms of the control strategies implemented, which can lead to uncertainty in test results and unstable operation. Thus, it becomes necessary to develop a robust, dynamic and efficient power amplifier. The present work aims to develop and implement control strategies to operate a power electronics based bidirectional converter as a power amplifier with robust tracking and higher bandwidth when compared to conventional controls.

Key words: PHIL, power amplifier, bidirectional converter, advanced control

6. Investigating the DC link dynamics of grid-connected inverters

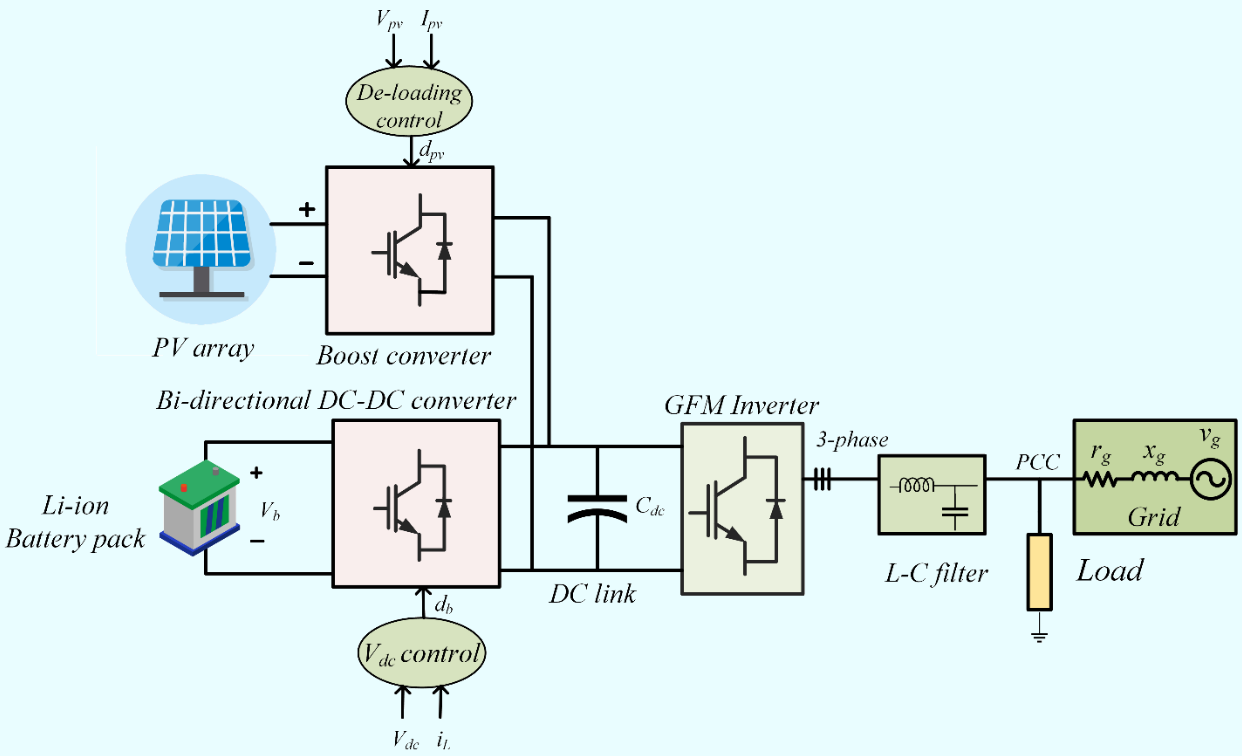


Figure 11 System architecture

Integration of distributed generation (DG) has seen an exponential rise thanks to the presence of renewable sources. Most DGs employ a two-stage topology to transmit the generated power to the grid or feed its local loads. In most of the literature, strategies for the grid-forming operation of a single DG or parallel DG operation have been developed, considering a stiff DC source. However, due to intermittencies in renewables and limited reserves from storage, a stiff DC source cannot be guaranteed. Thus, it would be evident to consider the non-stiff nature of DC sources to imitate a much more practical study. To ensure a stable operation on the AC side of the grid-connected system, it must be guaranteed that the DC side dynamics are well within bounds. This project focuses on maintaining a stiff DC link using a PI-based control strategy with sources on the DC side, such as PV and battery, working in coordination to achieve the desired control objective while preserving a stable operation during normal and during faults.

Key words: Distributed generation, Grid-forming, DC side dynamics, DC link control.

7. Design and development of a battery charger for electric vehicles

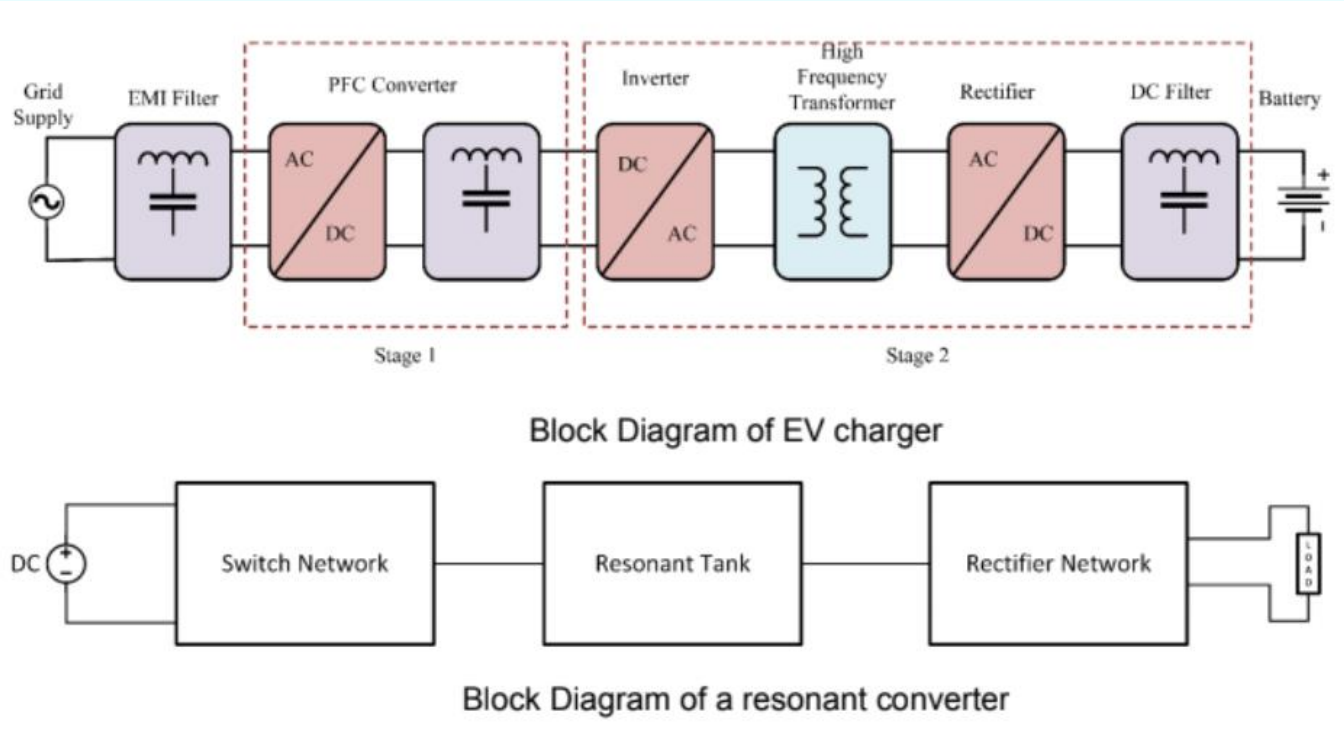
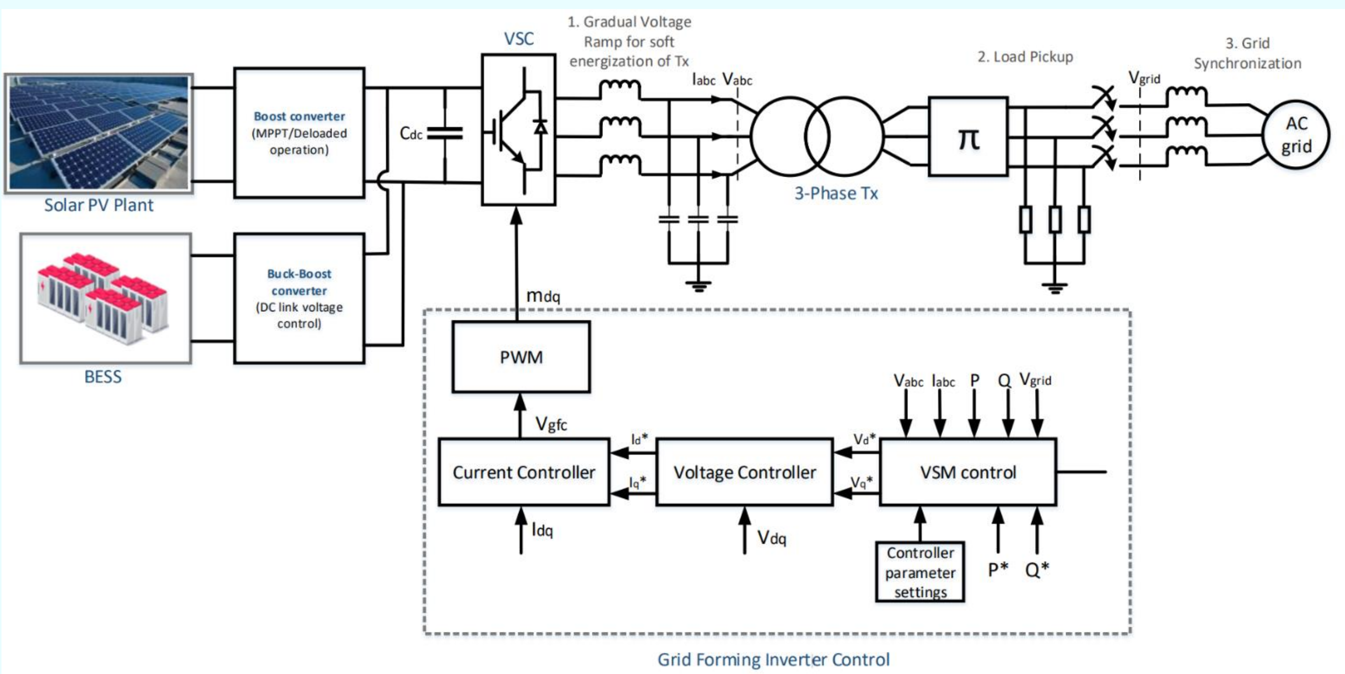


Figure 12 Block diagram explaining the implementation

The rapid growth in electric vehicle (EV) adoption has prompted the need for efficient and reliable charging infrastructure to support the widespread deployment of electric mobility. This project focuses on the design and development of an EV charger on the basis of LLC resonant converter topology for EV applications. The power conversion topologies, such as resonant DC-DC converters with soft-switching techniques, are investigated to improve power efficiency and reduce switching losses. The LLC resonant DC-DC converter gave promising results in terms of higher efficiency, lower power dissipation, and better EMI performance. Simulation results are presented for converting 400 V from the input DC link to an output voltage range of 36-57 V DC at 1.2 kW. The small signal modelling technique based on the Extended Describing Functions (EDF) methodology is used to investigate the dynamics of the LLC resonant converter. Additionally, a comprehensive description of compensator design is presented for control of the LLC converter.

Keywords: Resonant Converter, LLC DC-DC Converter, Soft Switching, Small signal modeling, Switching losses

8. Blackstart Capability of Grid Forming Inverter based Solar PV Power Plants



The rise of renewable energy sources like wind and solar is leading to more inverter based generation in power systems, causing stability concerns due to the lack of inherent inertia in inverters. Grid-forming inverters (GFMIs) have emerged as a solution, capable of regulating voltage and frequency unlike grid-following inverters (GFLIs). With the increasing integration of solar photovoltaics (PVs), there is a growing interest in assessing their potential to support the grid. Blackouts are the events that disrupt the system, and restoring it is challenging. Traditionally, hydro and gas turbine provides the black start capability, but as power systems shift towards renewables, such as PV plants, their role in power system restoration becomes vital. Efforts are underway to maximize the effectiveness of solar energy, including its black start support capability, highlighting its significance in ensuring power system resilience and reliability using GFMIs. This project introduces a Blackstart capability of large scale solar PV plants using Virtual synchronous machine (VSM) control of a GFMIs.

Key words: Grid forming inverter (GFMIs), Grid following inverters (GFLIs), Solar PV, Blackstart, Virtual synchronous machine (VSM)

9. Unbalance Mitigation and Neutral Current Suppression in Distribution Networks using 3 Phase-4 Leg Grid Forming Inverter

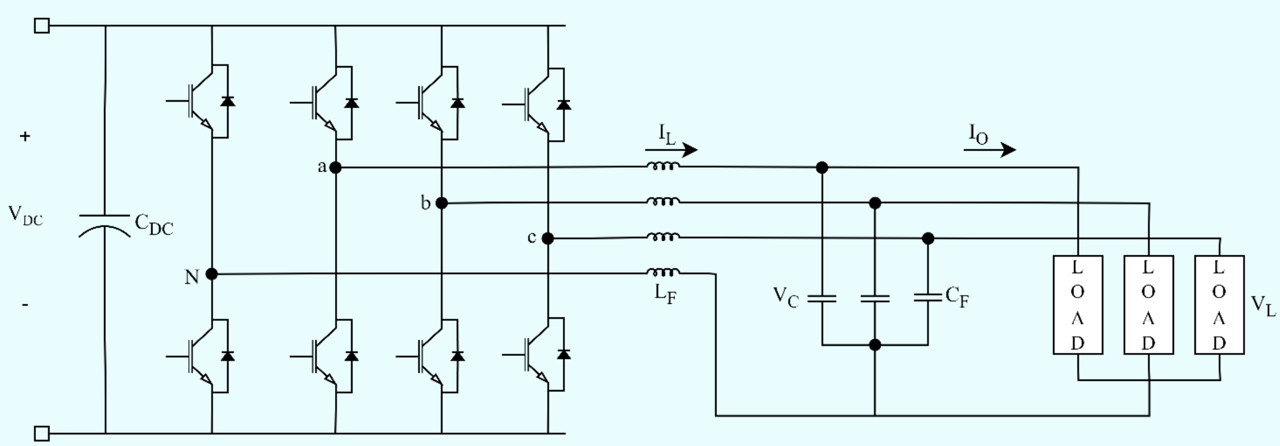


Figure 13   3 Phase 4 leg power electronic converter

This study investigates the challenges posed by unbalanced loads in distribution networks and proposes a novel approach for mitigating unbalance and suppressing neutral currents using a three-phase four-leg grid-forming inverter. Unbalance in distribution networks arises from the presence of various single-phase loads dispersed throughout the system. The proposed method employs adaptive adjustments to voltage references to effectively suppress current imbalances while ensuring that the voltage unbalance factor remains within acceptable limits. By integrating advanced control strategies within the grid-forming inverter, the research aims to enhance the stability and efficiency of distribution networks, thereby contributing to the overall reliability and performance of the electrical power system. The findings of this study offer valuable insights into addressing the challenges associated with unbalanced loads in distribution networks, providing a pathway towards more resilient and sustainable power distribution infrastructures.

Keywords: Grid Forming Inverter, Unbalance Mitigation, Voltage Unbalance Factor, Neutral current

10. Vehicle to Grid (V2G) Support Services

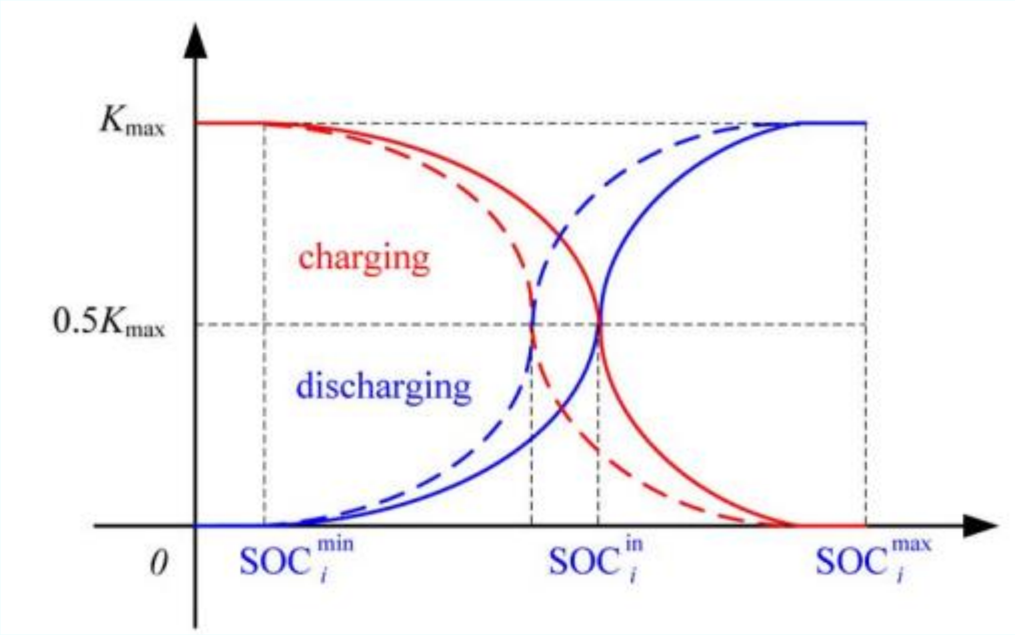


Figure 14 Adaptive drop of the BSH for maintaining the initial SOC

With growing pollution levels from the transportation sector and increased environmental concerns, a transition from fossil fuel vehicles to electric vehicles is being empowered globally. As electric vehicles (EVs) become increasingly prevalent, a novel concept known as Vehicle to-Grid (V2G) has emerged, promising to revolutionize the energy landscape. V2G support services involve bi-directional power flow, allowing EV batteries to not only draw electricity from the grid but also to inject power back into the grid when required. Vehicle-to-Grid support services represent a promising and innovative solution for sustainable energy integration and grid stability. The study focuses on modelling EV charger to meet specific power requirements and outlines the charging management system for four CHAdeMO chargers. The analysis of the obtained results aims to validate the facilitation of bidirectional power flow using Power Hardware-in-the-Loop (PHIL) by effectively controlling current in both G2V and V2G modes. V2G control has the potential to offer frequency regulation services for power system operation through EVs. A smart charging method, known as charging with frequency regulation (CFR), has been developed to enable scheduled charging while simultaneously providing frequency regulation. A simulation study is conducted on the IEEE 9 bus system to demonstrate the effectiveness of the proposed CFR method.

Key words: Electric Vehicles (EVs), Vehicle-to-Grid (V2G), Bidirectional chargers, Ancillary services, Frequency Regulation.

11. Re-synchronization of Multi-Power Islands during Blackstart with Enhanced Grid Resiliency

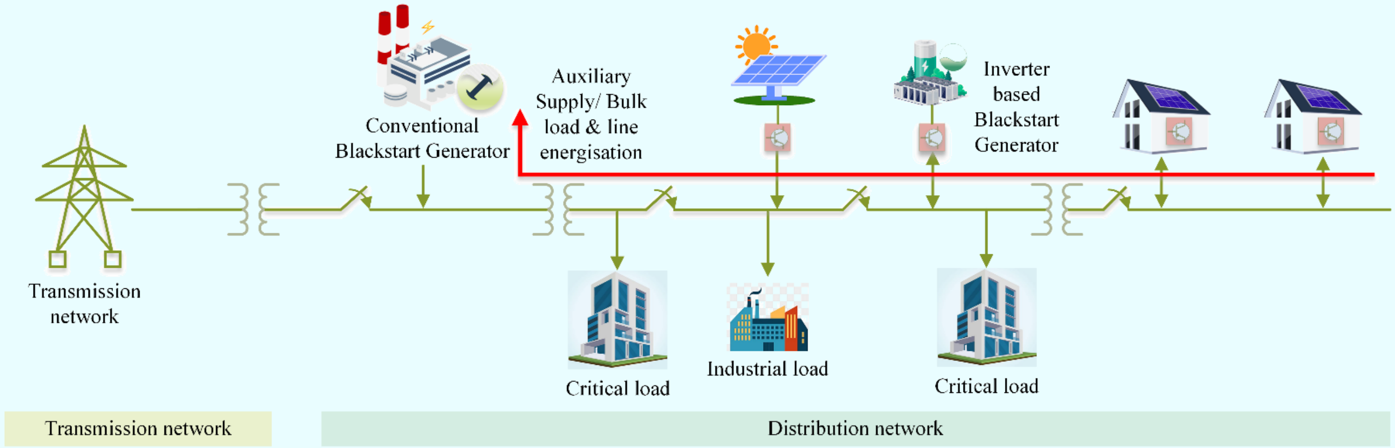


Fig: Bottom to top restoration approach

Restoring power system after an outage involves reconnecting and re-synchronizing power islands due to presence of renewable rich systems, which can cause high transient currents and result in circuit breaker tripping, ultimately reducing grid resiliency. One effective way to address this issue is by minimizing inrush currents during cold load pickup, which is particularly crucial during blackstart events, especially in systems with high renewable energy integration. This research paper proposes a bottom-to-top approach for restoring and re-synchronizing a large distribution network comprising multiple small power islands. The proposed approach is evaluated using a modified IEEE 33-bus system equipped with four renewable distributed generators. Results demonstrate a significant reduction in inrush current during the restoration process using the proposed technique, which complies with the re-connection standards outlined in IEEE-1547. This reduction in inrush currents contributes to improved grid resiliency. The effectiveness of the algorithm is further validated using software in loop in real-time through the development of a test bed utilizing Opal-RT.

Key words: Blackstart, blackout, cold load pick up, grid-forming converter, grid outage, intelligent electronic device, re-synchronization

12. Field-Oriented Control of Permanent Magnet Synchronous Machine for Electric Vehicles

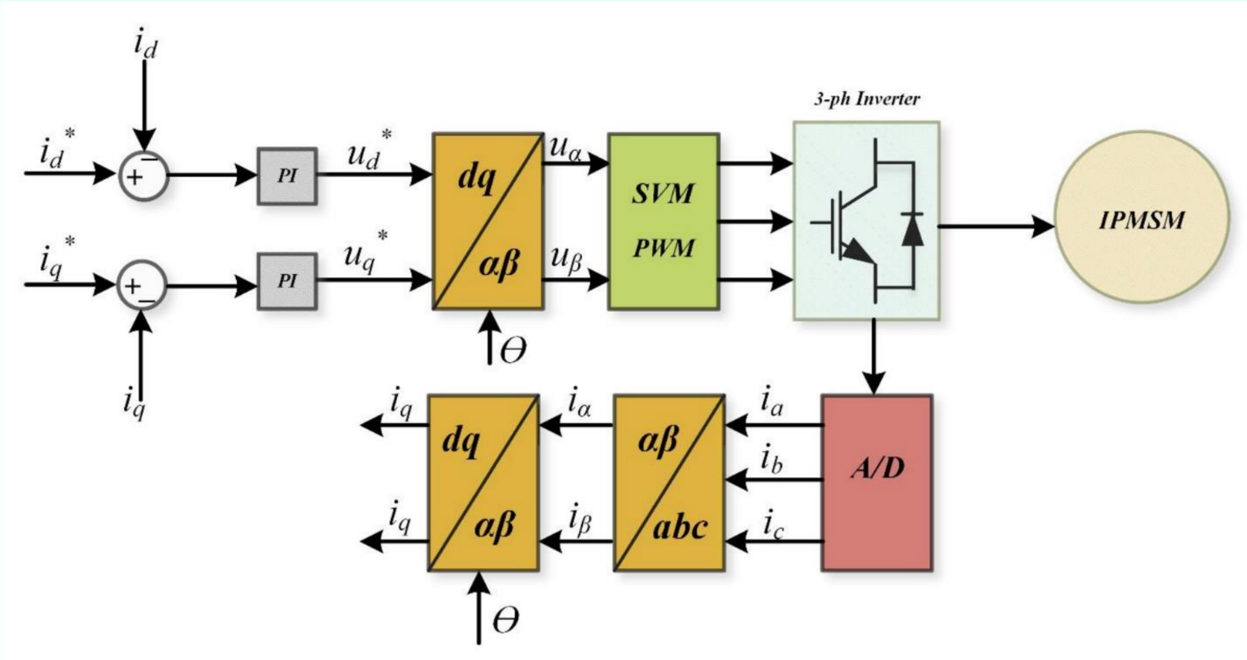


Figure 15 Field Oriented Control Scheme of IPMSM

Permanent magnet synchronous machines(PMSM) are the most preferred machines in the present world. It finds applications in electric vehicles(EVs), industrial pumps etc., due to its numerous advantages including high efficiency, high power density and high torque to inertia ratio. In applications like EVs precise and accurate control of machine becomes very important for high-performance control of PMSM drives. Field-oriented control (FOC) is one of the high-performance control schemes, that provides independent control of torque and flux, by decoupling flux and torque. In motor control techniques, FOC has become a conventional method nowadays. This project deals with FOC for interior permanent magnet synchronous machine with shunt resistor-based current sensing techniques. The study begins with modelling of the IPMSM in synchronously rotating reference frame(d-q frame). A closed loop control has been developed to control speed and torque. The FOC is implemented and simulated with the designed controls. The current measurement is important factor for working of FOC so in this project different shunt based current sensing techniques will be studied.

Keywords: IPMSM, FOC, Synchronous reference frame, Current sensing Techniques

13. Harmonic Analysis of Grid Connected Solar PV Systems

In an era of rapid renewable energy integration, grid-connected photovoltaic (PV) systems have become a vital source of clean electricity. However, their seamless operation within the electrical grid necessitates a meticulous analysis of power quality. Variations in solar irradiation and temperature can significantly impact the performance of grid connected PV systems, leading to potential power quality issues. To address these concerns, this study embarked on a rigorous literature review, delving into existing research on the impact of irradiation and temperature fluctuations on power quality in grid connected PV systems.

The study progressed to the design and simulation of a three-phase grid-connected PV system using MATLAB Simulink. This hands-on approach allowed for the assessment of real-world scenarios, offering valuable insights into the system's power quality characteristics. The simulation results reveal critical insights into the behavior of the grid-connected PV system under the influence of varying irradiance and temperature.

Keywords: Power Quality, Harmonic, Grid Connected, Solar PV, Irradiance

C. Renewable Energy and Sustainability

1. Feasibility Of Sea Water Air Conditioning For Data Center Cooling Application At Andaman And Nicobar Islands

Deep sea water cooling (DSWC) emerges as a promising solution for data center cooling in remote coastal regions like the Andaman and Nicobar Islands. This innovative cooling approach harnesses the natural thermal properties of deep sea water to efficiently dissipate heat generated by data center operations. By utilizing cold water from the ocean depths, DSWC minimizes the environmental impact of cooling systems and significantly reduces energy consumption compared to traditional air conditioning methods. In the context of the Andaman and Nicobar Islands, where traditional cooling solutions face challenges due to limited freshwater resources and high ambient temperatures, DSWC offers a sustainable and reliable alternative. This project explores the feasibility and benefits of implementing DSWC for data center cooling applications in the region. It discusses the technical aspects of DSWC systems, including seawater intake, heat exchange processes, and environmental considerations. Furthermore, it highlights the potential economic and environmental advantages of adopting DSWC technology, such as reduced operational costs, lower carbon emissions, and enhanced resilience to climate change impacts. Overall, the integration of DSWC into data center infrastructure represents a forward-thinking approach towards achieving sustainable and efficient cooling solutions in coastal areas like the Andaman and Nicobar Islands.

Keywords: Deep Sea water cooling or sea water air conditioning, Data center, Sustainability

2. Comparative Techno-Economic Analysis and Carbon Footprint Evaluation of Hydrogen Fuel Cell Vehicles versus Battery Electric Vehicles

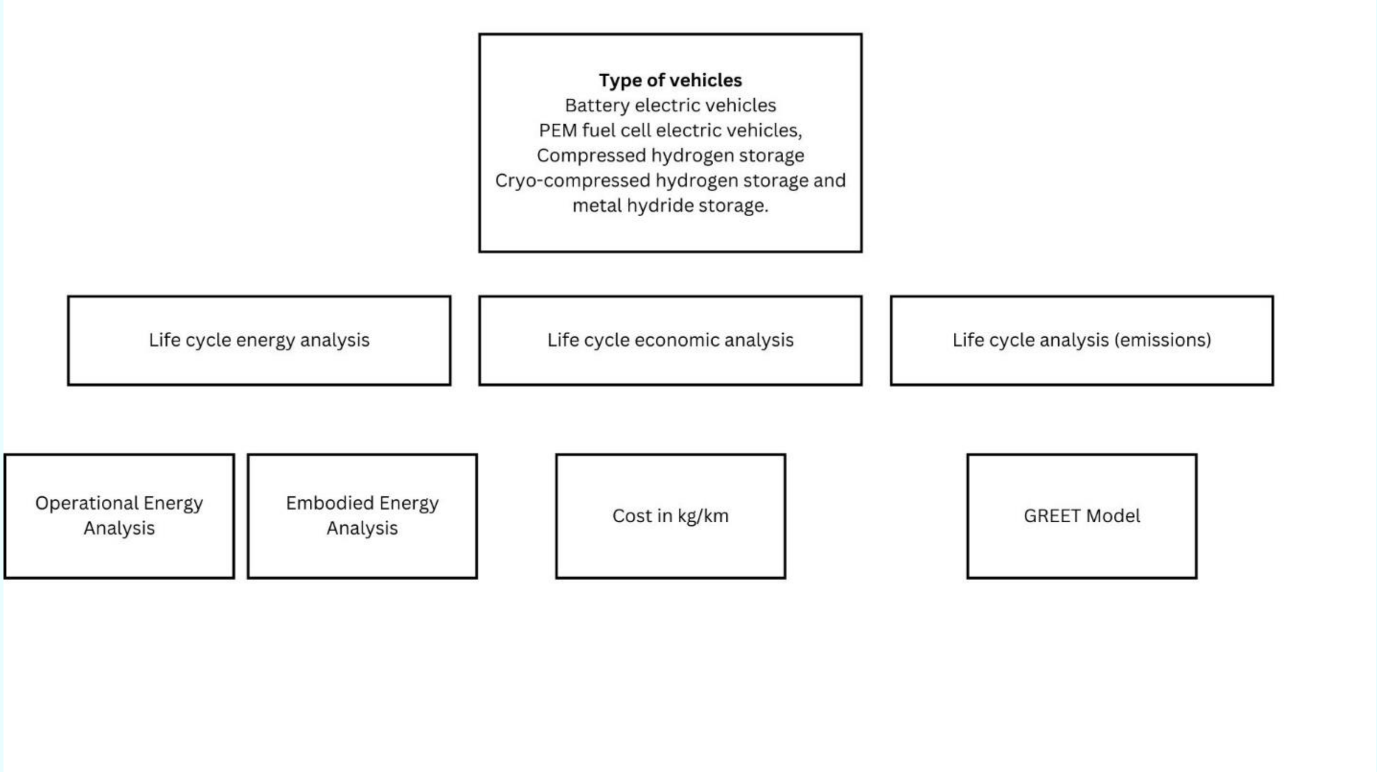


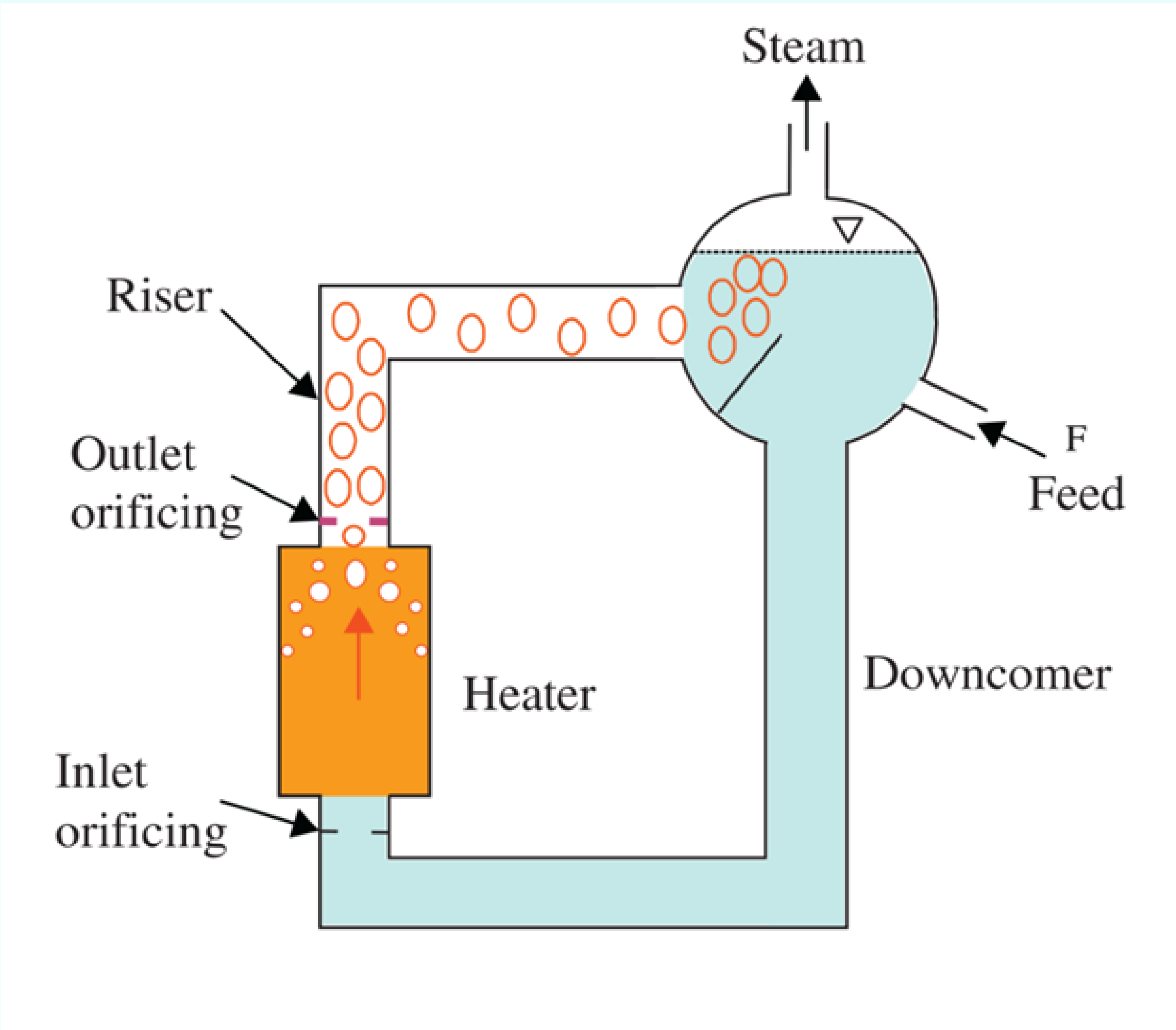
Figure 16 Block Diagram of the Implementation

The transportation sector is a significant contributor which is nearly 20% of global carbon dioxide emissions, necessitating the adoption of sustainable alternatives to combat climate change. One such alternative is the utilisation of Fuel Cell Electric Vehicles (FCEVs) powered by hydrogen, which emits zero tailpipe emissions and offers fast refuelling times. This project explores the potential of FCEVs in achieving energy savings and reducing greenhouse gas emissions in the transportation sector by doing a techno-economic feasibility study by comparing it with Battery electric vehicles. 4 types of vehicles ahs been considered - Battery electric vehicles, PEM fuel cell electric vehicles, compressed hydrogen storage, cryo-compressed hydrogen storage and metal hydride storage. Life cycle energy

analysis has been performed and fuel cell vehicles consume 23% -27% more energy during their life cycle than battery electric vehicles. For economic analysis, BEV cost has been calculated, which comes to around 7.26 INR/km. This project also aims to discuss life cycle emissions evaluation of all 4 vehicles by considering different methods of hydrogen production such as steam methane reforming and electrolysis of water.

Keywords: Hydrogen Fuel cell vehicles, Life cycle analysis, Energy analysis

3. Bifurcation Analysis of Natural Circulation Loop



A detailed analysis of the natural circulation loop has been carried out by analyzing the pressure drop vs mass flow rate curve. The pressure drop vs mass flow rate curve shows the behavior of two-phase flow in a heated section against inlet velocity at a steady state. The different pressure drop components including gravitation pressure drop, pressure drop due to change in cross-section, single-phase frictional pressure drops and two-phase frictional pressure have been shown separately along with the final N-shaped curve. It has also been found that multiple solutions for the system don't exist for all the values of the parameter. A parametric effect on the shape and nature of the curve has been analysed by variation power (Npch), subcooling (Nsub), heated section diameter, and height. The range of existence of multiple solutions has also been obtained by analysing the N-shaped curve for different parametric values.

Keywords: Natural circulation loop, heat transfer, stability analysis, pressure drop vs flow rate

4. Modelling Net Zero Scenarios for the Indian Industrial Sector by 2070

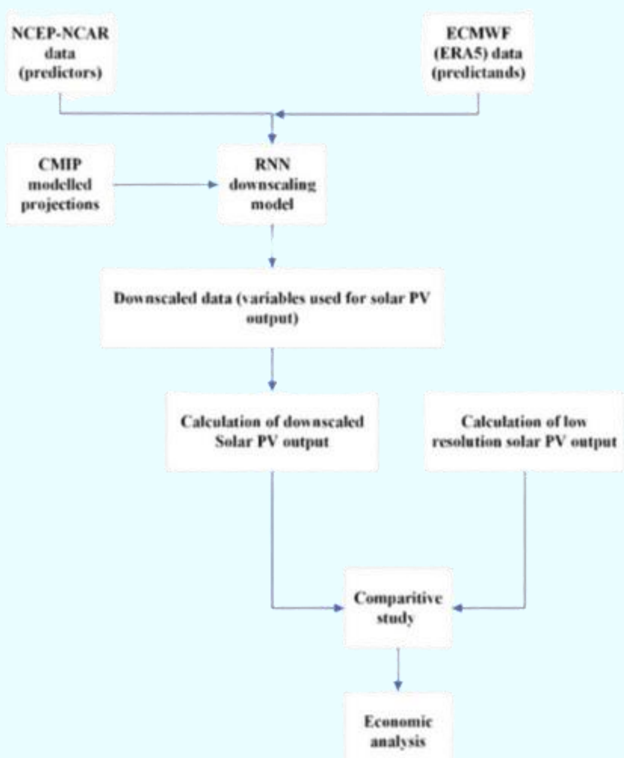


Figure 17 Block Diagram for downscaling of solar PV output

The transition towards a net-zero emissions future demands comprehensive planning and analysis, particularly in high-emitting sectors such as industry. Our work focuses on modelling net-zero scenarios for the Indian industrial sector, with a primary emphasis on key industries such as Iron & Steel and Cement. By projecting future demand based on current per capita consumption trends and potential trajectories, we aim to provide insights into the scale of transformation required to align with the decarbonisation goals set by the government, targeting 2070. The supply side of the equation will be modelled using the TIMES (The Integrated MARKAL-EFOM System) f ramework developed by the Energy Technology Systems Analysis Programme (ETSAP) under the International Energy Agency (IEA). This modelling approach enables us to understand the economic implications associated with decarbonising industrial processes and infrastructure. By integrating demand projections with supply-side modelling, our study offers a holistic perspective on the challenges and opportunities inherent in achieving net-zero emissions in the Indian industrial sector. The findings of this research are expected to inform policymakers, industry stakeholders, and researchers, facilitating the design of effective strategies and policies to accelerate the transition towards a sustainable and low-carbon industrial landscape in India.

Key Words: Net-zero emissions, Indian industrial sector, Decarbonization goals, Sustainable industrial landscape

5. Biomass-derived activated carbon for supercapacitor application

Biomass represents an eco-friendly, and cost-effective source for sustainable energy generation, as well as a clean feedstock for green chemistry and bioproducts development. Waste biomass is a reliable and cheap precursor for the production of activated carbon. The carbonizing temperature and chemical treatment method determine the attributed properties of activated carbons in terms of specific surface area, pore size distribution and tuning nature of surface functionality required for the fabrication of electrode material of supercapacitor. Generally, the two primary routes used in the synthesis of activated carbon are physical and chemical activation process. Despite of the application of subabul sawdust derived activated carbon (SAC) in CO_2 adsorption, water and gas purification, it also exhibits the flexibility of fabricating electrode materials for supercapacitor with well-defined geometries. In the present study, subabul sawdust derived activated carbon was prepared by the chemical activation process. Precursor mixed with optimized ratio of activating agent synthesized at 800°C temperature for 3 hours generated efficient activated carbon in terms of specific surface area and pore size distribution. Characterization techniques such as X-ray diffraction, Raman spectroscopy, fourier-transfer infrared spectroscopy, N_2 physisorption, and field emission scanning and transmission electron microscopy were performed to assess the physicochemical properties of the carbon material. These characterization studies reported the amorphous

nature, surface functional group and porous structure of activated carbon material which qualifies its application as electrode for supercapacitor. The process of synthesizing activated carbon substantially increased the surface area with interconnected porous morphology that enhance charge transport and accumulation. The electrochemical characterization of activated carbon was conducted in aqueous electrolyte with different mass loading using technique such as cyclic voltammetry, galvanostatic charge-discharge test and electrochemical impedance spectroscopy. Distortion in cyclic voltammetry and charge-discharge curve from its symmetrical behaviour reported pseudo-capacitance effect. Electrochemical performance of SAC is yet to be optimized in three electrode system and as well as two electrode system. This study has shown that SAC has a significant potential to be utilized as an electrode material for electrochemical energy storage system.

Key Words: Biomass, Chemical activation, Activated carbon, Supercapacitor

6. Feasible Operating Region of Unbalanced Distribution Networks with Distributed Photovoltaics

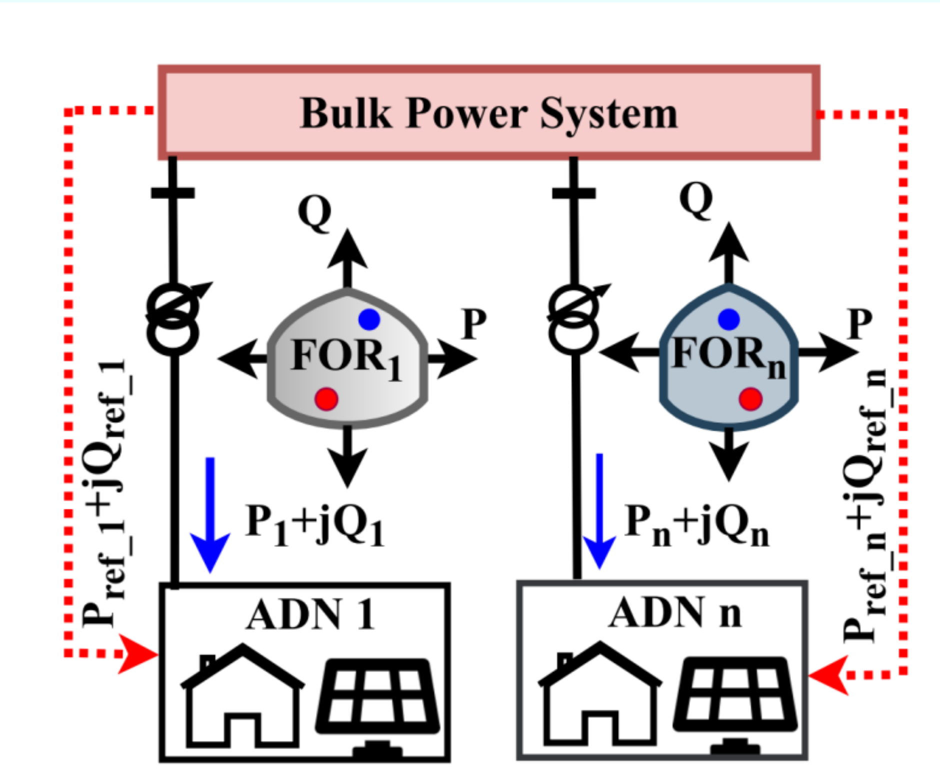
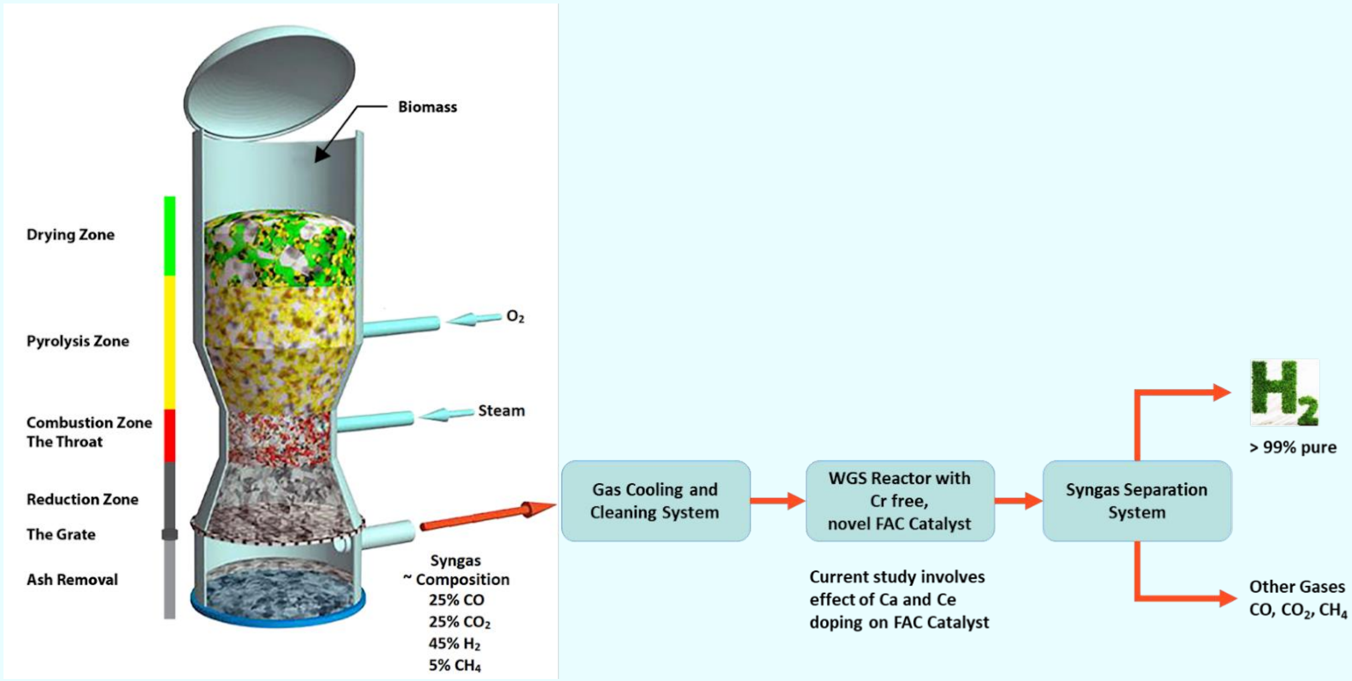


Figure 18 FORs at BPS-ADN interfaces for grid support applications

Amidst rising distributed generation and its potential to play an active role in grid management, this study presents a new realistic approach to determine the operational space and flexibility potential of an unbalanced active distribution network (ADN). The feasible operating region (FOR) of an ADN is constituted by its range of active-reactive power exchange with the bulk power system (BPS) without breaching network constraints. This study explores the potential of highly penetrated single- and three-phase distributed photovoltaics (DPVs) and voltage-sensitive loads to obtain FOR at different ADN operating points. The cumulative response of Volt-Var controlled DPVs and voltage-sensitive loads determines the BPS-ADN interconnection power flow, whose feasibility is ensured with respect to voltage magnitude and voltage unbalance constraints. Further, the correspondence of FOR with the tap-settings of BPS-ADN substation transformer enables a novel feature to traverse throughout the available operating region and facilitate BPS-ADN power coordination. Additionally, a nodal sensitivity-based adjustable Volt-Var control scheme is proposed for DPVs considering both voltage magnitude and voltage unbalance constraints, ultimately improving the FOR.

Keywords: Active distribution network (ADN), bulk power system (BPS), feasible operating region (FOR), distribution systems, grid support, TSO-DSO coordination, operating envelopes

7. Hydrogen production by Catalytic upgradation of syngas obtained through oxy-steam Gasification of waste biomass



In the current era we are facing the pressing issue of climate change resulting from the CO2 emission from fossil fuel burning. Researchers identified Hydrogen as a clean fuel and energy carrier for today's need. Among many technologies, the biomass gasification is a promising one for generating clean energy and valuable chemicals from bio-waste. Specifically, the focus is on oxy-steam gasification; it gives higher hydrogen yield and higher calorific value Syngas. Some preliminary calculation suggests that oxy-steam gasification with lower steam to biomass ratio (SBR) and externally converting CO + H2O to CO2 + H2 in water gas shift reactor is more economical and efficient than the one with only higher SBR for getting higher Hydrogen yield. The earlier high temperature water gas

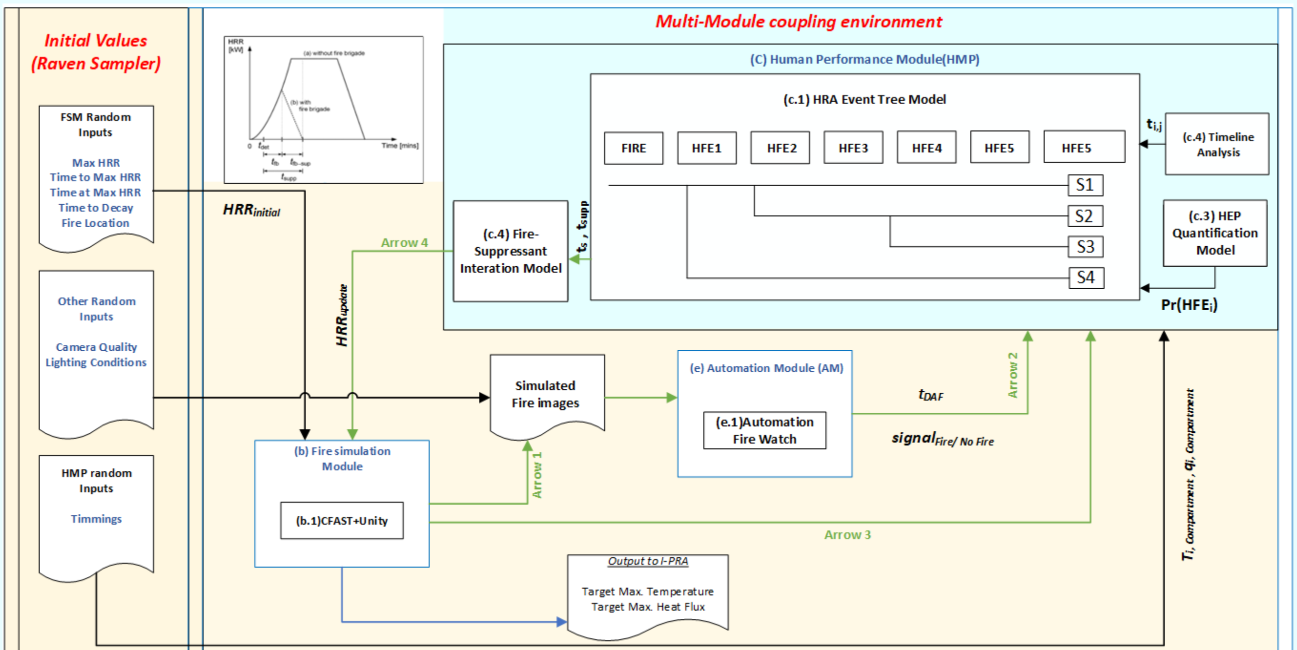
shift (HT-WGS) catalyst, Fe_2O_3-Cr_2O_3 was proven to be hazardous due to carcinogenic Cr^{+6}. The novel Cr-free catalysts, Fe/Al/Cu oxides (wt. % - 83/7/10) was proven to be active, thermally stable, and efficient; it can potentially replace the earlier HT-WGS catalyst. Current study involves the effect of doping Ca and Ce in FAC catalyst for further improvement. The ongoing work includes developing these catalysts, their characterization, and determining it's activity for water gas shift reaction.
Keywords: Sustainable H2 Production, Novel-Catalyst, Biomass Gasification, Waste to Energy

8. Battery Thermal Management

This study delves into the thermal management of lithium-ion battery configurations, employing a comprehensive numerical methodology to analyse different cell configurations. The research primarily centred on understanding the thermal dynamics of lithium-ion battery (LIB) cell operation during discharge, given that higher temperatures typically manifest during this phase. A comparison analysis was conducted for three distinct cell configurations (2, 3, and 4 cells) at varying C-rates and mass flow rates. Notably, the two-cell configuration exhibited the most favourable results based on maximum temperature, while the four-cell configuration demonstrated the least thermal gradient, making it optimal for thermal gradient analysis. The study also emphasized the impact of mass flow rates on temperature and thermal gradient, revealing that a flow rate of 0.25 m/s is efficient for cooling.

Looking ahead, future research will focus on optimizing key parameters for cell configuration, exploring alternative cooling fluids, and delving into the design intricacies of the heat sink. The aim is to enhance battery efficiency, longevity, and safety, while also investigating the potential of alternative fluids for better thermal management. Additionally, the design and contact analysis of the heat sink with the battery cell will be explored to ensure optimal thermal conductivity and heat dissipation.

9. Assessment of trustworthiness of human-automation interaction in nuclear power plants.



Nomenclature

HFE_i: i-th Human Failure Event HFE_i, t_{DAF}: Time to Automatic Detection, $HRR_{Initial}$: Initial Heat Release Rate, HRR_{update}: Updated Heat Release Rate, $signal_{Fire/\,No\,Fire}$: Fire/ No Fire Recommendation, $T_{i,\,Compartment}$: Compartment Temperature of I-layer of Compartment (where, I= upper, lower), $q_{i,\,Compartment}$: Heat Flux of the layer I-layer of of Compartment (where, I -upper, lower), t_s: Time to Start Suppression, t_{supp}: Time to Suppression

Figure 19 Flowchart of Process

The nuclear industry is progressively integrating automation technologies into the Nuclear Power Plants(NPPs). To make informed decisions about large-scale investments in automation technologies specifically used for safety-critical applications, stakeholders require robust evidence of their transparency, trustworthiness, and operational acceptability. This study introduces a risk-informed approach to evaluate automation trustworthiness by leveraging and making advancements to the Integrated Probabilistic Risk Assessment (I-PRA) methodological framework and the Probabilistic Validation (PV) methodology that were previously developed by some of the authors. I-PRA connects simulation models of underlying physical and social phenomena with the existing plant PRA model through a probabilistic interface. This study advances the I-PRA framework to explicitly capture relationships between the plant risk metrics and input parameters associated with the underlying human-automation-physics interactions. This paper currently includes initial results of an ongoing case study evaluating the trustworthiness of an Artificial Intelligence (AI)-based automated firewatch system suggested for use in NPPs.

Keywords: Integrated Probabilistic Risk Assessment (I-PRA), Automation Trustworthiness, Probabilistic Validation (PV), AI-Based Automated Firewatch, Nuclear Power Plants.

10. Performance analysis of passive cooling design strategies for hot and dry climatic conditions

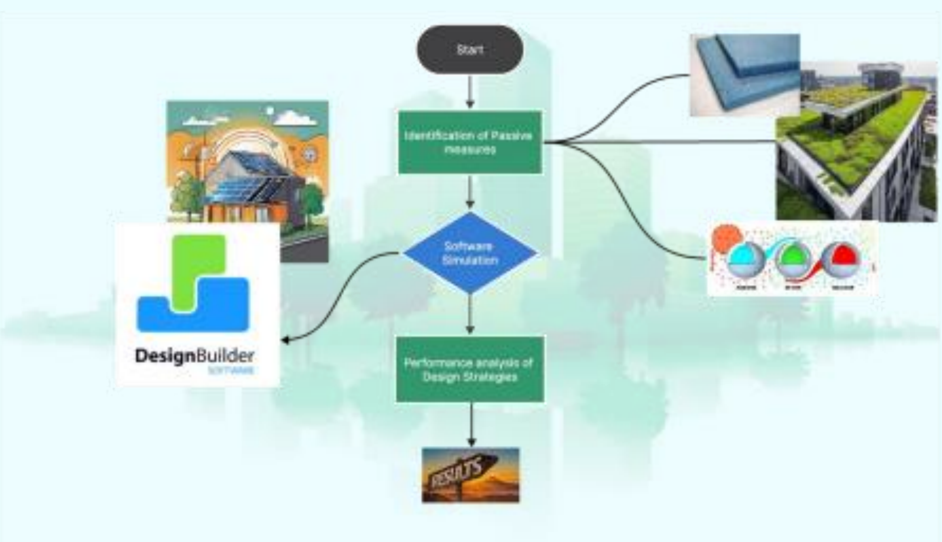


Figure 20 Workflow Diagram

Addressing the pressing need for energy-efficient solutions amidst climate change challenges, this study emphasizes the importance of focusing on air conditioning (AC) load management. Passive measures such as cool roofs, green roofs, and insulation play a pivotal role in reducing AC loads by mitigating outdoor heat infiltration into indoor spaces. Specifically tailored for hot and dry climates, these measures have shown significant promise, with observed reductions ranging from 25% to 35% in annual cooling loads. Furthermore, ongoing life cycle cost analysis aims to quantify the economic viability of these measures, providing stakeholders with essential insights into their cost-effectiveness and sustainability. Through interdisciplinary research spanning engineering, environmental science, and economics, this study contributes to advancing energy-efficient building practices and fostering resilient built environments.

Keywords: Green Roof, Cool Roof, Energy Savings, Thermal Comfort, Energy Efficiency, Insulation, Urban Heat Island

11. Investigation and characterisation of potential induced degradation in crystalline silicon photovoltaic module

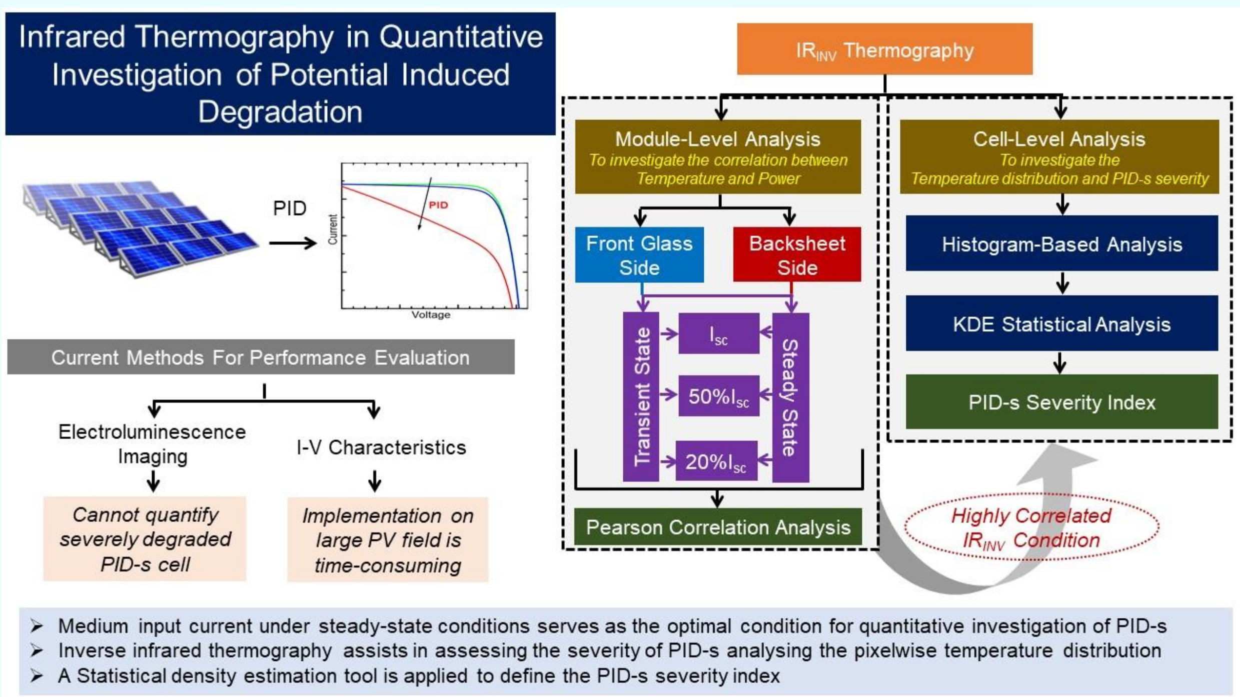


Figure 21 Research gap and methodology

Potential-induced degradation-shunting (PID-s) is a severe degradation mechanism in photovoltaic (PV) cells that significantly impact module performance. To prevent further degradation, periodic monitoring of PIDs is essential. Current-voltage (I-V) characteristics and electroluminescence (EL) imaging are commonly used for quantitative performance evaluation of PID-s affected PV modules. However, conducting I-V measurements in the field is time-consuming, while EL imaging has limitations for severely PID-affected cells

with no EL emission. To address these challenges, this abstract proposes the use of infrared thermography as an alternative evaluation technique. Infrared imaging offers a faster and more efficient approach, enabling the visualization of temperature distributions even in severely PID-affected PV cells where EL imaging falls short. This paper presents insights exploring the possibility of a correlation between PV cell temperature and power output. Analysis of shunting using simulations confirms the one-to-one relationship between power output and heat dissipation. Experimental measurements of cell power exhibit a strong correlation with the average cell temperature in a PV module.

Keywords: Green Roof, Cool Roof, Energy Savings, Thermal Comfort, Energy Efficiency, Insulation, Urban Heat Island

12. Root Cause Evaluation of PV Module Degradation

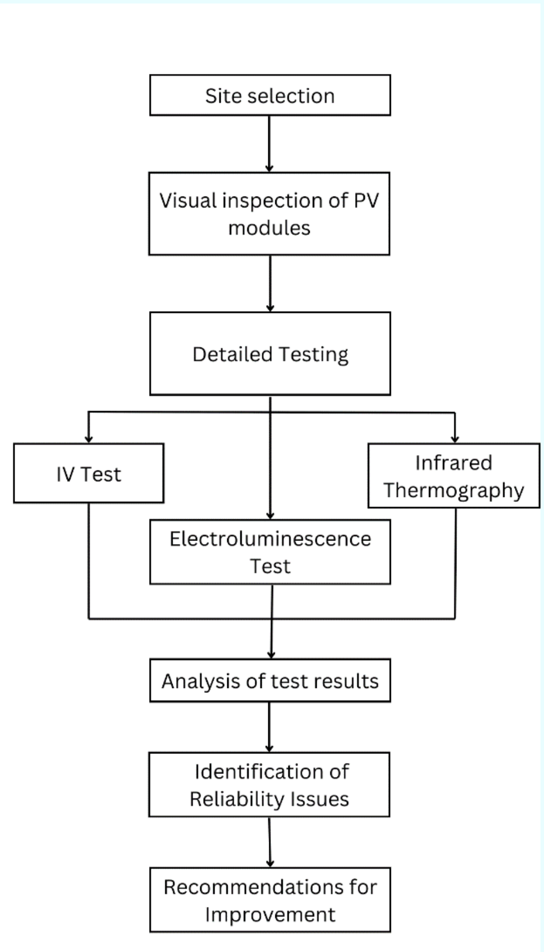


Figure 22 Block Diagram for the study of PV module degradation

The photovoltaic (PV) industry plays a crucial role in the global energy transition towards a net-zero emission energy system. However, to ensure the widespread adoption of PV systems, it is essential to understand and address reliability challenges associated with PV module technologies. This study aims to provide an overview of PV system reliability, focusing on degradation mechanisms. It analyses PV modules installed on the rooftop solar PV power plant at IIT Bombay, conducting tests such as visual inspection, I-V test, electroluminescence tests, and infrared thermography. Results show a significant decrease in power generation of up to 99%, signs of PID in the modules, and the possibility of solder bond failure, which contributes to very high series resistance. Addressing these challenges is vital for successful PV integration, prolonging operational lifetimes, reducing degradation, and lowering electricity production costs. Ultimately, this promotes the adoption of renewable energy sources in the global energy landscape.

Keywords: Green Roof, Cool Roof, Energy Savings, Thermal Comfort, Energy Efficiency, Insulation, Urban Heat Island.