MODELING AND SIMULATION OF A LITHIUM-ION BATTERY FED INDUCTION MOTOR DRIVE USING CASCADED H-BRIDGE MULTILEVEL INVERTER

Mrs.S. Jeyaseeli[1], K. Kaviya[2]

[1]Assistant Professor, [2]Student, Dept of EEE, VV College of Engineering,Tamilnadu,India

* * *

Abstract - *This project presents a comparative performance analysis of Single-Phase Induction Motors, namely Split Phase, Capacitor-Start, and Capacitor Start–Capacitor Run induction motors, using MATLAB/Simulink. The study focuses on analyzing the operational characteristics of these motors under different supply conditions to evaluate their performance in terms of speed, current, and electromagnetic torque. The motor models are developed and simulated to observe their dynamic behavior and operating efficiency.*

To improve power quality and motor operation, a Cascaded H-Bridge Multilevel Inverter (CHBMLI) is integrated with the induction motors. The multilevel inverter converts DC power into stepped AC voltage with reduced harmonic distortion and smoother output characteristics. In addition, a Lithium-Ion Battery is used as a DC source to develop a battery-fed inverter system, making the model suitable for energy-efficient and modern electric drive applications. The performance of the motors is analyzed through parameters such as maximum speed, mean speed, median speed, RMS speed, and peak-to-peak variation. Simulation results show that the Capacitor Start–Run Induction Motor provides better speed performance, smoother operation, and lower fluctuations compared to the Split Phase and Capacitor-Start motors. Thus, the proposed system demonstrates the effectiveness of multilevel inverter-fed induction motors for applications such as household appliances, motor drives, renewable energy systems, and electric vehicles.

1. INTRODUCTION

Single-phase induction motors are widely used in domestic and industrial applications due to their simple construction, reliability, low maintenance, and cost-effectiveness. Among the various types of single-phase induction motors, the Split Phase, Capacitor-Start, and Capacitor Start–Capacitor Run induction motors are commonly used for applications requiring different starting torque and speed characteristics. The performance of these motors mainly depends on their starting mechanism, torque production, speed stability, and operating efficiency.

In this project, a comparative analysis of Split Phase, Capacitor-Start, and Capacitor Start–Run induction motors has been carried out using MATLAB/Simulink. The motor models are developed to study important performance parameters such as main winding current, rotor speed, and electromagnetic torque. The split-phase motor uses an auxiliary winding for starting, whereas the capacitor-start motor employs a starting capacitor to provide higher starting torque. The capacitor start–run motor uses both starting and running capacitors to improve starting performance, efficiency, and smooth operation. To improve power quality and motor performance, a Cascaded H-Bridge Multilevel Inverter (CHBMLI) is integrated with the induction motors. The multilevel inverter converts DC power into stepped AC voltage with reduced harmonic distortion, smoother output waveform, and improved efficiency. The inverter is designed using MOSFET switches, pulse generators, and logical operator blocks in MATLAB/Simulink. In addition, a Lithium-Ion Battery is used as the DC power source to create a battery-fed inverter system, making the model suitable for energy storage and electric drive applications. The performance of the motors is analyzed under different operating conditions, including direct AC supply, cascaded H-bridge inverter supply, and battery-fed inverter supply. Parameters such as maximum speed, mean speed, median speed, RMS speed, and peak-to-peak variation are compared to evaluate the efficiency and stability of each motor type. From the analysis, it is observed that the Capacitor Start–Run induction motor provides better speed performance, smoother operation, and reduced speed fluctuation compared to the Split Phase and Capacitor-Start motors. Therefore, this study helps in understanding the dynamic behavior and comparative performance of different single-phase induction motors for practical applications such as motor drives, household appliances, renewable energy systems, and electric vehicles.

1.1 LITERATURE REVIEW

The literature review provides an overview of previous research works related to cascaded H-bridge multilevel inverters and induction motor drive systems. Several researchers have studied different multilevel inverter topologies, control techniques, and their applications in electric vehicles, renewable energy systems, and motor drives. The reviewed studies mainly focus on improving power quality, reducing Total Harmonic Distortion (THD), enhancing motor efficiency, and achieving smooth operation through advanced inverter configurations and Pulse Width Modulation (PWM) techniques. These research works provide valuable insights and form the foundation for the present study on cascaded H-bridge multilevel inverter-fed single-phase induction motors.

[1] Recent studies on cascaded H-bridge (CHB) multilevel inverters for electric vehicle applications have demonstrated their effectiveness in improving output voltage quality and enhancing motor drive performance. Researchers emphasized that the use of multiple H-bridge cells powered by separate DC sources generates a stepped multilevel waveform that closely resembles a sinusoidal waveform, thereby reducing Total Harmonic Distortion (THD) and improving power quality. The findings also highlighted improved motor efficiency, reduced switching losses, and lower voltage stress across semiconductor devices, making CHB inverters a reliable and efficient solution for electric vehicle drive systems.**[2]** Research on three-phase five-level cascaded H-bridge inverter-fed induction motor systems for renewable energy applications focused on generating high-quality AC power through multilevel voltage synthesis. The studies demonstrated that stepped output waveforms produced by CHB inverters significantly reduce harmonics, improve efficiency, and ensure smooth induction motor operation. The reduced torque ripple and enhanced speed stability observed in these systems make them highly suitable for renewable energy and industrial applications.**[3]** Several investigations into cascaded H-bridge multilevel inverter configurations for electric vehicle systems have highlighted the role of increasing voltage levels in improving waveform quality. By generating multiple voltage steps, the inverter minimizes harmonic distortion and improves system efficiency. The studies also evaluated parameters such as switching losses, power quality, and voltage stress, concluding that CHB inverters provide reliable operation and improved motor performance in electric vehicle applications.**[4]** Comparative reviews of multilevel inverter topologies have analyzed diode-clamped, flying capacitor, and cascaded H-bridge configurations based on efficiency, harmonic distortion, and implementation complexity. These studies concluded that the CHB inverter topology offers superior flexibility due to its modular structure and ability to efficiently utilize multiple battery sources. The inverter also provides lower harmonic distortion and improved efficiency, making it suitable for electric vehicle and renewable energy applications.**[5]** Research focused on the optimal design of cascaded H-bridge inverter configurations emphasized the importance of proper arrangement and independent control of multiple DC sources. The findings indicated that optimized inverter structures significantly improve energy management, increase system reliability, reduce switching losses, and enhance overall efficiency. Such optimized designs were found to improve the performance of motor drive systems and electric vehicle applications.**[6]** Studies on inductor-less cascaded H-bridge inverter configurations proposed simplified system architectures aimed at reducing hardware complexity and implementation cost. By eliminating passive components such as inductors, the inverter structure becomes more compact while still maintaining acceptable output voltage quality and efficiency. The results demonstrated improved reliability and suitability for applications where compactness and cost-effectiveness are critical.**[7]** Research on reduced-switch cascaded H-bridge multilevel inverter topologies introduced modified configurations designed to reduce the number of semiconductor switching devices. These studies showed that reducing the switch count lowers hardware complexity and switching losses while maintaining acceptable multilevel output voltage quality. The findings confirmed that such inverter structures improve efficiency and provide economical solutions for motor drives and renewable energy systems.**[8]** Investigations into control strategies for cascaded H-bridge multilevel inverters highlighted the significance of advanced Pulse Width Modulation (PWM) techniques in improving inverter performance. Researchers explained that appropriate switching signal control significantly reduces harmonic distortion, enhances output waveform quality, and improves system efficiency. Various modulation methods were evaluated to determine their impact on reliability and overall inverter operation.**[9]** Studies on multicarrier PWM techniques for multilevel inverters analyzed different modulation strategies and their effectiveness in reducing harmonics and improving voltage quality. The results indicated that advanced PWM methods produce smoother output waveforms, reduce distortion, and enhance the efficiency of motor drive systems. These findings underline the importance of selecting suitable control methods for optimized inverter performance.**[10]** Research comparing Phase Opposition Disposition (POD) and Alternate Phase Opposition Disposition (APOD) PWM techniques demonstrated their ability to significantly reduce Total Harmonic Distortion and improve voltage quality in multilevel inverter systems. The comparative analysis revealed that proper PWM selection greatly influences inverter efficiency and output waveform characteristics under varying operating conditions.**[11]** Comparative studies between Modular Multilevel Converters (MMC) and Cascaded H-Bridge (CHB) inverters examined performance based on parameters such as efficiency, harmonic distortion, switching complexity, voltage balancing, and reliability. The findings indicated that CHB inverters are more suitable for motor drive systems due to their modularity, simpler control requirements, reduced hardware complexity, and better fault tolerance. As a result, CHB topologies were identified as practical and efficient solutions for electric vehicle and motor drive applications.**[12]** Research on solar-powered cascaded H-bridge multilevel inverter systems focused on integrating renewable energy sources, particularly solar photovoltaic systems, with multilevel inverter technology. The studies demonstrated that CHB inverters efficiently utilize multiple DC sources from solar panels to generate high-quality AC output with reduced harmonic distortion. This integration improves energy utilization, minimizes conversion losses, and enhances system reliability for renewable energy and motor drive applications.**[13]** Comparative evaluations of different multilevel inverter topologies highlighted the superior performance of cascaded H-bridge inverters in terms of scalability, reduced switching losses, efficiency, and reliability. The modular structure of CHB inverters enables easy expansion to higher voltage levels while maintaining improved power quality and lower harmonic distortion.

These characteristics make CHB inverters highly suitable for industrial motor drives, renewable energy systems, and electric vehicle applications.**[14]** Reviews on multilevel inverter control strategies emphasized the importance of advanced PWM methods such as multicarrier PWM, sinusoidal PWM, and space vector modulation in improving inverter performance. The studies concluded that proper switching control reduces harmonic distortion, minimizes switching losses, improves voltage quality, and enhances overall system stability and efficiency. Furthermore, the research suggested that future developments should focus on simplified and intelligent control strategies for achieving better performance in modern inverter systems.

2. INDUCTION MOTOR

An induction motor is a widely used AC motor known for its simple construction, reliability, low cost, and easy maintenance. It operates on the principle of electromagnetic induction, where electrical energy is converted into mechanical energy without direct electrical contact between the stator and rotor. When AC supply is applied, the stator produces a rotating magnetic field, which induces current in the rotor and causes it to rotate. Induction motors are commonly used in pumps, fans, compressors, and household appliances. Based on application requirements, single-phase induction motors are classified into split-phase, capacitor-start, capacitor-run, and capacitor start–run motors.

2.1 Split Phase Induction Motor

A single-phase split-phase induction motor is a type of single-phase AC motor commonly used in household and small industrial applications. It consists of two windings, namely the main winding and the starting winding, connected on the stator. The main winding is directly connected to the AC supply, while the starting winding is connected through a centrifugal switch. Since a single-phase supply cannot produce a rotating magnetic field, the motor is not self-starting. To overcome this problem, the starting winding creates a phase difference between the currents, producing the required starting torque.

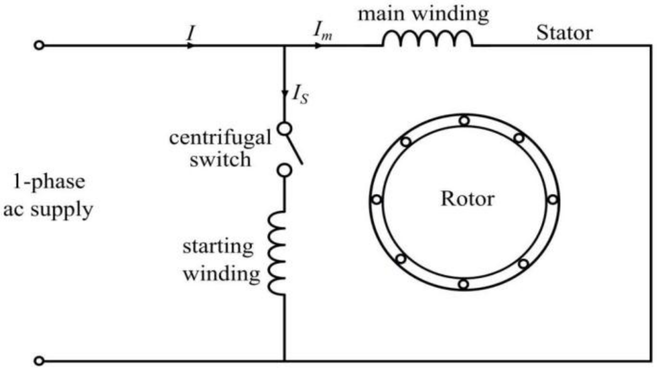


Figure 1: Circuit Diagram of Single Phase Split-Phase Induction Motor

When the motor is switched ON, current flows through both windings and the rotor starts rotating. Once the motor reaches about 70–80% of its rated speed, the centrifugal switch automatically disconnects the starting winding. After that, the motor continues to operate only with the main winding. These motors are simple, economical, and widely used in fans, blowers, pumps, and washing machines.

2.2 Capacitor Start Induction Motor

A capacitor start induction motor is a type of single-phase induction motor designed to provide high starting torque. It consists of a main winding, starting winding, capacitor, and a centrifugal switch. The capacitor is connected in series with the starting winding to create a larger phase difference between the currents in the two windings. This phase difference produces a strong rotating magnetic field, enabling the motor to start effectively.

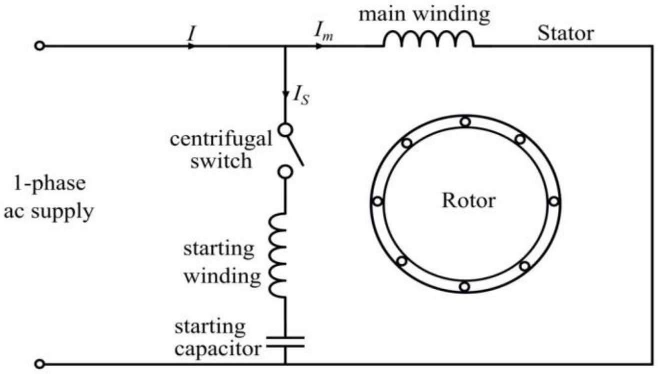


Figure 2: Circuit Diagram of Capacitor-Start Induction Motor

When the motor is switched ON, current flows through both the main winding and the starting winding with the capacitor connected in series. The capacitor improves the starting torque and helps the rotor begin rotating. Once the motor reaches about 70–80% of its rated speed, the centrifugal switch disconnects the starting winding and capacitor from the circuit. After this, the motor continues to run only on the main winding. Capacitor start motors are widely used in air compressors, pumps, refrigerators, and washing machines, where high starting torque is required.

2.3 Cascaded H Bridge Multilevel Inverter

A capacitor start - run induction motor is a type of single-phase induction motor that provides high starting torque and improved running performance. It consists of a main winding, auxiliary winding, starting capacitor, running capacitor, and a centrifugal switch. The starting capacitor is connected during the starting period to produce a large phase difference between the windings, resulting in high starting torque. The running capacitor remains connected continuously to improve efficiency, power factor, and smooth operation of the motor.

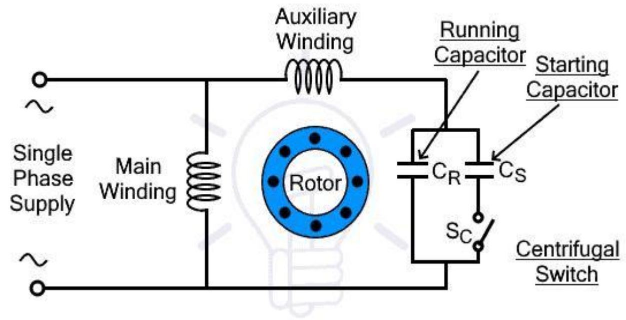


Figure 3: Circuit Diagram of Capacitor Start–Capacitor Run Induction Motor

When the motor is switched ON, both the starting capacitor and running capacitor operate along with the auxiliary winding to create a strong rotating magnetic field, helping the rotor start quickly. After the motor reaches about 70–80% of its rated speed, the centrifugal switch disconnects the starting capacitor, while the running capacitor stays connected to the circuit. The motor then continues running smoothly with better efficiency and quieter operation. These motors are commonly used in air conditioners, refrigerators, compressors, pumps, and heavy-duty household appliances where high starting torque and smooth performance are required.

3.1 Lithium Ion Battery

The MATLAB/Simulink model of a Lithium-Ion Battery is developed to analyze the charging and discharging characteristics of the battery under electrical load conditions. In this model, a battery block is connected to a series RLC branch, which acts as the load. The powergui block is used to perform power system simulation in continuous mode. The battery supplies electrical energy to the load, and the performance parameters such as State of Charge (SOC), current, and voltage are measured during operation. The measured signals from the battery are connected to a scope block through a measurement port to observe the battery characteristics graphically. The SOC (%) indicates the remaining charge available in the battery, while the current (A) and voltage (V) represent the electrical behavior during charging or discharging. This MATLAB model helps in studying battery performance, efficiency, and energy storage behavior, making it useful for applications such as electric vehicles, renewable energy systems, and battery management systems (BMS).

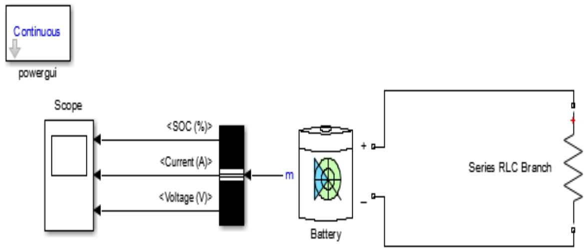


Figure 4: MATLAB/Simulink Model of Lithium-Ion Battery

The graph represents the performance characteristics of a Lithium-Ion Battery in MATLAB/Simulink, showing the variation of State of Charge (SOC), current, and voltage with respect to time. The SOC (%) graph shows a gradual decrease from approximately 48% to 46%, indicating that the battery is discharging continuously during the simulation period. This reduction in SOC confirms the transfer of stored energy from the battery to the connected load.

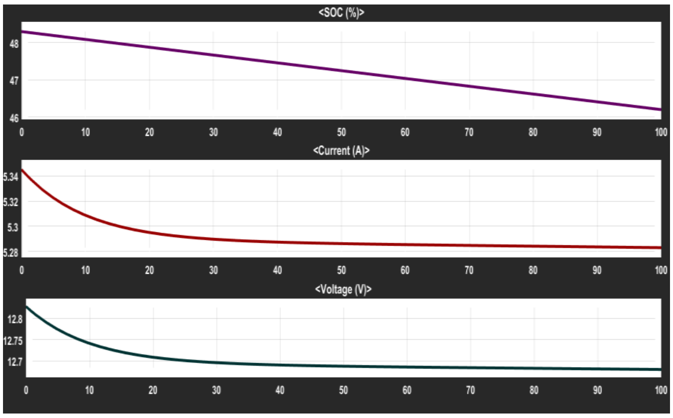


Figure 5: Performance Characteristics of Lithium-Ion Battery

The current (A) graph shows an initial higher current value, which gradually decreases and becomes nearly constant over time. This behavior indicates that the battery initially supplies more current and later stabilizes according to the load requirement. Similarly, the voltage (V) graph shows a slight decrease from the initial value and then becomes stable, which is a normal characteristic of lithium-ion batteries during discharge. The gradual reduction in voltage indicates energy utilization while maintaining stable output performance. These results demonstrate the efficient and stable operation of the lithium-ion battery under load conditions.

3.2 Cascaded H Bridge Multilevel Inverter

The MATLAB/Simulink model of the Cascaded H-Bridge Multilevel Inverter (CHBMLI) is developed to generate a multilevel AC output voltage from multiple DC sources. In this model, several MOSFET switches are arranged in the form of cascaded H-bridge cells and are controlled using pulse generators. Each H-bridge is supplied by an independent DC voltage source, and the switching signals are controlled through logical operator blocks to obtain the required switching sequence. The powergui block is used for continuous simulation and analysis of the inverter system.

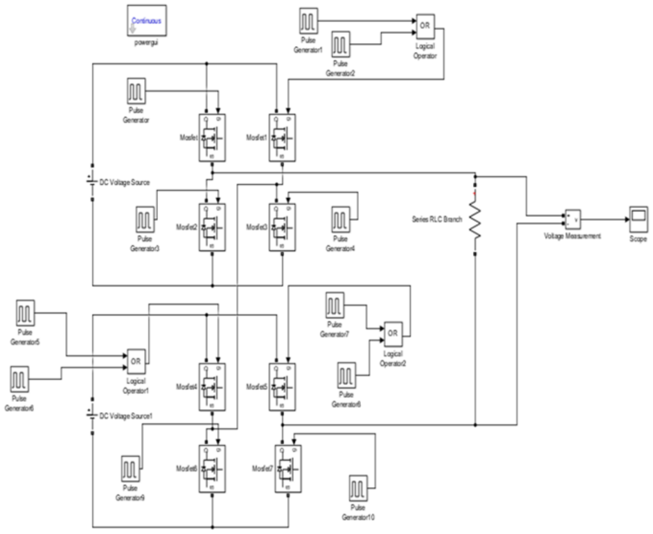


Figure 6: MATLAB/Simulink Model of Cascaded H-Bridge Multilevel Inverter

The cascaded H-bridge inverter combines the output voltages of multiple H-bridge cells to produce a stepped multilevel output waveform, which reduces harmonic distortion and improves power quality. A Series RLC branch is connected as the load to analyze the inverter performance under operating conditions. The voltage measurement block measures the output voltage and displays it on the scope for waveform analysis. This MATLAB model is useful for studying inverter performance, harmonic reduction, voltage control, and efficient power conversion in applications such as renewable energy systems, motor drives, and electric vehicles.

The graph represents the output voltage waveform of the Cascaded H-Bridge Multilevel Inverter (CHBMLI) obtained from the MATLAB/Simulink model. The waveform shows a stepped multilevel AC output voltage, where different voltage levels are generated by combining the outputs of multiple H-bridge cells. The output voltage varies between positive and negative voltage levels, forming a staircase waveform that closely resembles a sinusoidal wave. From the graph, it can be observed that the inverter produces multiple voltage levels such as ±200 V, ±100 V, and 0 V, which helps in reducing harmonic distortion and improving output power quality.

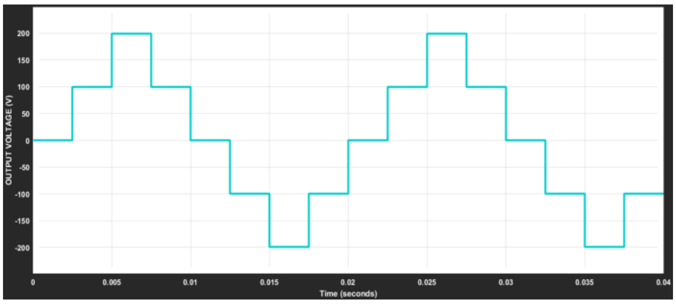


Figure 7: Output Voltage Waveform of Cascaded H-Bridge Multilevel Inverter

The stepped waveform indicates proper switching of the MOSFETs according to the pulse signals provided by the control circuit. Compared to conventional inverters, the cascaded H-bridge multilevel inverter provides smoother voltage output with reduced switching losses and lower Total Harmonic Distortion (THD). Hence, this inverter is suitable for applications such as motor drives, renewable energy systems, and electric vehicle power conversion.

4.1 SPLIT PHASE INDUCTION MOTOR

The MATLAB/Simulink model of the Single-Phase Split-Phase Induction Motor is developed to analyze the performance of the motor under single-phase AC supply conditions. In this model, the AC voltage source supplies power to the single-phase asynchronous machine (split-phase motor). A constant block is connected to provide the mechanical load torque input (Tm) to the motor. The motor consists of main winding and starting winding, where the starting winding helps in producing the initial starting torque.

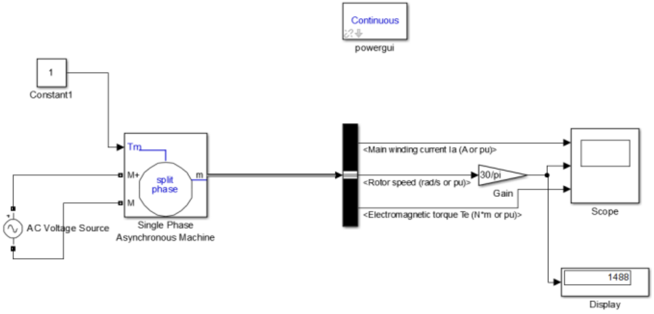


Figure 8: MATLAB/Simulink Model of Single-Phase Split-Phase Induction Motor

The output parameters such as main winding current, rotor speed, and electromagnetic torque are measured and connected to a scope block for graphical analysis. A gain block (30/π) is used to convert rotor speed from radians per second (rad/s) to revolutions per minute (RPM), and the speed value is displayed using the display block. The powergui block is used for continuous simulation of the electrical system. This MATLAB model helps in studying the starting behavior, speed characteristics, torque response, and performance of the split-phase induction motor under different operating conditions.

The graph represents the performance characteristics of the Single-Phase Split-Phase Induction Motor obtained from the MATLAB/Simulink model. The first graph shows the main winding current (A), which varies sinusoidally with time due to the AC supply. The current waveform indicates stable motor operation with slight variations during running conditions. The second graph represents the rotor speed (rad/s) of the motor. It can be observed that the motor speed remains nearly constant around its rated value, indicating stable performance after starting. This shows that the motor reaches steady-state operation and maintains uniform speed during the simulation period.

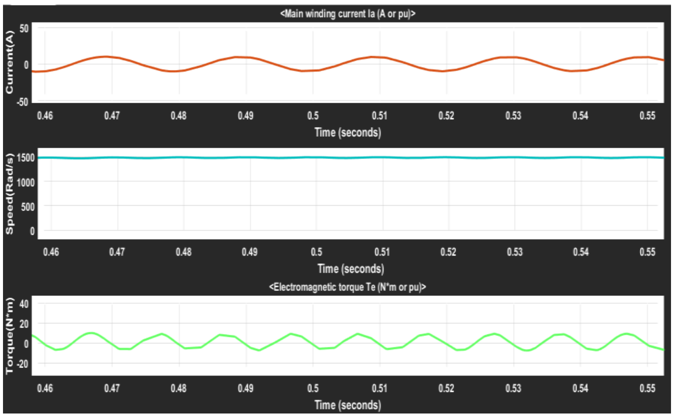


Figure 9: Performance Characteristics of Single-Phase Split-Phase Induction Motor

The third graph shows the electromagnetic torque (N·m) developed by the motor. Initially, torque fluctuations occur due to the starting action of the motor, and later it stabilizes with small oscillations. These variations are normal in split-phase induction motors and indicate proper torque generation for continuous operation. Overall, the results confirm the stable performance and efficient running of the single-phase split-phase induction motor.

4.1.1SPLIT PHASE INDUCTION MOTOR FED BY CASCADED H BRIDGE ML

The MATLAB/Simulink model of the Single-Phase Split-Phase Induction Motor connected with a Cascaded H-Bridge Multilevel Inverter (CHBMLI) is developed to analyze the motor performance using inverter-fed AC supply. In this model, the cascaded H-bridge multilevel inverter is used to convert the DC voltage from multiple DC sources into a multilevel AC output voltage. The inverter consists of several MOSFET switches controlled by pulse generators and logical operator blocks, which generate the required switching pulses for proper inverter operation. The output of the cascaded H-bridge inverter is connected to the single-phase split-phase asynchronous motor, which receives the inverter-generated AC supply for operation. A constant block is used to provide mechanical load torque to the motor. The output parameters such as main winding current, rotor speed, and electromagnetic torque are measured and displayed using the scope block for performance analysis.

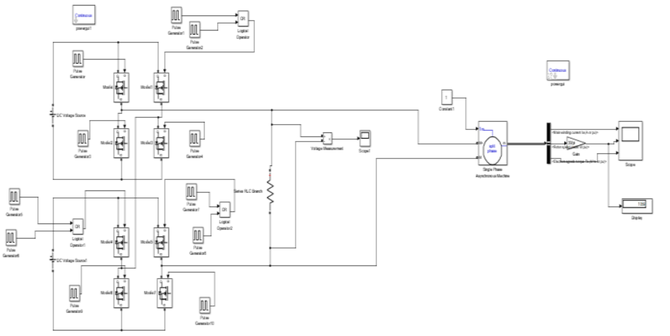


Figure 10: MATLAB/Simulink Model of Split-Phase Induction Motor Connected with Cascaded H-Bridge Multilevel Inverter

A gain block converts motor speed into RPM and displays the value. The powergui block enables continuous simulation of the electrical system. This model helps in studying the dynamic performance, speed control, torque characteristics, and efficient operation of the split-phase induction motor when supplied through a cascaded H-bridge multilevel inverter.

The graph represents the performance characteristics of the Single-Phase Split-Phase Induction Motor connected with a Cascaded H-Bridge Multilevel Inverter (CHBMLI) obtained from the MATLAB/Simulink model. The first graph shows the main winding current (A) waveform, which appears as a periodic AC waveform with slight harmonics due to inverter switching. The current remains stable, indicating proper power supply from the cascaded H-bridge multilevel inverter to the motor. The second graph represents the rotor speed (rad/s) of the motor. It can be observed that the motor speed remains nearly constant throughout the simulation period, showing stable and efficient motor operation. Small fluctuations in speed occur due to inverter switching effects, but the motor maintains steady-state performance.

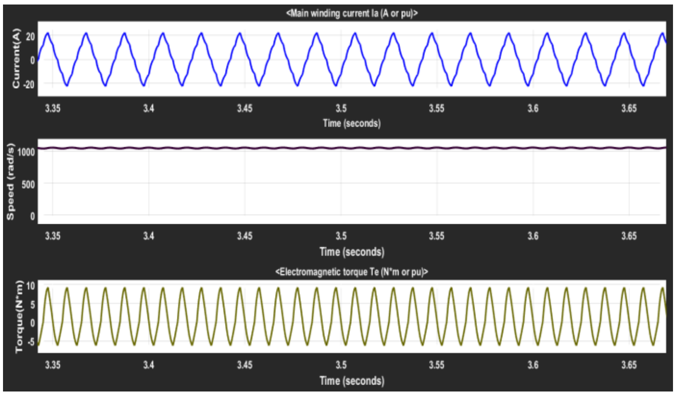


Figure 11: Performance Characteristics of Split-Phase Induction Motor Connected with Cascaded H-Bridge Multilevel Inverter

The third graph shows the electromagnetic torque (N·m) developed by the motor. The torque waveform contains periodic oscillations due to the multilevel inverter switching action, but it remains within a stable operating range. These torque ripples are comparatively lower because the cascaded H-bridge multilevel inverter produces a stepped output waveform with reduced harmonic distortion. Overall, the results indicate that the split-phase induction motor operates efficiently with stable speed, controlled current, and improved torque performance when supplied through the cascaded H-bridge multilevel inverter.

4.1.2 BATTERY-FED CASCADED H-BRIDGE MULTILEVEL INVERTER DRIVING SPLIT PHASE INDUCTION MOTOR

The MATLAB/Simulink model of a Battery-Fed Cascaded H-Bridge Multilevel Inverter connected with a Single-Phase Induction Motor is developed to analyze the motor performance using battery-powered inverter supply. In this model, lithium-ion batteries are used as DC power sources for the cascaded H-bridge multilevel inverter (CHBMLI). The battery parameters such as State of Charge (SOC), current, and voltage are monitored using measurement blocks and displayed through the scope for battery performance analysis.

The cascaded H-bridge inverter consists of multiple MOSFET switches, pulse generators, and logical operator blocks to generate switching signals and produce a stepped multilevel AC output voltage from the DC battery supply. A Series RLC branch is connected to analyze inverter output behavior. The multilevel AC output is then supplied to the single-phase asynchronous induction motor, which converts electrical energy into mechanical energy. A constant block is used to provide mechanical load torque to the motor.

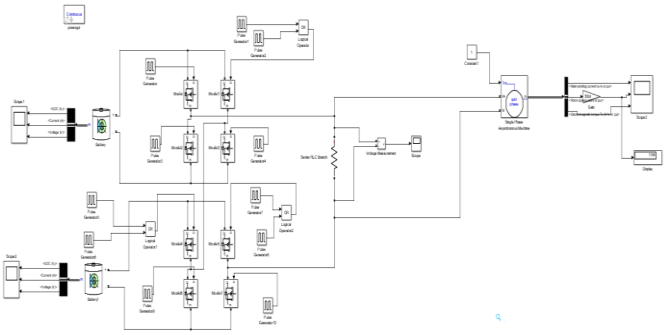


Figure 12: MATLAB/Simulink Model of Battery-Fed Cascaded H-Bridge Multilevel Inverter Connected with Split-Phase Induction Motor

The motor output parameters such as main winding current, rotor speed, and electromagnetic torque are measured and displayed using a scope block for performance evaluation. A gain block (30/π) converts the motor speed from rad/s to RPM, and the speed is shown in the display block. The powergui block is used for continuous simulation of the system. This model helps in studying the battery performance, inverter efficiency, motor speed control, torque characteristics, and overall system behavior, making it suitable for applications such as electric vehicles, renewable energy systems, and battery-powered motor drives.

The graph represents the performance characteristics of the Battery-Fed Cascaded H-Bridge Multilevel Inverter connected with the Single-Phase Induction Motor obtained from the MATLAB/Simulink model. The first graph shows the main winding current (A) waveform of the motor, which varies periodically between approximately +25 A and −25 A. The current waveform is smooth and stable, indicating proper power supply from the battery-fed cascaded H-bridge inverter to the motor with reduced harmonic distortion.

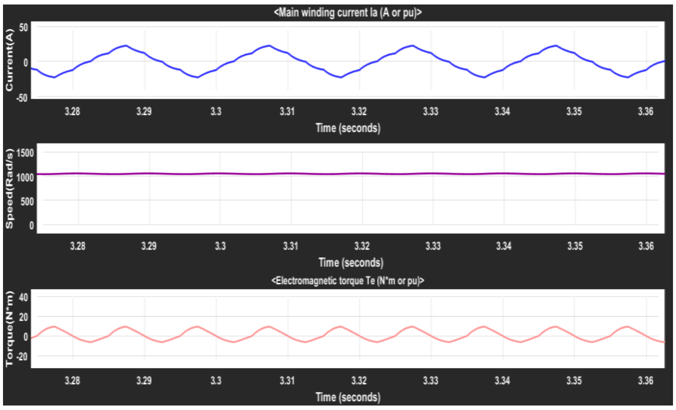


Figure 13: Performance Characteristics of Battery-Fed Split-Phase Induction Motor System

The second graph represents the rotor speed (rad/s) of the induction motor. It can be observed that the motor speed remains nearly constant at around 1050–1100 rad/s throughout the simulation period, indicating stable and efficient operation. Minor fluctuations in speed occur due to inverter switching and load variations, but the motor maintains steady-state performance. The third graph shows the electromagnetic torque (N·m) developed by the motor. The torque varies approximately between −5 N·m and +10 N·m, showing periodic oscillations during operation. These torque ripples are due to inverter switching effects but remain controlled because of the multilevel stepped output waveform generated by the cascaded H-bridge inverter. Overall, the results confirm that the battery-fed cascaded H-bridge inverter provides stable current, constant motor speed, and smooth torque response, ensuring efficient operation of the single-phase induction motor system.

4.2 CAPACITOR START INDUCTION MOTOR

The MATLAB/Simulink model of the Single-Phase Capacitor Start Induction Motor is developed to analyze the performance of the motor under single-phase AC supply conditions. In this model, the AC voltage source provides power to the single-phase asynchronous machine (capacitor start motor). A constant block is connected to provide the mechanical load torque (Tm) input to the motor. In the capacitor start motor, a starting capacitor is connected in series with the auxiliary winding to produce a larger phase difference, which helps in generating high starting torque during motor starting.

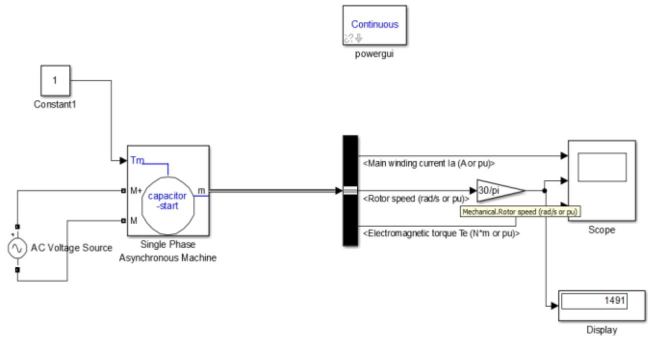


Figure 14: MATLAB/Simulink Model of Capacitor-Start Induction Motor

The output parameters such as main winding current, rotor speed, and electromagnetic torque are measured and connected to a scope block for graphical analysis. A gain block (30/π) is used to convert the rotor speed from radians per second (rad/s) to revolutions per minute (RPM), and the speed value is displayed using the display block, showing approximately 1491 RPM. The powergui block is used for continuous simulation of the system. This MATLAB model helps in studying the starting characteristics, speed response, torque performance, and current behavior of the capacitor start induction motor under different operating conditions.

The graph represents the performance characteristics of the Single-Phase Capacitor Start Induction Motor obtained from the MATLAB/Simulink model. The first graph shows the main winding current (A) waveform, which varies sinusoidally between approximately +10 A and −10 A. The smooth current waveform indicates stable motor operation and proper current supply during running conditions

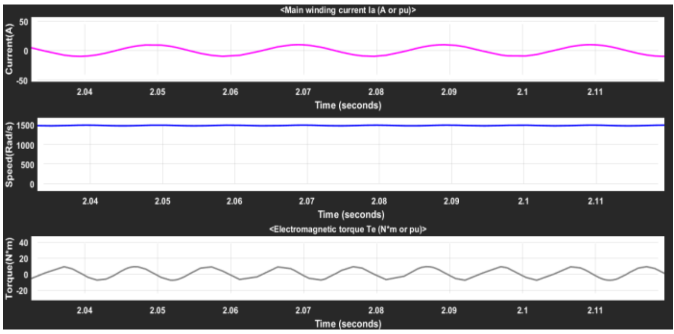


Figure 15: Performance Characteristics of Capacitor-Start Induction Motor

The second graph represents the rotor speed (rad/s) of the motor. It can be observed that the motor speed remains nearly constant at around 1490–1500 rad/s, indicating stable and efficient operation after starting. Minor fluctuations in speed are observed due to load and motor dynamic response, but the motor maintains steady-state performance throughout the simulation. The third graph shows the electromagnetic torque (N·m) developed by the motor. The torque varies approximately between −10 N·m and +10 N·m, showing periodic oscillations during operation. These torque variations occur due to electromagnetic interactions inside the motor but remain stable during continuous running. Overall, the results indicate that the capacitor start induction motor operates efficiently with smooth current, stable speed, and controlled torque characteristics, ensuring reliable performance under single-phase supply conditions.

4.2.1 CAPACITOR START INDUCTION MOTOR FED BY CASCADED H BRIDGE ML

The MATLAB/Simulink model of the Capacitor Start Induction Motor connected with a Cascaded H-Bridge Multilevel Inverter (CHBMLI) is developed to analyze the motor performance using an inverter-fed AC supply. In this model, the cascaded H-bridge multilevel inverter converts the DC input voltage into a multilevel AC output voltage using multiple MOSFET switches, pulse generators, and logical operator blocks. The switching pulses control the MOSFET operation and generate a stepped AC waveform with reduced harmonic distortion.

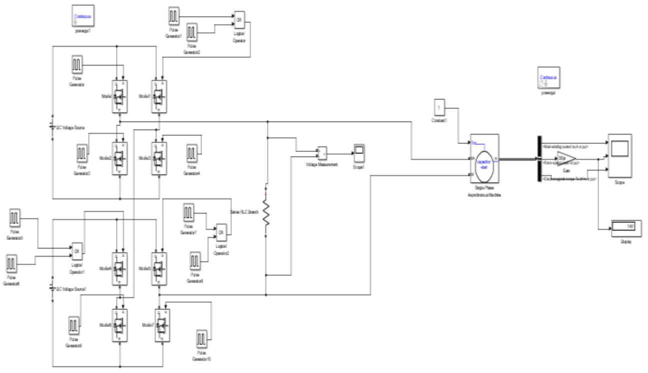


Figure 16: MATLAB/Simulink Model of Capacitor-Start Induction Motor Connected with Cascaded H-Bridge Multilevel Inverter

The output of the cascaded H-bridge inverter is connected to the single-phase capacitor start induction motor, which operates using the inverter-generated AC supply. A constant block is used to apply mechanical load torque (Tm) to the motor. The motor utilizes a starting capacitor to provide high starting torque during the starting period. The output parameters such as main winding current, rotor speed, and electromagnetic torque are measured and displayed through a scope block for performance analysis. A gain block (30/π) converts motor speed from rad/s to RPM, and the speed value is displayed, showing approximately 1491 RPM. The powergui block is used for continuous simulation of the electrical system. This model helps in studying the speed response, current characteristics, torque performance, and harmonic reduction of the capacitor start induction motor when supplied through a cascaded H-bridge multilevel inverter. The multilevel inverter improves power quality and provides smoother motor operation with reduced switching losses.

The graph represents the performance characteristics of the Capacitor Start Induction Motor connected with a Cascaded H-Bridge Multilevel Inverter (CHBMLI) obtained from the MATLAB/Simulink model. The first graph shows the main winding current (A) waveform, which varies periodically between approximately +8 A and −8 A. The current waveform contains small ripples due to the switching action of the multilevel inverter, but it remains stable, indicating smooth power delivery to the motor.

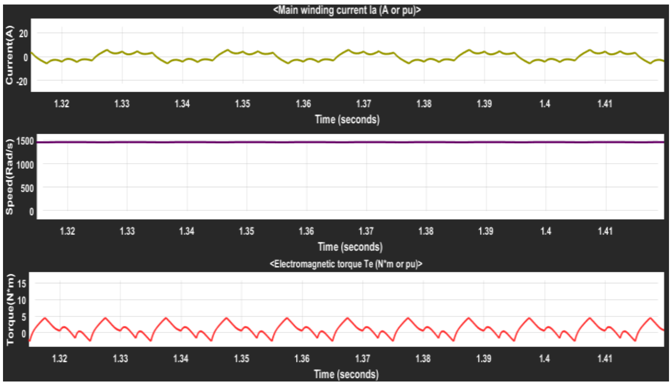


Figure 17: Performance Characteristics of Capacitor-Start Induction Motor Connected with Cascaded H-Bridge Multilevel Inverter

The second graph represents the rotor speed (rad/s) of the motor. It can be observed that the motor speed remains nearly constant at around 1490–1500 rad/s, showing stable and efficient motor performance. The speed waveform has only minor fluctuations, which indicates that the cascaded H-bridge inverter provides a smooth AC supply to the motor. The third graph shows the electromagnetic torque (N·m) developed by the motor. The torque varies approximately between 0 N·m and 5 N·m, showing periodic oscillations due to inverter switching and load conditions. However, the torque ripple remains controlled because of the stepped output voltage produced by the multilevel inverter. Overall, the results indicate that the capacitor start induction motor operates efficiently with stable current, nearly constant speed, and controlled torque characteristics when connected to the cascaded H-bridge multilevel inverter, ensuring improved power quality and smoother operation.

4.2.2 BATTERY-FED CASCADED H-BRIDGE MULTILEVEL INVERTER DRIVING CAPACITOR START INDUCTION MOTOR

The MATLAB/Simulink model of the Battery-Fed Cascaded H-Bridge Multilevel Inverter connected with a Capacitor Start Induction Motor is developed to analyze the motor performance using a battery-powered inverter supply. In this model, lithium-ion batteries are used as DC voltage sources for the cascaded H-bridge multilevel inverter (CHBMLI). The battery parameters such as State of Charge (SOC), current, and voltage are monitored using measurement blocks and displayed through scope blocks for battery performance analysis. The cascaded H-bridge multilevel inverter consists of multiple MOSFET switches, pulse generators, and logical operator blocks, which generate switching pulses to produce a multilevel AC output voltage from the battery DC supply. A Series RLC branch is connected to study the inverter output characteristics. The inverter output is then supplied to the single-phase capacitor start induction motor, which uses a starting capacitor to provide high starting torque during motor starting.

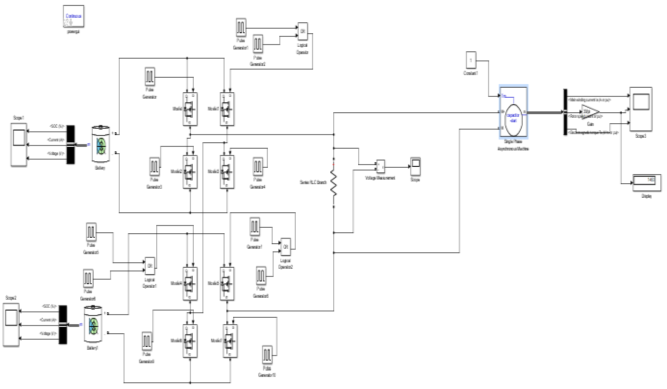


Figure 18: MATLAB/Simulink Model of Battery-Fed Cascaded H-Bridge Multilevel Inverter Connected with Capacitor-Start Induction Motor

The output parameters such as main winding current, rotor speed, and electromagnetic torque are measured and displayed using the scope block for performance analysis. A gain block (30/π) converts motor speed from rad/s to RPM, and the speed is displayed, showing approximately 1492 RPM. The powergui block is used for continuous simulation of the system. This model helps in analyzing the battery performance, inverter efficiency, motor speed control, torque response, and overall system stability, making it suitable for applications such as electric vehicles, renewable energy systems, and battery-powered motor drive systems.

The graph represents the performance characteristics of the Battery-Fed Cascaded H-Bridge Multilevel Inverter connected with the Capacitor Start Induction Motor obtained from the MATLAB/Simulink model.

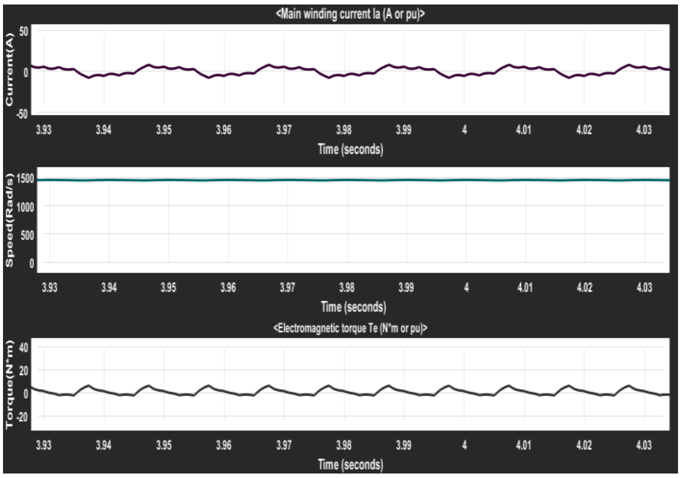


Figure 19: Performance Characteristics of Battery-Fed Capacitor-Start Induction Motor System

The first graph shows the main winding current (A) waveform, which varies periodically between approximately +8 A and −8 A. The current waveform is smooth with small ripples, indicating stable current supply from the battery-fed multilevel inverter to the motor. The second graph represents the rotor speed (rad/s) of the motor. It can be observed that the motor speed remains nearly constant at around 1490–1500 rad/s, indicating stable and efficient operation. Only minor fluctuations are present, showing good speed regulation of the motor under inverter-fed conditions. The third graph shows the electromagnetic torque (N·m) developed by the motor. The torque varies approximately between 0 N·m and 8 N·m, with small periodic oscillations due to inverter switching and load effects. However, the torque remains stable, indicating smooth motor performance. Overall, the results confirm that the battery-fed cascaded H-bridge multilevel inverter provides stable current, constant speed, and smooth torque response, ensuring efficient operation of the capacitor start induction motor system.

4.3 CAPACITOR START – INDUCTION MOTOR

The MATLAB/Simulink model of the Single-Phase Capacitor Start–Capacitor Run Induction Motor is developed to analyze the performance of the motor under single-phase AC supply conditions. In this model, the AC voltage source supplies power to the single-phase asynchronous machine (capacitor start–run motor). A constant block is connected to provide the mechanical load torque (Tm) input to the motor. This motor uses both a starting capacitor and a running capacitor, where the starting capacitor provides high starting torque and the running capacitor improves efficiency, power factor, and smooth operation during running conditions.

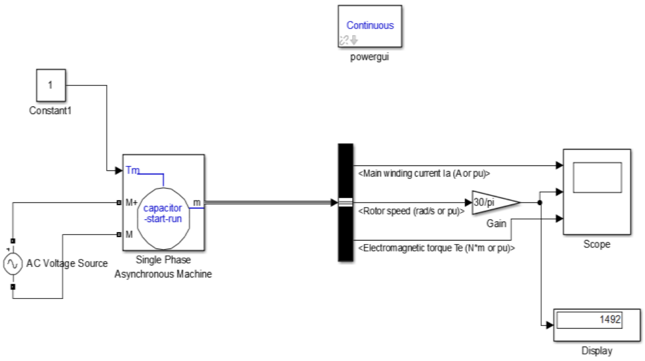


Figure 20: MATLAB/Simulink Model of Capacitor Start–Run Induction Motor

The output parameters such as main winding current, rotor speed, and electromagnetic torque are measured and connected to a scope block for graphical analysis. A gain block (30/π) is used to convert rotor speed from rad/s to RPM, and the speed is displayed using the display block, showing approximately 1492 RPM. The powergui block is used for continuous simulation of the electrical system. This model helps in studying the starting characteristics, speed response, torque performance, and running efficiency of the capacitor start–run induction motor.

The graph represents the performance characteristics of the Single-Phase Capacitor Start–Capacitor Run Induction Motor obtained from the MATLAB/Simulink model. The first graph shows the main winding current (A) waveform, which varies sinusoidally between approximately +10 A and −10 A. The smooth current waveform indicates stable motor operation with reduced fluctuations due to the presence of the running capacitor.

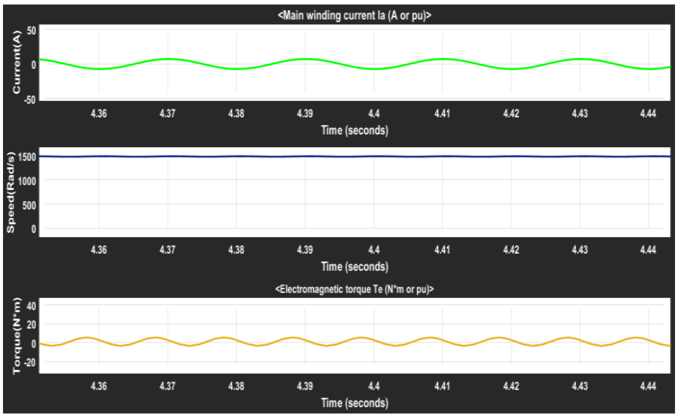


Figure 21: Performance Characteristics of Capacitor Start– Run Induction Motor

The second graph represents the rotor speed (rad/s) of the motor. It can be observed that the motor speed remains nearly constant at around 1490–1500 rad/s, indicating stable and efficient motor operation. Only very small speed variations are present, showing smooth running performance and good speed regulation. The third graph shows the electromagnetic torque (N·m) developed by the motor. The torque varies approximately between –5 N·m and +10 N·m, showing smooth periodic oscillations during operation. These torque variations are minimal due to the capacitor run arrangement, which improves motor efficiency and reduces torque ripple. Overall, the results indicate that the capacitor start–capacitor run induction motor provides stable current, constant speed, and smooth torque performance, ensuring efficient and reliable operation under single-phase supply conditions.

4.3.1 CAPACITOR START – RUN INDUCTION MOTOR FED BY CASCADED H BRIDGE ML

The MATLAB/Simulink model of the Capacitor Start–Capacitor Run Induction Motor connected with a Cascaded H-Bridge Multilevel Inverter (CHBMLI) is developed to analyze the motor performance using an inverter-fed AC supply. In this model, the cascaded H-bridge multilevel inverter converts the DC input voltage into a multilevel AC output voltage using multiple MOSFET switches, pulse generators, and logical operator blocks. The stepped output waveform produced by the inverter helps in reducing harmonic distortion and improving power quality.

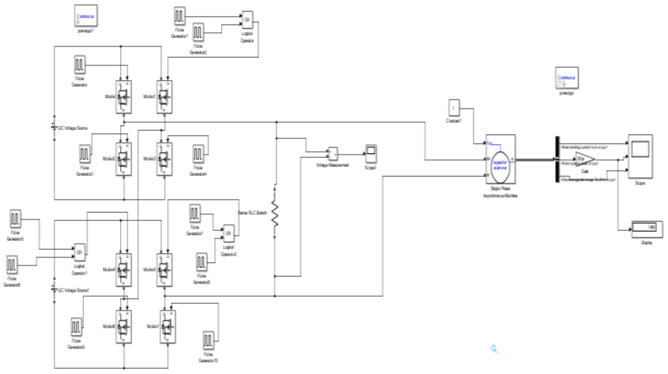


Figure 22: MATLAB/Simulink Model of Capacitor Start–Run Induction Motor Connected with Cascaded H-Bridge Multilevel Inverter

The inverter output is supplied to the single-phase capacitor start–capacitor run induction motor, which uses a starting capacitor for high starting torque and a running capacitor for smooth and efficient operation. A constant block provides the mechanical load torque (Tm) to the motor. The output parameters such as main winding current, rotor speed, and electromagnetic torque are measured and displayed using a scope block for analysis. A gain block (30/π) converts rotor speed from rad/s to RPM, and the speed is displayed, showing approximately 1492 RPM. The powergui block is used for continuous simulation. This model helps in studying the speed response, current characteristics, torque performance, and inverter-fed motor behavior under different operating conditions.

The graph represents the performance characteristics of the Capacitor Start–Capacitor Run Induction Motor connected with a Cascaded H-Bridge Multilevel Inverter (CHBMLI) obtained from the MATLAB/Simulink model. The first graph shows the main winding current (A) waveform, which varies periodically between approximately +8 A and –8 A. Small ripples are present in the current waveform due to the switching action of the multilevel inverter, but the current remains stable, indicating smooth power supply to the motor.

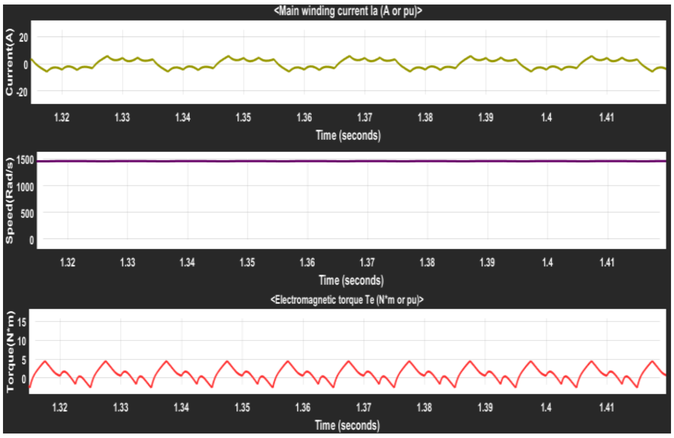


Figure 23: Performance Characteristics of Capacitor Start–Run Induction Motor Connected with Cascaded H-Bridge Multilevel Inverter

The second graph represents the rotor speed (rad/s) of the motor. It can be observed that the motor speed remains nearly constant at around 1490–1500 rad/s, indicating stable and efficient motor operation. Only very small fluctuations are observed, showing that the inverter provides smooth speed control and steady-state performance.The third graph shows the electromagnetic torque (N·m) developed by the motor. The torque varies approximately between 0 N·m and 5 N·m, with periodic oscillations due to inverter switching and load conditions. However, the torque ripple is controlled because of the multilevel stepped output voltage produced by the cascaded H-bridge inverter. Overall, the results indicate that the capacitor start–capacitor run induction motor operates efficiently with stable current, constant speed, and smooth torque characteristics when connected with the cascaded H-bridge multilevel inverter.

4.3.2 BATTERY-FED CASCADED H-BRIDGE MULTILEVEL INVERTER DRIVING CAPACITOR START – RUN INDUCTION MOTOR

The MATLAB/Simulink model of the Battery-Fed Cascaded H-Bridge Multilevel Inverter connected with a Capacitor Start–Capacitor Run Induction Motor is developed to analyze the motor performance using a battery-powered inverter supply. In this model, lithium-ion batteries are used as DC voltage sources for the cascaded H-bridge multilevel inverter (CHBMLI). The battery parameters such as State of Charge

(SOC), current, and voltage are monitored using measurement blocks and displayed through scope blocks for battery analysis. The cascaded H-bridge multilevel inverter consists of multiple MOSFET switches, pulse generators, and logical operator blocks, which generate switching pulses to convert the battery DC voltage into a multilevel AC output voltage with reduced harmonic distortion. The inverter output is supplied to the single-phase capacitor start–capacitor run induction motor, where the starting capacitor provides high starting torque and the running capacitor ensures smooth and efficient operation.

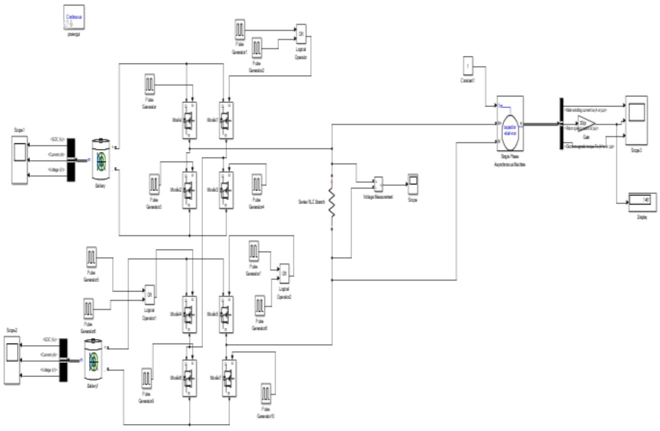


Figure 24: MATLAB/Simulink Model of Battery-Fed Cascaded H-Bridge Multilevel Inverter Connected with Capacitor Start–Run Induction Motor

The motor output parameters such as main winding current, rotor speed, and electromagnetic torque are measured and displayed through a scope block for performance analysis. A gain block (30/π) converts motor speed from rad/s to RPM, and the speed is displayed, showing approximately 1492 RPM. The powergui block is used for continuous simulation of the system. This model helps in studying the battery behavior, inverter performance, motor speed control, torque characteristics, and overall system efficiency under operating conditions.

The graph represents the performance characteristics of the Battery-Fed Cascaded H-Bridge Multilevel Inverter connected with the Capacitor Start–Capacitor Run Induction Motor obtained from the MATLAB/Simulink model. The first graph shows the main winding current (A) waveform, which varies periodically between approximately +5 A and –5 A. The current waveform is smooth with small ripples due to the inverter switching action, indicating stable current supply from the battery-fed multilevel inverter to the motor. The second graph represents the rotor speed (rad/s) of the motor. It can be observed that the motor speed remains nearly constant at around 1490–1500 rad/s, indicating stable and efficient motor operation. The speed waveform is smooth with very small fluctuations, showing good speed regulation and steady-state performance.

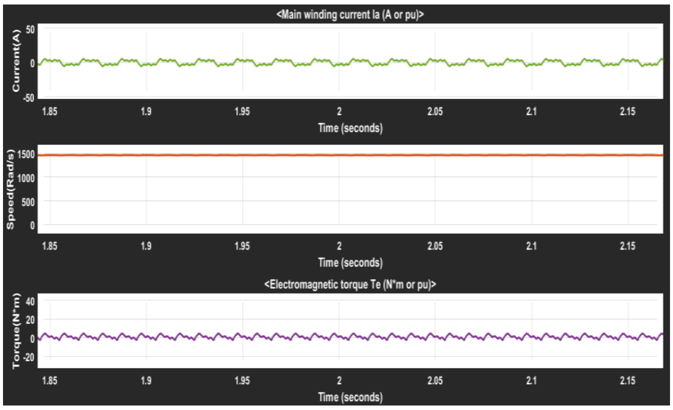


Figure 25: Performance Characteristics of Battery-Fed Capacitor Start–Run Induction Motor System

The third graph shows the electromagnetic torque (N·m) developed by the motor. The torque varies approximately between –5 N·m and +5 N·m, with small oscillations caused by inverter switching and load conditions. However, the torque ripple remains very low, indicating smooth motor operation and improved performance. Overall, the results confirm that the battery-fed cascaded H-bridge multilevel inverter provides stable current, constant speed, and smooth torque response for the capacitor start–capacitor run induction motor, ensuring efficient and reliable system performance.

5.1 TABULATION OF COMPARING SPEED THE THREE TYPES OF IM

The table represents the speed comparison of different types of single-phase induction motors based on their operating performance. From the results, the Split Phase Induction Motor achieves a speed of approximately 1488 RPM, which is slightly lower due to moderate starting torque and the absence of a running capacitor during operation.

Table 1: Comparison table for speed of all the three types of IM

S.NO	TYPES	SPEED(RPM)
1	Split Phase	1488
2	Capacitor Start	1491
3	Capacitor Start - Run	1492

The Capacitor-Start Induction Motor operates at around 1491 RPM, showing improved performance compared to the split-phase motor. This improvement is due to the presence of a starting capacitor, which provides higher starting torque and better motor acceleration.

The Capacitor Start–Run Induction Motor achieves the highest speed of approximately 1492 RPM among the three motors. This is because it uses both a starting capacitor and a running capacitor, which improve starting performance, efficiency, and smooth operation during running conditions. From the comparison, it can be concluded that the Capacitor Start–Run Induction Motor provides better speed performance and stable operation, making it more suitable for applications requiring high efficiency and smooth motor functioning.

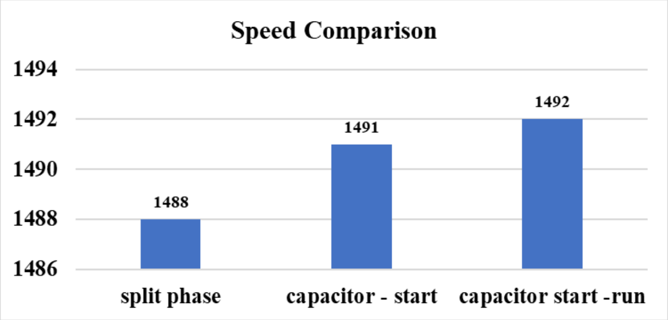


Figure 26: Speed Comparison of Different Single-Phase Induction Motors

The graph represents the speed comparison of different types of single-phase induction motors, namely Split Phase, Capacitor-Start, and Capacitor Start–Run motors. From the graph, it can be observed that the Split Phase Induction Motor has a speed of approximately 1488 RPM, which is the lowest among the three motors due to its moderate starting torque and simpler design. The Capacitor-Start Induction Motor achieves a speed of about 1491 RPM, showing slightly better performance than the split-phase motor because the starting capacitor provides higher starting torque and improved acceleration. The Capacitor Start–Run Induction Motor shows the highest speed of approximately 1492 RPM. This improved performance is due to the use of both starting and running capacitors, which enhance motor efficiency, reduce losses, and ensure smoother operation. From the comparison, it is concluded that the Capacitor Start–Run motor provides the best speed performance and stable operation among the three motor types.

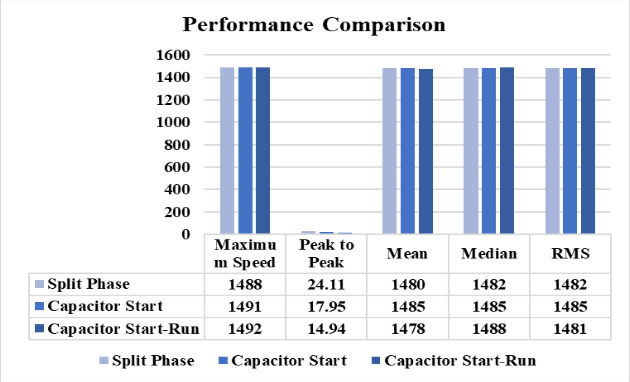


Figure 27: Performance Comparison of Different Single-Phase Induction Motors

The graph represents the performance comparison of Split Phase, Capacitor Start, and Capacitor Start–Run Induction Motors based on parameters such as Maximum Speed, Peak-to-Peak value, Mean Speed, Median Speed, and RMS Speed. From the graph, it can be observed that the Capacitor Start–Run Motor achieves the highest maximum speed of 1492 RPM, followed by the Capacitor Start Motor (1491 RPM) and the Split Phase Motor (1488 RPM). This indicates that capacitor-based motors provide improved speed performance compared to the split-phase motor.The Peak-to-Peak value, which represents speed variation, is highest for the Split Phase Motor (24.11), indicating more fluctuations during operation. The Capacitor Start Motor (17.95) shows reduced variation, while the Capacitor Start–Run Motor (14.94) has the lowest value, indicating smoother and more stable operation. In terms of Mean Speed, the Capacitor Start Motor has the highest average speed of 1485 RPM, while the Split Phase Motor and Capacitor Start–Run Motor show 1480 RPM and 1478 RPM, respectively.

The Median Speed is highest in the Capacitor Start–Run Motor (1488 RPM), followed by the Capacitor Start Motor (1485 RPM) and the Split Phase Motor (1482 RPM). Similarly, the RMS Speed, which represents effective motor performance, is highest for the Capacitor Start Motor (1485 RPM), while the Split Phase and Capacitor Start–Run motors achieve 1482 RPM and 1481 RPM, respectively. Overall, the graph shows that the Capacitor Start–Run Motor provides smoother and more stable operation, while the Capacitor Start Motor exhibits better average speed performance, making both capacitor-based motors more efficient than the split-phase motor.

5.2 TABULATION OF COMPARING SPEED OF THE THREE TYPES OF IM UNDER CHBML SUPPLY

The table represents the speed comparison of different types of induction motors when operated under the given conditions. From the results, the Split Phase Induction Motor achieves a speed of approximately 1059 RPM, which is the lowest among the three motors.

Table 2: Comparison table for speed of all the three types of IM under CHBML Supply

S.NO	TYPES	SPEED(RPM)
1	Split Phase	1059
2	Capacitor Start	1451
3	Capacitor Start - Run	1460

This lower speed is due to its moderate starting torque and the absence of capacitors during operation, resulting in comparatively lower performance. The Capacitor-Start

Induction Motor operates at around 1451 RPM, showing a significant improvement in speed performance. The presence of a starting capacitor provides higher starting torque and better acceleration, allowing the motor to reach a higher operating speed.

The Capacitor Start–Run Induction Motor achieves the highest speed of approximately 1460 RPM. This improved performance is due to the use of both a starting capacitor and a running capacitor, which enhance starting torque, improve efficiency, and ensure smooth motor operation. From the comparison, it can be concluded that the Capacitor Start–Run Motor provides the best speed performance, while the Split Phase Motor shows the lowest speed among the three motors. The graph represents the speed comparison of Split Phase, Capacitor-Start, and Capacitor Start–Run Induction Motors under the given operating conditions. From the graph, it can be observed that the Split Phase Induction Motor has the lowest speed of 1059 RPM, indicating comparatively lower performance due to the absence of capacitors for improved starting and running characteristics. The Capacitor-Start Induction Motor achieves a speed of approximately 1451 RPM, showing a significant improvement over the split-phase motor. This increase in speed is due to the starting capacitor, which provides higher starting torque and better acceleration during operation.

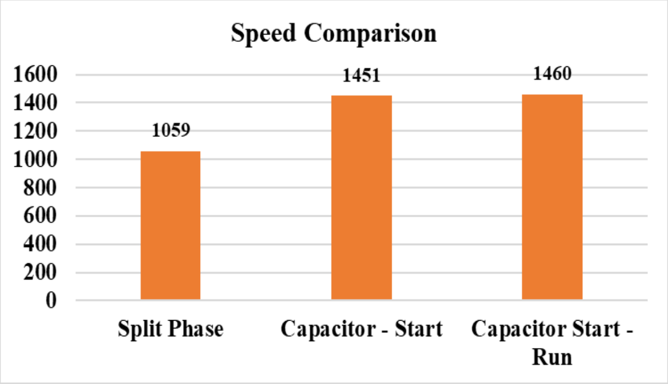
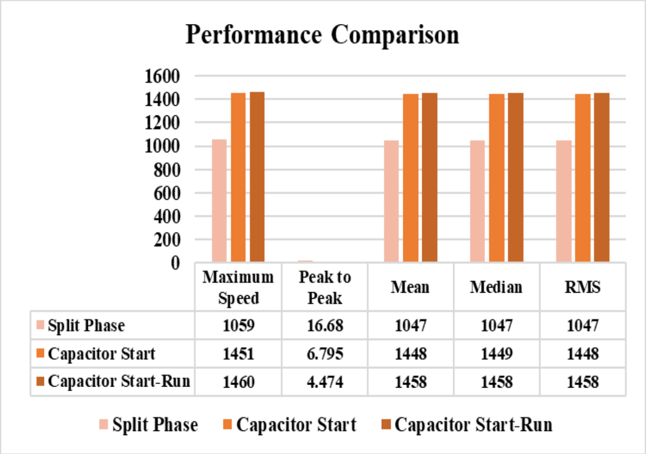


Figure 28: Speed Comparison of Different Single-Phase Induction Motors under CHBML Supply

The Capacitor Start–Run Induction Motor shows the highest speed of 1460 RPM among the three motors. This improved performance is achieved by using both a starting capacitor and a running capacitor, which enhance starting torque, improve efficiency, and provide smoother operation. From the comparison, it can be concluded that the Capacitor Start–Run Motor offers the best speed performance and stable operation, while the Split Phase Motor shows the lowest speed performance

The graph represents the performance comparison of Split Phase, Capacitor Start, and Capacitor Start–Run Induction Motors based on parameters such as Maximum Speed, Peak-to-Peak value, Mean Speed, Median Speed, and RMS Speed.



	Maximum Speed	Peak to Peak	Mean	Median	RMS
■ Split Phase	1059	16.68	1047	1047	1047
■ Capacitor Start	1451	6.795	1448	1449	1448
■ Capacitor Start-Run	1460	4.474	1458	1458	1458

Figure 29: Performance Comparison of Different Single-Phase Induction Motors under CHBML Supply

From the graph, it can be observed that the Capacitor Start–Run Motor achieves the highest maximum speed of 1460 RPM, followed by the Capacitor Start Motor (1451 RPM), while the Split Phase Motor has the lowest speed of 1059 RPM. This indicates that capacitor-based motors provide better speed performance and efficiency.The Peak-to-Peak value, which represents speed fluctuation, is highest in the Split Phase Motor (16.68), indicating more variation and unstable operation. The Capacitor Start Motor (6.795) shows lower fluctuations, while the Capacitor Start–Run Motor (4.474) has the lowest speed variation, indicating smoother and more stable performance.

The Mean, Median, and RMS Speed values are also highest for the Capacitor Start–Run Motor (1458 RPM), followed by the Capacitor Start Motor (1448–1449 RPM) and the Split Phase Motor (1047 RPM). These values show that the capacitor start–run motor maintains better speed consistency and effective performance during operation. Overall, the graph confirms that the Capacitor Start–Run Motor provides the best performance with higher speed, lower fluctuation, and smoother operation, whereas the Split Phase Motor shows the lowest efficiency and performance among the three motors.

5.3 TABULAITON OF COMPARING SPEED OF THE THREE TYPES OF INDUCTION MOTOR(BATTERY FED CHBMLI

The table represents the speed comparison of Split Phase, Capacitor-Start, and Capacitor Start–Run Induction Motors under the given operating conditions. From the results, the Split Phase Induction Motor achieves a speed of approximately 1056 RPM, which is the lowest among the three motors. This lower speed is due to the absence of capacitors, resulting in lower starting torque and comparatively reduced motor performance.

Table 3: Comparison table for speed of all the three types of IM (Battery Fed CHBMLI)

S.NO	TYPES	SPEED(RPM)
1	Split Phase	1056
2	Capacitor Start	1453
3	Capacitor Start-Run	1461

The Capacitor-Start Induction Motor operates at around 1453 RPM, showing a significant improvement in speed compared to the split-phase motor. The presence of a starting capacitor provides higher starting torque and better acceleration, allowing the motor to achieve improved operating performance.
The Capacitor Start–Run Induction Motor achieves the highest speed of approximately 1461 RPM among all three motors. This improved performance is due to the use of both a starting capacitor and a running capacitor, which enhance motor efficiency, improve torque characteristics, and ensure smoother operation. From the comparison, it is concluded that the Capacitor Start–Run Motor provides the best speed performance and stable operation, while the Split Phase Motor shows the lowest speed performance among the three motors.

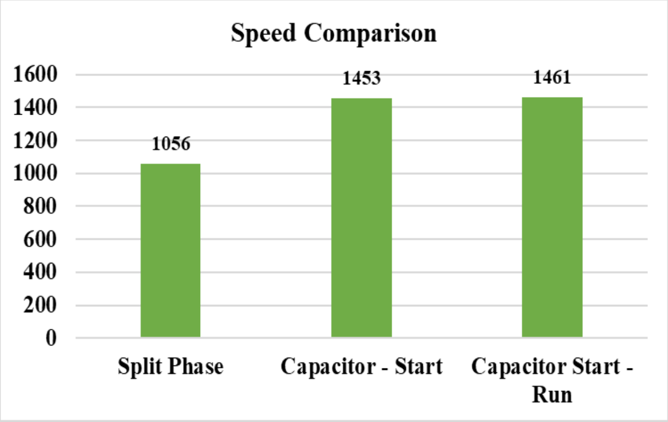


Figure 30: Speed Comparison of Different Single-Phase Induction Motors (Battery Fed CHBMLI)

The graph represents the speed comparison of Split Phase, Capacitor-Start, and Capacitor Start–Run Induction Motors under the given operating conditions. From the graph, it can be observed that the Split Phase Induction Motor has the lowest speed of 1056 RPM, indicating lower performance due to the absence of capacitors, which results in reduced starting torque and lower operating efficiency.

The Capacitor-Start Induction Motor achieves a speed of approximately 1453 RPM, showing a considerable improvement over the split-phase motor. This enhanced performance is due to the starting capacitor, which provides higher starting torque and better acceleration during operation.

The Capacitor Start–Run Induction Motor shows the highest speed of 1461 RPM among the three motors. This improved speed is achieved through the use of both a starting capacitor and a running capacitor, which enhance efficiency, reduce losses, and provide smoother motor operation. From the comparison, it can be concluded that the Capacitor Start–Run Motor provides the best speed performance and stable operation, while the Split Phase Motor exhibits the lowest speed performance.

The graph represents the performance comparison of Split Phase, Capacitor Start, and Capacitor Start–Run Induction Motors based on parameters such as Maximum Speed, Peak-to-Peak value, Mean Speed, Median Speed, and RMS Speed.

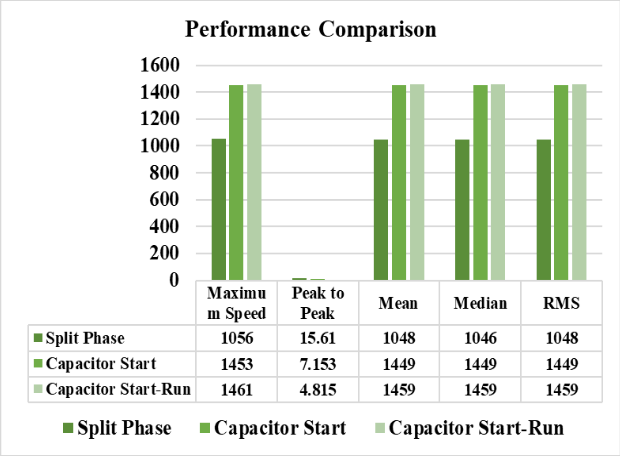


Figure 31: Performance Comparison of Different Single-Phase Induction Motors (Battery Fed CHBMLI)

From the graph, it can be observed that the Capacitor Start–Run Motor achieves the highest maximum speed of 1461 RPM, followed by the Capacitor Start Motor (1453 RPM), while the Split Phase Motor has the lowest speed of 1056 RPM. This indicates that capacitor-assisted motors provide better speed performance and efficiency.The Peak-to-Peak value, which represents speed variation, is highest for the Split Phase Motor (15.61), indicating greater fluctuations and less stable operation. The Capacitor Start Motor (7.153) shows lower speed variation, while the Capacitor Start–Run Motor (4.815) has the lowest fluctuation, indicating smoother and more stable motor performance.The Mean Speed values show that the Capacitor Start–Run Motor has the highest average speed of 1459 RPM, followed by the Capacitor Start Motor (1449 RPM) and the Split Phase Motor (1048 RPM). Similarly, the Median Speed values are 1459 RPM for Capacitor Start–Run, 1449 RPM for Capacitor Start, and 1046 RPM for Split Phase, indicating consistent motor operation. The RMS Speed, which represents effective speed performance, is also highest for the Capacitor Start–Run

Motor (1459 RPM), followed by the Capacitor Start Motor (1449 RPM) and the Split Phase Motor (1048 RPM). Overall, the graph confirms that the Capacitor Start–Run Motor provides the best performance with higher speed, lower fluctuation, and smoother operation, while the Split Phase Motor exhibits the lowest performance among the three motors.

6. CONCLUSION

In this project, a comparative analysis of Single-Phase Induction Motors, namely Split Phase, Capacitor-Start, and Capacitor Start–Capacitor Run induction motors, has been carried out using MATLAB/Simulink. The performance of these motors was analyzed under different operating conditions by observing important parameters such as main winding current, rotor speed, and electromagnetic torque. The study also included the implementation of a Cascaded H-Bridge Multilevel Inverter (CHBMLI) and a battery-fed system using a Lithium-Ion Battery to improve motor performance and power quality.

From the simulation results, it was observed that the Split Phase Motor showed lower speed and higher fluctuations compared to the other motors. The Capacitor-Start Motor provided better starting performance and improved speed characteristics due to the use of a starting capacitor. Among all the motors, the Capacitor Start–Capacitor Run Motor exhibited the best performance, with higher speed, lower peak-to-peak variation, smoother torque characteristics, and stable operation.

The integration of the Cascaded H-Bridge Multilevel Inverter reduced harmonic distortion and provided a smoother AC output waveform, resulting in improved motor efficiency and performance. The battery-fed inverter system also demonstrated stable motor operation and suitability for modern energy storage applications. Therefore, it is concluded that the Capacitor Start–Capacitor Run Induction Motor fed through a Battery-Fed Cascaded H-Bridge Multilevel Inverter provides superior performance and is more suitable for efficient motor drive applications, renewable energy systems, and electric vehicle technologies.

REFERENCES

[1] M. Malinowski and K. Gopal Kumar, “Cascaded H-Bridge Multilevel Inverter for Electric Vehicles: Configuration and Performance Investigation,” IEEE/Journal, Year.

[2] B. P. McGrath and D. G. Holmes, “Three-Phase Five-Level Cascaded H-Bridge Inverter Fed Induction Motor for Renewable Applications,” IEEE/Journal, Year.

[3] Z. Ul Islam and T. F. Karim, “Cascaded H-Bridge Multilevel Inverter for Electric Vehicles: Configuration and Performance Investigation,” International Journal/ResearchGate, 2025.

[4] A. Poorfakhraei, M. Narimani, and A. Emadi, “Multilevel Inverters for Electric Vehicle Applications: Current Status and Future Trends,” IEEE Open Journal of Power Electronics, vol. 2, pp. 155–170, 2021.

[5] F. Roemer et al., “Optimal Design of Cascaded H-Bridge Inverter for Electric Vehicles,” IEEE Conference, 2019.

[6] S. Vijayalakshmi, “Inductor-Less Cascaded H-Bridge Multilevel Inverter for EV Applications,” International Journal of Engineering Research, 2021.

[7] K. T. Maheswari, “Reduced Switch Cascaded H-Bridge Multilevel Inverter Topology,” Journal of Power Electronics, 2021.

[8] S. R. Hameed, “Control Techniques for Cascaded H-Bridge Multilevel Inverters,” International Journal, 2024.

[9] A. K. Maheshwari, M. A. Mahar, A. S. Larik, and A. H. Soomro, “Analysis of Multicarrier PWM Techniques for Multilevel Inverters,” European Journal of Electrical Engineering, vol. 23, 2021.

[10] K. Bano et al., “Performance Analysis of POD and APOD PWM Techniques in Multilevel Inverters,” Mathematics Journal, vol. 12, 2024.

[11] N. M. El-Naggar, M. A. Esmaeel, and S. Ali, “Comparison of Modular Multilevel Converter and Cascaded H-Bridge Inverter,” International Journal of Electrical and Computer Engineering, vol. 13, 2023.

[12] I. Ahamad et al., “Solar Powered Cascaded H-Bridge Multilevel Inverter for Renewable Applications,” Microsystem Technologies, 2024.

[13] B. Jyothi et al., “Multiphase Cascaded H-Bridge Inverter for Induction Motor Drive,” Scientific Reports, 2024.

[14] T. Bhaumik, S. Bhaumik, S. Paul, and S. Mitra, “Comparative Study of Multilevel Inverter Topologies,” IRJET, vol. 9, 2022.