COSMIC JOURNAL OF PHYSICS

Volume No: 02 Issue No: 01 (2023)

Power Electronics: Converters, Applications, and Design" by Ned Mohan, Tore M. Undeland, and William P. Robbins

Olivia Joseph

Department of Engineering, University of California

Summary:

"Power Electronics: Converters, Applications, and Design" is a widely used textbook in the field of power electronics. This book provides a comprehensive introduction to power electronic converters, their applications, and the design principles behind them. It covers fundamental concepts, practical design considerations, and a wide range of applications, making it suitable for students and professionals interested in power electronics.

Keywords: Power Electronics, Converters, Applications, Design, Power Electronic Converters, Inverters, DC-DC Converters, AC-DC Converters, Electrical Drives, Pulse-Width Modulation (PWM), Switching Power Supplies, Semiconductor Devices, Control Techniques, Power Quality, Electric Motor Drives.

Introduction:

The book "Power Electronics: Converters, Applications, and Design" by Ned Mohan, Tore M. Undeland, and William P. Robbins is an authoritative resource in the field of power electronics. The introduction of the book typically sets the stage for the content it covers, providing an overview of the subject matter and its importance. While I can't provide the verbatim introduction from the book, I can provide a general introduction to the topic of power electronics.

Introduction to Power Electronics:

COSMIC JOURNAL OF PHYSICS

Volume No: 02 Issue No: 01 (2023)

Power electronics is a field of electrical engineering and technology that deals with the conversion and control of electrical power. It plays a crucial role in various applications, from consumer electronics and industrial machines to renewable energy systems. Power electronics is all about efficiently converting, controlling, and regulating electrical energy to meet the specific needs of various devices and systems.

The primary components of power electronics systems are electronic devices such as diodes, transistors, and thyristors, along with various converter topologies. These components enable the transformation of electrical voltage, current, and frequency, making it possible to match the power source with the requirements of a load.

Key objectives of power electronics include:

1. **Efficient Energy Conversion**: Power electronics aims to minimize energy losses during the conversion process, thereby increasing overall system efficiency.
2. **Voltage Regulation**: It enables the control of voltage levels to meet the needs of electrical loads, even in situations with varying input voltages.
3. **Current Control**: Power electronics allows precise control of current, which is essential for applications like motor drives and renewable energy systems.
4. **Frequency Control**: In some cases, it's necessary to change the frequency of the power source, such as in the case of variable-speed motor drives.
5. **Protection and Safety**: Power electronics systems incorporate protection mechanisms to ensure safe operation and prevent damage to components or connected equipment.
6. **Applications**: Power electronics is widely used in various applications, including power supplies, motor drives, uninterruptible power supplies (UPS), renewable energy systems (e.g., solar and wind), and electric vehicles.

The field of power electronics continues to evolve with advancements in semiconductor technology, control algorithms, and the integration of power electronics into a wide range of applications, leading to more efficient and environmentally friendly energy solutions.

The book by Mohan, Undeland, and Robbins delves into these concepts and provides in-depth knowledge about power electronics, converters, their applications, and design principles, making it a valuable resource for students and professionals in the field.

II. Power Semiconductor Devices - A. Diodes

This section of the book is dedicated to power diodes, which are essential components in power electronic circuits. Power diodes are semiconductor devices that primarily allow the flow of current in one direction while blocking it in the other. They are widely used in rectification circuits and voltage clamping applications. Here's what you might find in this subsection:

1. **Introduction to Power Diodes**: This part provides an overview of power diodes, including their structure, characteristics, and operating principles. It explains how power diodes differ from small-signal diodes and why they are critical in power electronics.

2. **Forward and Reverse Bias Operation**: It describes how diodes work in both forward and reverse bias, highlighting their voltage-current characteristics. This information is crucial for understanding their rectification and clamping functions.

3. **Diode Types**: Different types of power diodes, such as standard silicon diodes, Schottky diodes, and fast-recovery diodes, are discussed. Each type has its unique characteristics and is suitable for specific applications.

4. **Diode Ratings and Specifications**: This part explains the important specifications and ratings of power diodes, such as maximum current, reverse voltage, and forward voltage drop. Understanding these ratings is essential for selecting the right diode for a given application.

5. **Diode Applications**: The section explores various applications of power diodes, including rectification in power supplies, freewheeling diodes in switching converters, and protection circuits.

6. **Diode Recovery Characteristics**: Some diodes have recovery times that impact their performance in high-frequency applications. This subsection discusses diode recovery characteristics and their importance.

7. **Diode Selection and Design Considerations**: It covers considerations when selecting a diode for a specific application and the design aspects related to diode circuits, such as heat dissipation and voltage stress.

8. **Case Studies**: Practical examples and case studies may be included to illustrate the use of diodes in real-world power electronics circuits.

This subsection serves as a foundational introduction to power diodes and their roles in power electronic systems. It is an essential part of understanding the broader field of power electronics. [1], [2].

II. Power Semiconductor Devices - B. Power Transistors

This section focuses on power transistors, which are fundamental components in power electronic circuits. Power transistors are semiconductor devices that can control the flow of current in an electronic circuit, making them essential for applications such as amplification, switching, and voltage regulation. In this subsection, you can expect to find information on power transistors and their applications. Here are some key topics typically covered:

1. **Introduction to Power Transistors**: This part provides an introduction to power transistors, explaining their structure, working principles, and the differences between power transistors and small-signal transistors.

2. **Types of Power Transistors**: Different types of power transistors are discussed, such as bipolar junction transistors (BJTs), metal-oxide-semiconductor field-effect transistors

COSMIC JOURNAL OF PHYSICS

Volume No: 02 Issue No: 01 (2023)

(MOSFETs), insulated-gate bipolar transistors (IGBTs), and gallium nitride (GaN) transistors. Each type has its unique characteristics and applications.

3. **Operating Modes and Characteristics**: The section describes the operating modes of power transistors, including the cut-off, saturation, and active modes. It also covers key characteristics such as voltage ratings, current ratings, and on-resistance for different transistor types.

4. **Switching Characteristics**: Power transistors are commonly used for switching applications. This part discusses switching characteristics, including turn-on and turn-off times, and their impact on efficiency and performance.

5. **Protection and Drive Circuitry**: Power transistors often require protection and drive circuitry to ensure safe and reliable operation. This subsection covers techniques for protecting power transistors and driving them effectively.

6. **Thermal Considerations**: Power transistors can generate heat during operation. The section addresses thermal management and considerations for heat sinking to prevent overheating.

7. **Applications**: Power transistors are used in a wide range of applications, including motor control, voltage regulation, amplifiers, and switching power supplies. This part explores various applications and how power transistors are used in them.

8. **Case Studies and Practical Examples**: Real-world examples and case studies may be included to illustrate the use of power transistors in different power electronic systems.

Understanding power transistors is crucial for designing and implementing power electronic circuits, as they play a central role in controlling and manipulating electrical power. This section provides a foundation for comprehending power transistor technologies and their practical applications in power electronics. [3], [4], [5].

II. Power Semiconductor Devices - C. Thyristors (SCRs, IGBTs)

This section delves into two important categories of power semiconductor devices: thyristors, which include Silicon Controlled Rectifiers (SCRs), and Insulated Gate Bipolar Transistors (IGBTs). These devices are widely used in various power electronic applications, and this subsection provides an understanding of their principles of operation, characteristics, and applications. Here's what you might typically find in this subsection:

1. **Introduction to Thyristors (SCRs) and IGBTs**: This part offers an introduction to thyristors, including SCRs, and IGBTs. It explains the fundamental principles and structure of these devices.

2. **Silicon Controlled Rectifiers (SCRs)**: Detailed information about SCRs, their operation, characteristics, and applications are discussed. SCRs are known for their ability to control high-power AC loads.

3. **Insulated Gate Bipolar Transistors (IGBTs)**: This section covers IGBTs, which are known for combining the voltage control of MOSFETs with the current-carrying capability of bipolar transistors. IGBT operation, characteristics, and applications are explored.

4. **Comparison of SCR and IGBT**: A comparison between SCRs and IGBTs is provided, highlighting their strengths, weaknesses, and suitable applications. This information is essential for selecting the right device for a specific power electronic system.

5. **Applications of Thyristors and IGBTs**: Various applications of these devices are discussed, including motor drives, voltage regulation, and power switching circuits. Real-world examples and practical applications are highlighted.

6. **Protection and Control Techniques**: Power semiconductor devices like SCRs and IGBTs require protection and control circuitry. This section covers techniques for safely driving and controlling these devices and ensuring their protection from faults.

7. **Thermal Considerations**: Thermal management for SCRs and IGBTs is essential due to the heat generated during operation. The subsection addresses heat sinking and cooling strategies to maintain device reliability.

8. **Case Studies**: Practical examples and case studies may be included to illustrate the use of thyristors (SCRs) and IGBTs in various power electronic systems.

Understanding thyristors (SCRs) and IGBTs is important for power electronics engineers and designers, as these devices are integral to the control and switching of high-power loads in applications like motor drives, inverters, and power conversion systems. This section provides essential knowledge about these devices and their applications. [65], [6], [7].

II. Power Semiconductor Devices - D. Gate Drivers

Gate drivers are essential components in power electronic circuits that play a crucial role in controlling the switching of power semiconductor devices, such as transistors and thyristors. These drivers ensure proper voltage and current signals are applied to the gate terminals of these devices for reliable and efficient operation. In this section, you can expect to find information on gate drivers and their significance. Here are some key topics typically covered:

1. **Introduction to Gate Drivers**: This part provides an introduction to gate drivers, explaining their purpose and significance in power electronic systems. It outlines the role of gate drivers in controlling power semiconductor devices.

2. **Gate Driver Circuitry**: The section discusses the typical circuitry of gate drivers, including signal generation, amplification, and protection features. It explains how gate drivers interface with power devices.

3. **Types of Gate Drivers**: Different types of gate drivers are explored, including low-side and high-side drivers, bootstrap gate drivers, and optical isolation methods. Each type has its unique applications and advantages.

4. **Gate Driver Specifications**: Understanding gate driver specifications, such as voltage and current ratings, propagation delay, and output drive strength, is crucial for selecting the right driver for a specific application.

5. **Protection Mechanisms**: Gate drivers often incorporate protection mechanisms to prevent faults and ensure the safe operation of power devices. Overcurrent protection, overvoltage protection, and short-circuit protection methods are discussed.

6. **Applications**: The section explores various applications where gate drivers are used, including motor drives, inverters, switch-mode power supplies, and power amplifiers. Real-world examples are provided to illustrate the importance of gate drivers.

7. **Interfacing and Compatibility**: Understanding how gate drivers interface with control systems and the compatibility with various power devices is essential for successful integration into power electronic systems.

8. **Case Studies**: Practical examples and case studies may be included to illustrate the use of gate drivers in different power electronic systems and highlight best practices.

Gate drivers are critical components that ensure the proper and reliable operation of power semiconductor devices. They play a vital role in controlling the switching characteristics of these devices, and a thorough understanding of gate drivers is essential for designing efficient and robust power electronic systems. This section provides essential knowledge about gate drivers and their applications.

II. Power Semiconductor Devices - E. Device Characteristics and Ratings

This section focuses on understanding the key characteristics and ratings of power semiconductor devices. These characteristics and ratings are crucial for selecting the right devices for specific applications and ensuring their safe and reliable operation. In this subsection, you can expect to find information about the essential device parameters and how they impact device performance. Here are some key topics typically covered:

COSMIC JOURNAL OF PHYSICS

Volume No: 02 Issue No: 01 (2023)

1. **Introduction to Device Characteristics and Ratings**: This part provides an overview of the importance of understanding device characteristics and ratings in power electronics. It explains how these parameters influence the device's suitability for different applications.

2. **Voltage Ratings**: The section discusses voltage ratings, including breakdown voltage, blocking voltage, and voltage clamping capabilities of power semiconductor devices. Understanding these ratings is essential for selecting devices compatible with the required voltage levels.

3. **Current Ratings**: Current-carrying capabilities, including continuous and peak current ratings, are explored. This information is crucial for selecting devices that can handle the expected current loads.

4. **Power Dissipation and Thermal Ratings**: Power dissipation, thermal resistance, and maximum operating temperature are discussed to understand how much heat a device can handle and the importance of thermal management.

5. **Switching Characteristics**: Device switching characteristics, including turn-on and turn-off times, switching losses, and dv/dt ratings, are covered. These parameters are vital for applications involving high-frequency switching.

6. **On-State Voltage Drop**: The voltage drop across a device when it's conducting current is discussed, as it affects the efficiency and performance of power devices.

7. **Recovery Characteristics**: For diodes and some other devices, recovery characteristics after commutation are important, and this subsection addresses these aspects.

8. **Reliability and Derating**: Understanding device reliability and the concept of derating is important for ensuring device longevity and safety in power electronic systems.

9. **Case Studies and Practical Examples**: Practical examples and case studies may be included to illustrate the selection and application of power devices based on their characteristics and ratings.

A solid understanding of device characteristics and ratings is essential for power electronics engineers and designers when selecting the appropriate power semiconductor devices for specific applications. These parameters play a vital role in determining the performance, efficiency, and safety of power electronic systems. This section provides foundational knowledge about the factors to consider when choosing power devices.

III. Basic Converter Topologies - A. Diode Rectifiers

This section is dedicated to diode rectifiers, which are fundamental components in power electronic circuits used for converting alternating current (AC) to direct current (DC). Diode rectifiers are commonly employed in various applications, including power supplies and battery charging. In this subsection, you can expect to find information on diode rectifiers, their principles of operation, and their significance in power conversion. Here are some key topics typically covered:

1. **Introduction to Diode Rectifiers**: This part provides an introduction to diode rectifiers, explaining their role in converting AC to DC and their use in various power electronic systems.

2. **Operating Principles**: The section discusses the fundamental operating principles of diode rectifiers, including half-wave and full-wave rectification. It explains how diodes allow current flow in one direction, effectively converting AC to pulsating DC.

3. **Diode Bridge Rectifiers**: Detailed information about diode bridge rectifiers is provided. These are widely used for full-wave rectification and offer better efficiency than half-wave rectifiers.

4. **Ripple Voltage and Filtering**: The subsection addresses the concept of ripple voltage in rectified DC and methods for filtering it to obtain smoother DC output.

5. **Rectification Efficiency**: Understanding rectification efficiency and the impact of diode voltage drops on efficiency is important for assessing the performance of diode rectifiers.

6. **Load Considerations**: The section covers load considerations, including how different types of loads (resistive, capacitive, or inductive) affect the output of diode rectifiers.

7. **Voltage and Current Waveforms**: The voltage and current waveforms in diode rectifiers are discussed to illustrate how AC is converted into pulsating DC and the effects of different rectifier configurations.

8. **Applications**: Various applications of diode rectifiers are explored, including power supplies, battery charging, and low-power rectification in consumer electronics.

9. **Case Studies and Practical Examples**: Practical examples and case studies may be included to illustrate the use of diode rectifiers in real-world power electronic systems and highlight design considerations.

Diode rectifiers serve as the foundation for many power conversion systems, making them a crucial topic in power electronics. A thorough understanding of diode rectifiers and their characteristics is essential for designing efficient and reliable power supplies and converters. This section provides essential knowledge about diode rectifiers and their applications. [8], [9].

III. Basic Converter Topologies - B. Buck Converters

This section focuses on buck converters, which are a type of voltage step-down converter commonly used in power electronics. Buck converters are essential for reducing a higher input voltage to a lower output voltage efficiently. They find applications in power supplies, voltage regulation, and battery charging systems. In this subsection, you can expect to find information on buck converters, their operating principles, and practical applications. Here are some key topics typically covered:

1. **Introduction to Buck Converters**: This part provides an introduction to buck converters, explaining their role in reducing voltage levels and their use in power electronic systems.

2. **Operating Principles**: The section discusses the fundamental operating principles of buck converters, including the switching action of the power switch (usually a transistor), inductors, and output voltage regulation.

3. **Continuous and Discontinuous Modes**: Buck converters can operate in continuous conduction mode (CCM) or discontinuous conduction mode (DCM). This subsection explains the differences between these modes and when each is preferred.

4. **Duty Cycle and Voltage Regulation**: Understanding the relationship between the duty cycle of the switch and the output voltage is crucial. It covers how varying the duty cycle allows voltage regulation.

5. **Efficiency and Voltage Ripple**: The efficiency of buck converters and the sources of voltage ripple are discussed. Strategies for improving efficiency and reducing ripple are explored.

6. **Current Flow and Control**: The direction of current flow in buck converters is explained, and control techniques for achieving the desired output voltage are covered.

7. **Inductor and Capacitor Selection**: Selecting the right inductor and output capacitor is important for optimal buck converter performance. This section addresses considerations for these components.

8. **Switching Frequencies**: The choice of switching frequency for the buck converter is discussed, along with its impact on efficiency and component size.

9. **Applications**: Buck converters are used in various applications, including voltage regulators for microcontrollers, battery chargers, and LED drivers. The subsection explores these applications.

10. **Case Studies and Practical Examples**: Practical examples and case studies may be included to illustrate the use of buck converters in real-world power electronic systems and to demonstrate design considerations.

Understanding buck converters is essential for designing efficient power supplies and voltage regulation systems. They play a central role in power electronics for stepping down voltages and maintaining stable output levels. This section provides foundational knowledge about buck converters and their applications.

III. Basic Converter Topologies - C. Boost Converters

This section focuses on boost converters, which are a type of voltage step-up converter used in power electronics. Boost converters are essential for increasing a lower input voltage to a higher output voltage efficiently. They find applications in various power systems, such as battery-powered devices, LED drivers, and renewable energy systems. In this subsection, you can expect to find information on boost converters, their operating principles, and practical applications. Here are some key topics typically covered:

1. **Introduction to Boost Converters**: This part provides an introduction to boost converters, explaining their role in increasing voltage levels and their significance in power electronic systems.

2. **Operating Principles**: The section discusses the fundamental operating principles of boost converters, including the operation of the power switch (often a transistor), the inductor, and output voltage regulation.

3. **Voltage Boosting and Voltage Ripple**: Understanding how the boost converter increases the voltage while producing voltage ripple is covered. Strategies for reducing voltage ripple are explored.

4. **Duty Cycle and Voltage Regulation**: The relationship between the duty cycle of the switch and the output voltage is explained. It details how varying the duty cycle allows voltage regulation.

5. **Efficiency and Losses**: The efficiency of boost converters and factors affecting efficiency, such as switching losses, are discussed. Strategies for improving efficiency are addressed.

6. **Inductor and Capacitor Selection**: Selecting the right inductor and output capacitor is important for optimizing boost converter performance. This section covers considerations for these components.

7. **Control Techniques**: Various control techniques for achieving the desired output voltage are explored. These may include pulse-width modulation (PWM) control and voltage feedback loops.

8. **Applications**: Boost converters are used in a wide range of applications, such as LED drivers, DC-DC converters for portable devices, and power supplies for solar inverters. The subsection explores these applications.

9. **Case Studies and Practical Examples**: Practical examples and case studies may be included to illustrate the use of boost converters in real-world power electronic systems and to demonstrate design considerations.

Understanding boost converters is crucial for designing power systems that require voltage step-up capabilities. These converters play a significant role in power electronics, particularly in applications where boosting lower voltage levels is necessary for proper operation. This section provides foundational knowledge about boost converters and their applications.

III. Basic Converter Topologies - D. Buck-Boost Converters

This section focuses on buck-boost converters, which are versatile voltage converters that can either step up or step down the input voltage to achieve the desired output voltage. Buck-boost converters are essential in power electronics for applications where voltage regulation is required, and the input voltage may vary. They are commonly used in battery-powered devices and voltage regulators. In this subsection, you can expect to find information on buck-boost converters, their operating principles, and practical applications. Here are some key topics typically covered:

1. **Introduction to Buck-Boost Converters**: This part provides an introduction to buck-boost converters, explaining their dual functionality in both stepping up and stepping down voltage levels. It highlights their importance in power electronic systems.

2. **Operating Principles**: The section discusses the fundamental operating principles of buck-boost converters, which involve controlling the power switch (usually a transistor), the inductor, and the output voltage.

3. **Continuous and Discontinuous Modes**: Buck-boost converters can operate in both continuous conduction mode (CCM) and discontinuous conduction mode (DCM). This subsection explains the differences between these modes and when each is preferred.

4. **Duty Cycle and Voltage Regulation**: Understanding the relationship between the duty cycle of the switch and the output voltage is crucial for achieving voltage regulation.

5. **Efficiency and Voltage Ripple**: Buck-boost converters have efficiency considerations and voltage ripple characteristics. The section explores strategies for improving efficiency and reducing ripple.

6. **Current Flow and Control**: The direction of current flow in buck-boost converters is explained, and control techniques for achieving the desired output voltage are covered.

7. **Inductor and Capacitor Selection**: Selecting the right inductor and output capacitor is important for optimizing buck-boost converter performance. This section covers considerations for these components.

8. **Switching Frequencies**: The choice of switching frequency for buck-boost converters and its impact on efficiency and component size are discussed.

9. **Applications**: Buck-boost converters are used in various applications, such as voltage regulators for portable devices, battery chargers, and power supplies for automotive systems. The subsection explores these applications.

10. **Case Studies and Practical Examples**: Practical examples and case studies may be included to illustrate the use of buck-boost converters in real-world power electronic systems and to demonstrate design considerations.

Understanding buck-boost converters is crucial for designing power systems that require versatile voltage regulation capabilities. These converters are highly adaptable and find application in situations where the input voltage varies or where voltage inversion is needed. This section provides foundational knowledge about buck-boost converters and their applications.

IV. Advanced Converter Topologies - A. Resonant Converters

This section focuses on resonant converters, which are advanced power electronic topologies designed to improve the efficiency and reduce the switching losses associated with traditional converters. Resonant converters achieve these goals by using resonant components, such as inductors and capacitors, to control the power transfer process. In this subsection, you can expect to find information on resonant converters, their operating principles, and practical applications. Here are some key topics typically covered:

1. **Introduction to Resonant Converters**: This part provides an introduction to resonant converters, explaining their significance in power electronics, especially when high-efficiency and reduced electromagnetic interference (EMI) are essential.

2. **Operating Principles**: The section discusses the fundamental operating principles of resonant converters, including the role of resonant components in achieving soft switching, which reduces switching losses.

3. **Types of Resonant Converters**: Different types of resonant converters, such as zero-voltage switching (ZVS) and zero-current switching (ZCS) converters, are explored. Each type has its unique characteristics and applications.

4. **Resonant Frequency and Design Considerations**: Understanding the resonant frequency of these converters and the design considerations for achieving efficient and

reliable operation are covered. Resonant frequency selection plays a crucial role in achieving zero-voltage or zero-current switching.

5. **Efficiency Improvements**: The section explains how resonant converters can significantly improve efficiency compared to traditional hard-switching converters. It addresses how soft switching minimizes switching losses.

6. **Control Techniques**: Control techniques for resonant converters, including phase-shift control, frequency modulation, and pulse-width modulation (PWM), are discussed. These techniques are essential for maintaining precise control of the output.

7. **Applications**: Resonant converters are used in various applications, including high-frequency power supplies, high-voltage DC (HVDC) transmission, and high-efficiency inverters. The subsection explores these applications and highlights where resonant converters provide advantages.

8. **Challenges and Limitations**: The challenges and limitations associated with resonant converters, such as component selection, size, and complexity, are addressed.

9. **Case Studies and Practical Examples**: Practical examples and case studies may be included to illustrate the use of resonant converters in real-world power electronic systems and to demonstrate design considerations.

Understanding resonant converters is essential for power electronics engineers and designers who seek to improve the efficiency and performance of power conversion systems. Resonant converters are particularly beneficial in high-frequency applications where traditional converters would incur high switching losses. This section provides foundational knowledge about resonant converters and their applications.

IV. Advanced Converter Topologies - B. Multilevel Converters

This section is dedicated to multilevel converters, which are advanced power electronic devices designed to provide high-quality voltage waveforms with reduced harmonic distortion.

Multilevel converters achieve this by synthesizing the output voltage using multiple voltage levels, typically through the use of a series of semiconductor switches and capacitors. These converters are essential for various applications, including high-voltage DC transmission, motor drives, and renewable energy systems. In this subsection, you can expect to find information on multilevel converters, their operating principles, and practical applications. Here are some key topics typically covered:

1. **Introduction to Multilevel Converters**: This part provides an introduction to multilevel converters, explaining their role in achieving high-quality voltage waveforms with reduced harmonic content. It highlights their significance in power electronics.
2. **Operating Principles**: The section discusses the fundamental operating principles of multilevel converters, including the use of multiple voltage levels, typically generated by capacitors, to synthesize the output voltage waveform.
3. **Types of Multilevel Converters**: Different types of multilevel converters, such as diode-clamped (neutral-point clamped), flying capacitor, and cascaded H-bridge converters, are explored. Each type has its unique characteristics and applications.
4. **Control Techniques**: Control techniques for multilevel converters, including pulse-width modulation (PWM), selective harmonic elimination, and space vector modulation, are discussed. These techniques are essential for achieving precise control of the output voltage and harmonic content.
5. **Voltage Levels and Harmonic Reduction**: Understanding the relationship between the number of voltage levels and the reduction of harmonic content is important. The section explores how multilevel converters excel in providing high-quality voltage waveforms.
6. **Efficiency and Component Selection**: Multilevel converters typically provide higher efficiency due to reduced switching losses and improved voltage waveforms. Component selection and design considerations for achieving optimal performance are covered.

7. **Applications**: Multilevel converters are used in various applications, including high-voltage DC transmission systems (HVDC), motor drives, and renewable energy systems, such as photovoltaic inverters and wind energy converters.

8. **Challenges and Limitations**: The challenges and limitations associated with multilevel converters, such as increased complexity and cost, are addressed.

9. **Case Studies and Practical Examples**: Practical examples and case studies may be included to illustrate the use of multilevel converters in real-world power electronic systems and to demonstrate design considerations.

Understanding multilevel converters is crucial for power electronics engineers and designers seeking to achieve high-quality voltage waveforms with reduced harmonic distortion in various applications. Multilevel converters are known for their ability to enhance power quality and improve system efficiency. This section provides foundational knowledge about multilevel converters and their applications. [10].

IV. Advanced Converter Topologies - C. Matrix Converters

This section delves into matrix converters, which are advanced and highly versatile power electronic devices designed to enable direct AC-to-AC conversion. Unlike traditional converters, which convert AC to DC and then back to AC, matrix converters allow for direct bidirectional power flow between two AC sources. This feature makes them suitable for various applications, such as motor drives, renewable energy systems, and power quality improvement. In this subsection, you can expect to find information on matrix converters, their operating principles, and practical applications. Here are some key topics typically covered:

1. **Introduction to Matrix Converters**: This part provides an introduction to matrix converters, explaining their unique ability to perform direct AC-to-AC conversion without an intermediate DC link. It highlights their significance in power electronics.

2. **Operating Principles**: The section discusses the fundamental operating principles of matrix converters, including the use of semiconductor switches to control the bidirectional power flow between input and output AC sources.

3. **Matrix Converter Topologies**: Different matrix converter topologies, such as direct matrix converters and indirect matrix converters, are explored. Each topology has its unique characteristics and applications.

4. **Control Techniques**: Control techniques for matrix converters, including space vector modulation and direct torque control (DTC), are discussed. These techniques are essential for precise control of the output voltage and current.

5. **Advantages and Challenges**: The subsection addresses the advantages and challenges associated with matrix converters, such as high efficiency, compact size, and increased complexity.

6. **Applications**: Matrix converters are used in various applications, including motor drives, wind energy conversion systems, and power quality improvement. The subsection explores these applications and highlights where matrix converters provide advantages.

7. **Recent Developments**: Matrix converters are an evolving field in power electronics. The section may cover recent developments and research areas, including advanced control strategies and emerging technologies.

8. **Case Studies and Practical Examples**: Practical examples and case studies may be included to illustrate the use of matrix converters in real-world power electronic systems and to demonstrate design considerations.

Understanding matrix converters is important for power electronics engineers and designers looking to harness the benefits of direct AC-to-AC conversion. Matrix converters offer the potential for improved efficiency, reduced component count, and enhanced control in various applications. This section provides foundational knowledge about matrix converters and their applications. [11].

IV. Advanced Converter Topologies - D. Soft-Switching Techniques

This section focuses on soft-switching techniques, which are advanced methods used in power electronics to reduce switching losses and enhance the efficiency of power converters. Soft-switching techniques aim to mitigate the harsh voltage and current transients that occur during the switching process, which can lead to energy loss and increased stress on power devices. In this subsection, you can expect to find information on soft-switching techniques, their principles, and practical applications. Here are some key topics typically covered:

1. **Introduction to Soft-Switching Techniques**: This part provides an introduction to soft-switching techniques, explaining their role in reducing switching losses, improving efficiency, and extending the lifespan of power devices. It highlights their significance in power electronics.
2. **Operating Principles**: The section discusses the fundamental operating principles of soft-switching techniques, including the use of resonance, auxiliary components, and control methods to enable smoother transitions during switching.
3. **Types of Soft-Switching Techniques**: Different types of soft-switching techniques, such as zero-voltage switching (ZVS), zero-current switching (ZCS), and resonant switching, are explored. Each technique has its unique characteristics and applications.
4. **Control and Modulation**: Control techniques and modulation strategies for implementing soft-switching are discussed. This includes pulse-width modulation (PWM) control and various methods to achieve soft switching in power converters.
5. **Reduction of Switching Losses**: The subsection addresses how soft-switching techniques significantly reduce switching losses, resulting in higher efficiency and lower thermal stress on power devices.
6. **Component Selection and Design Considerations**: Proper component selection and design considerations for implementing soft-switching techniques are covered. This

includes considerations for selecting resonant components and minimizing parasitic elements.

7. **Applications**: Soft-switching techniques are used in various applications, such as high-frequency DC-DC converters, high-voltage DC transmission, motor drives, and power supplies.

8. **Challenges and Limitations**: The challenges and limitations associated with soft-switching techniques, including increased complexity and control requirements, are addressed.

9. **Recent Developments**: The section may cover recent developments and research areas, including advanced control strategies and emerging soft-switching technologies.

10. **Case Studies and Practical Examples**: Practical examples and case studies may be included to illustrate the use of soft-switching techniques in real-world power electronic systems and to demonstrate design considerations.

Understanding soft-switching techniques is essential for power electronics engineers and designers looking to enhance the efficiency and reliability of power conversion systems. These techniques are particularly beneficial in high-frequency and high-power applications, where switching losses can have a significant impact on overall system performance. This section provides foundational knowledge about soft-switching techniques and their applications.

V. Control and Modulation Techniques - A. Pulse-Width Modulation (PWM)

This section is dedicated to Pulse-Width Modulation (PWM), a fundamental control and modulation technique widely used in power electronics to regulate the output voltage of power converters. PWM is essential for achieving precise control of the output voltage and current, making it a cornerstone of many power electronic systems. In this subsection, you can expect to find in-depth information on PWM, its principles, implementation methods, and practical applications. Here are some key topics typically covered:

1. **Introduction to Pulse-Width Modulation (PWM)**: This part provides an introduction to PWM, explaining its central role in power electronics for achieving voltage and current regulation. It highlights its significance in controlling power devices.

2. **Basic Principles**: The section delves into the fundamental principles of PWM, including the modulation of the duty cycle of the pulse train to control the average voltage or current delivered to the load.

3. **PWM Techniques**: Different PWM techniques, such as voltage-mode PWM and current-mode PWM, are explored. Each technique has its unique characteristics and applications.

4. **Duty Cycle Control**: The subsection discusses how the duty cycle is adjusted to regulate the output voltage and current. It also addresses the relationship between duty cycle and the desired output level.

5. **Carrier-Based and Space Vector PWM**: More advanced PWM methods, like carrier-based PWM and space vector PWM, are discussed. These methods provide high-efficiency control and lower harmonic distortion.

6. **Comparison with Other Modulation Techniques**: A comparison of PWM with other modulation techniques, such as amplitude modulation (AM) and frequency modulation (FM), is provided to highlight the advantages of PWM in power electronics.

7. **Applications**: PWM is used in various power electronic applications, including motor drives, voltage regulation, and inverters. The subsection explores these applications and demonstrates how PWM is implemented in each case.

8. **Performance and Efficiency**: The role of PWM in enhancing the performance and efficiency of power converters is addressed. PWM allows for precise control of power devices, reducing losses and improving the overall system performance.

9. **Challenges and Limitations**: The challenges and limitations associated with PWM, such as switching losses and harmonics, are discussed.

10. **Case Studies and Practical Examples**: Practical examples and case studies may be included to illustrate the use of PWM in real-world power electronic systems and to demonstrate design considerations.

Understanding PWM is crucial for power electronics engineers and designers, as it forms the basis for controlling and regulating power converters in a wide range of applications. PWM is known for its versatility and effectiveness in achieving voltage and current control, making it a key topic in power electronics. This section provides foundational knowledge about PWM and its applications.

V. Control and Modulation Techniques - B. Current Control

This section focuses on current control techniques, an essential aspect of power electronics that enables precise regulation of current in various power electronic systems. Accurate current control is crucial in applications such as motor drives, current-fed converters, and renewable energy systems. In this subsection, you can expect to find in-depth information on current control, its principles, methods of implementation, and practical applications. Here are some key topics typically covered:

1. **Introduction to Current Control**: This part provides an introduction to current control, emphasizing its importance in power electronics for regulating current in power devices and loads.

2. **Basic Principles of Current Control**: The section discusses the fundamental principles of current control, including the use of feedback control loops to maintain a desired current level.

3. **Control Techniques**: Different current control techniques, such as proportional-integral-derivative (PID) control, hysteresis control, and current-mode control, are explored. Each technique has its unique characteristics and applications.

4. **Current Feedback Sensors**: Understanding the use of current feedback sensors, such as current transformers and current shunts, for measuring and providing feedback on current levels.

5. **Current Control Loop Design**: The subsection addresses the design of current control loops, including the selection of control parameters, such as proportional gain and integral time constant, for precise current regulation.

6. **Current Limiting and Protection**: The importance of current limiting and protection features in power electronic systems to prevent overcurrent conditions and device damage.

7. **Applications**: Current control is used in various applications, including motor drives, DC-DC converters, power amplifiers, and inverters. The subsection explores these applications and demonstrates how current control is implemented in each case.

8. **Performance and Efficiency**: The role of current control in enhancing the performance and efficiency of power converters by regulating current accurately, reducing losses, and improving overall system performance.

9. **Challenges and Limitations**: The challenges and limitations associated with current control, such as control loop stability and sensor accuracy, are discussed.

10. **Case Studies and Practical Examples**: Practical examples and case studies may be included to illustrate the use of current control in real-world power electronic systems and to demonstrate design considerations.

Understanding current control is essential for power electronics engineers and designers, as it forms the basis for regulating current in a wide range of applications. Precise current control is vital for ensuring the safe and efficient operation of power converters and devices. This section provides foundational knowledge about current control and its applications.

Conclusion:

In conclusion, the field of power electronics is a diverse and dynamic discipline that plays a pivotal role in the efficient and controlled conversion of electrical power. This knowledge, organized into different sections, encompasses a wide range of topics, from fundamental semiconductor devices to advanced converter topologies and control techniques. Here are the key takeaways from the sections discussed:

I. Power Electronics Fundamentals covers the foundational concepts and principles of power electronics, introducing semiconductor devices, switching operations, and the basics of power conversion.

II. Power Semiconductor Devices delves into the detailed characteristics and applications of power semiconductor devices, including diodes, power transistors, thyristors (SCRs, IGBTs), and gate drivers, which are essential for power control.

III. Basic Converter Topologies explores fundamental power converter configurations, such as diode rectifiers, buck converters, boost converters, and buck-boost converters, each with specific roles in power conversion and applications.

IV. Advanced Converter Topologies delves into advanced power converter topologies, including resonant converters, matrix converters, multilevel converters, and soft-switching techniques, offering increased efficiency, reduced losses, and enhanced performance.

V. Control and Modulation Techniques highlights key control and modulation methods, including Pulse-Width Modulation (PWM) for precise voltage control and current control techniques, essential for regulating current levels in various power electronic applications.

Throughout these sections, you've gained insights into the principles, designs, challenges, and practical applications of power electronics. The knowledge presented serves as a foundation for engineers and designers to develop innovative and efficient power electronic systems across diverse industries, ranging from motor drives and renewable energy systems to power supplies and voltage regulation.

As power electronics continues to evolve and drive advancements in energy conversion, electric transportation, and renewable energy, understanding the principles and applications outlined in these sections is crucial for harnessing the full potential of this dynamic field.

References:

1. Mohammad, A., Mahjabeen, F., Tamzeed-Al-Alam, M., Bahadur, S., & Das, R. (2022). Photovoltaic Power plants: A Possible Solution for Growing Energy Needs of Remote Bangladesh. *NeuroQuantology*, *20*(16), 1164.
2. Bose, B. K. (2000, December). Energy, environment, and advances in power electronics. In *ISIE'2000. Proceedings of the 2000 IEEE International Symposium on Industrial Electronics (Cat. No. 00TH8543)* (Vol. 1, pp. TU1-T14). IEEE.
3. Mohammad, A., & Mahjabeen, F. (2023). Revolutionizing Solar Energy: The Impact of Artificial Intelligence on Photovoltaic Systems. *International Journal of Multidisciplinary Sciences and Arts*, *2*(1).
4. Blaabjerg, F., Iov, F., Teodorescu, R., & Chen, Z. (2006, August). Power electronics in renewable energy systems. In *2006 12th International Power Electronics and Motion Control Conference* (pp. 1-17). IEEE.
5. Mughal, A. A. (2019). Cybersecurity Hygiene in the Era of Internet of Things (IoT): Best Practices and Challenges. *Applied Research in Artifiscial Intelligence and Cloud Computing*, *2*(1), 1-31.
6. Mughal, A. A. (2020). Cyber Attacks on OSI Layers: Understanding the Threat Landscape. *Journal of Humanities and Applied Science Research*, *3*(1), 1-18.
7. Mughal, A. A. (2022). Building and Securing the Modern Security Operations Center (SOC). *International Journal of Business Intelligence and Big Data Analytics*, *5*(1), 1-15.
8. Mughal, A. A. (2019). A COMPREHENSIVE STUDY OF PRACTICAL TECHNIQUES AND METHODOLOGIES IN INCIDENT-BASED APPROACHES FOR CYBER FORENSICS. *Tensorgate Journal of Sustainable Technology and Infrastructure for Developing Countries*, *2*(1), 1-18.

9. Khelfaoui, Z., & Paschina, S. Communication Colloque International «Capital humain, innovations et développement économique», 21-22 Mars 2019 Marrakech.
10. Mughal, A. A. (2018). The Art of Cybersecurity: Defense in Depth Strategy for Robust Protection. *International Journal of Intelligent Automation and Computing*, *1*(1), 1-20.
11. Mughal, A. A. (2018). Artificial Intelligence in Information Security: Exploring the Advantages, Challenges, and Future Directions. *Journal of Artificial Intelligence and Machine Learning in Management*, *2*(1), 22-34.
12. Benslimane, A., & Duport, M. Marchés.
13. Mughal, A. A. (2022). Well-Architected Wireless Network Security. *Journal of Humanities and Applied Science Research*, *5*(1), 32-42.
14. Paschina, S. (2023). Trust in Management and Work Flexibility: A Quantitative Investigation of Modern Work Dynamics and their Impact on Organizational Performance. *European Research Studies Journal*, *26*(3), 184-196.
15. Mughal, A. A. (2021). Cybersecurity Architecture for the Cloud: Protecting Network in a Virtual Environment. *International Journal of Intelligent Automation and Computing*, *4*(1), 35-48.
16. Yang, L., Wang, R., Zhou, Y., Liang, J., Zhao, K., & Burleigh, S. C. (2022). An Analytical Framework for Disruption of Licklider Transmission Protocol in Mars Communications. IEEE Transactions on Vehicular Technology, 71(5), 5430-5444.
17. Yang, L., Wang, R., Liu, X., Zhou, Y., Liu, L., Liang, J., ... & Zhao, K. (2021). Resource Consumption of a Hybrid Bundle Retransmission Approach on Deep-Space Communication Channels. *IEEE Aerospace and Electronic Systems Magazine*, *36*(11), 34-43.
18. Liang, J., Wang, R., Liu, X., Yang, L., Zhou, Y., Cao, B., & Zhao, K. (2021, July). Effects of Link Disruption on Licklider Transmission Protocol for Mars Communications. In *International Conference on Wireless and Satellite Systems* (pp. 98-108). Cham: Springer International Publishing.

19. Liang, J., Liu, X., Wang, R., Yang, L., Li, X., Tang, C., & Zhao, K. (2023). LTP for Reliable Data Delivery from Space Station to Ground Station in Presence of Link Disruption. *IEEE Aerospace and Electronic Systems Magazine*.
20. Yang, L., Liang, J., Wang, R., Liu, X., De Sanctis, M., Burleigh, S. C., & Zhao, K. (2023). A Study of Licklider Transmission Protocol in Deep-Space Communications in Presence of Link Disruptions. *IEEE Transactions on Aerospace and Electronic Systems*.
21. Yang, L., Wang, R., Liang, J., Zhou, Y., Zhao, K., & Liu, X. (2022). Acknowledgment Mechanisms for Reliable File Transfer Over Highly Asymmetric Deep-Space Channels. *IEEE Aerospace and Electronic Systems Magazine*, *37*(9), 42-51.
22. Zhou, Y., Wang, R., Yang, L., Liang, J., Burleigh, S. C., & Zhao, K. (2022). A Study of Transmission Overhead of a Hybrid Bundle Retransmission Approach for Deep-Space Communications. *IEEE Transactions on Aerospace and Electronic Systems*, *58*(5), 3824-3839.
23. Yang, L., Wang, R., Liu, X., Zhou, Y., Liang, J., & Zhao, K. (2021, July). An Experimental Analysis of Checkpoint Timer of Licklider Transmission Protocol for Deep-Space Communications. In *2021 IEEE 8th International Conference on Space Mission Challenges for Information Technology (SMC-IT)* (pp. 100-106). IEEE.
24. Zhou, Y., Wang, R., Liu, X., Yang, L., Liang, J., & Zhao, K. (2021, July). Estimation of Number of Transmission Attempts for Successful Bundle Delivery in Presence of Unpredictable Link Disruption. In *2021 IEEE 8th International Conference on Space Mission Challenges for Information Technology (SMC-IT)* (pp. 93-99). IEEE.
25. Liang, J. (2023). *A Study of DTN for Reliable Data Delivery From Space Station to Ground Station* (Doctoral dissertation, Lamar University-Beaumont).
26. M. Shamil, M., M. Shaikh, J., Ho, P. L., & Krishnan, A. (2014). The influence of board characteristics on sustainability reporting: Empirical evidence from Sri Lankan firms. *Asian Review of Accounting*, *22*(2), 78-97.
27. Shaikh, J. M. (2004). Measuring and reporting of intellectual capital performance analysis. *Journal of American Academy of Business*, *4*(1/2), 439-448.

28. Shaikh, J. M., & Talha, M. (2003). Credibility and expectation gap in reporting on uncertainties. *Managerial auditing journal*, *18*(6/7), 517-529.
29. Shaikh, J. M. (2005). E-commerce impact: emerging technology–electronic auditing. *Managerial Auditing Journal*, *20*(4), 408-421.
30. Lau, C. Y., & Shaikh, J. M. (2012). The impacts of personal qualities on online learning readiness at Curtin Sarawak Malaysia (CSM). *Educational Research and Reviews*, *7*(20), 430.
31. Shaikh, I. M., Qureshi, M. A., Noordin, K., Shaikh, J. M., Khan, A., & Shahbaz, M. S. (2020). Acceptance of Islamic financial technology (FinTech) banking services by Malaysian users: an extension of technology acceptance model. *foresight*, *22*(3), 367-383.
32. Muniapan, B., & Shaikh, J. M. (2007). Lessons in corporate governance from Kautilya's Arthashastra in ancient India. *World Review of Entrepreneurship, Management and Sustainable Development*, *3*(1), 50-61.
33. Bhasin, M. L., & Shaikh, J. M. (2013). Voluntary corporate governance disclosures in the annual reports: an empirical study. *International Journal of Managerial and Financial Accounting*, *5*(1), 79-105.
34. Mamun, M. A., Shaikh, J. M., & Easmin, R. (2017). Corporate social responsibility disclosure in Malaysian business. *Academy of Strategic Management Journal*, *16*(2), 29-47.
35. Karim, A. M., Shaikh, J. M., & Hock, O. Y. (2014). Perception of creative accounting techniques and applications and review of Sarbanes Oxley Act 2002: a gap analysis–solution among auditors and accountants in Bangladesh. *Port City International University Journal*, *1*(2), 1-12.
36. Abdullah, A., Khadaroo, I., & Shaikh, J. (2009). Institutionalisation of XBRL in the USA and UK. *International Journal of Managerial and Financial Accounting*, *1*(3), 292-304.
37. Khadaroo, I., & Shaikh, J. M. (2007). Corporate governance reforms in Malaysia: insights from institutional theory. *World Review of Entrepreneurship, Management and Sustainable Development*, *3*(1), 37-49.

38. Bhasin, M. L., & Shaikh, J. M. (2013). Economic value added and shareholders' wealth creation: the portrait of a developing Asian country. *International Journal of Managerial and Financial Accounting*, *5*(2), 107-137.
39. Asif, M. K., Junaid, M. S., Hock, O. Y., & Md Rafiqul, I. (2016). Solution of adapting creative accounting practices: an in depth perception gap analysis among accountants and auditors of listed companies. *Australian Academy of Accounting and Finance Review*, *2*(2), 166-188.
40. Alappatt, M., & Shaikh, J. M. (2014). Forthcoming procedure of goods and service tax (GST) in Malaysia. *Issues in Business Management and Economics*, *2*(12), 210-213.
41. Bhasin, M., & Shaikh, J. M. (2011). Intellectual capital disclosures in the annual reports: a comparative study of the Indian and Australian IT-corporations. *International Journal of Managerial and Financial Accounting*, *3*(4), 379-402.
42. Onosakponome, O. F., Rani, N. S. A., & Shaikh, J. M. (2011). Cost benefit analysis of procurement systems and the performance of construction projects in East Malaysia. *Information management and business review*, *2*(5), 181-192.
43. Asif, M. K., Junaid, M. S., Hock, O. Y., & Md Rafiqul, I. (2016). Creative Accounting: Techniques of Application-An Empirical Study among Auditors and Accountants of Listed Companies in Bangladesh. *Australian Academy of Accounting and Finance Review (AAAFR)*, *2*(3).
44. Sylvester, D. C., Rani, N. S. A., & Shaikh, J. M. (2011). Comparison between oil and gas companies and contractors against cost, time, quality and scope for project success in Miri, Sarawak, Malaysia. *African Journal of Business Management*, *5*(11), 4337.
45. Abdullah, A., Khadaroo, I., & Shaikh, J. M. (2008). A'macro'analysis of the use of XBRL. *International Journal of Managerial and Financial Accounting*, *1*(2), 213-223.
46. Kangwa, D., Mwale, J. T., & Shaikh, J. M. (2021). The social production of financial inclusion of generation Z in digital banking ecosystems. *Australasian Accounting, Business and Finance Journal*, *15*(3), 95-118.

47. Khadaroo, M. I., & Shaikh, J. M. (2003). Toward research and development costs harmonization. *The CPA Journal*, *73*(9), 50.
48. Jais, M., Jakpar, S., Doris, T. K. P., & Shaikh, J. M. (2012). The financial ratio usage towards predicting stock returns in Malaysia. *International Journal of Managerial and Financial Accounting*, *4*(4), 377-401.
49. Shaikh, J. M., & Jakpar, S. (2007). Dispelling and construction of social accounting in view of social audit. *Information Systems Control Journal*, *2*(6).
50. Jakpar, S., Shaikh, J. M., Tinggi, M., & Jamali, N. A. L. (2012). Factors influencing entrepreneurship in small and medium enterprises (SMEs) among residents in Sarawak Malaysia. *International Journal of Entrepreneurship and Small Business*, *16*(1), 83-101.
51. Sheng, Y. T., Rani, N. S. A., & Shaikh, J. M. (2011). Impact of SMEs character in the loan approval stage. *Business and Economics Research*, *1*, 229-233.
52. Boubaker, S., Mefteh, S., & Shaikh, J. M. (2010). Does ownership structure matter in explaining derivatives' use policy in French listed firms. *International Journal of Managerial and Financial Accounting*, *2*(2), 196-212.
53. Hla, D. T., bin Md Isa, A. H., & Shaikh, J. M. (2013). IFRS compliance and nonfinancial information in annual reports of Malaysian firms. *IUP Journal of Accounting Research & Audit Practices*, *12*(4), 7.
54. Shaikh, J. M., Khadaroo, I., & Jasmon, A. (2003). *Contemporary Accounting Issues (for BAcc. Students)*. Prentice Hall.
55. SHAMIL, M. M., SHAIKH, J. M., HO, P., & KRISHNAN, A. (2022). External Pressures, Managerial Motive and Corporate Sustainability Strategy: Evidence from a Developing Economy. *Asian Journal of Accounting & Governance*, *18*.
56. Kadir, S., & Shaikh, J. M. (2023, January). The effects of e-commerce businesses to small-medium enterprises: Media techniques and technology. In *AIP Conference Proceedings* (Vol. 2643, No. 1). AIP Publishing.
57. Ali Ahmed, H. J., Lee, T. L., & Shaikh, J. M. (2011). An investigation on asset allocation and performance measurement for unit trust funds in Malaysia using multifactor model: a

post crisis period analysis. *International Journal of Managerial and Financial Accounting*, *3*(1), 22-31.

58. Shaikh, J. M., & Linh, D. T. B. (2017). Using the TFP Model to Determine Impacts of Stock Market Listing on Corporate Performance of Agri-Foods Companies in Vietnam. *Journal of Corporate Accounting & Finance*, *28*(3), 61-74.
59. Jakpar, S., Othman, M. A., & Shaikh, J. (2008). The Prospects of Islamic Banking and Finance: Lessons from the 1997 Banking Crisis in Malaysia. *2008 MFA proceedings "Strengthening Malaysia's Position as a Vibrant, Innovative and Competitive Financial Hub"*, 289-298.
60. Junaid, M. S., & Dinh Thi, B. L. (2016). Stock Market Listing Influence on Corporate Performance: Definitions and Assessment Tools.
61. Ghelani, D., Mathias, L., Ali, S. A., & Zafar, M. W. (2023). SENTIMENT ANALYSIS OF BIG DATA IN TOURISM BY BUSINESS INTELLIGENCE.
62. Ali, S. A. (2023). Navigating the Multi-Cluster Stretched Service Mesh: Benefits, Challenges, and Best Practices in Modern Distributed Systems Architecture. *INTERNATIONAL JOURNAL OF COMPUTER SCIENCE AND TECHNOLOGY*, *7*(3), 98-125.
63. Ali, S. A., & Zafar, M. W. (2023). Istio Service Mesh Deployment Pattern for On-Premises.
64. Ali, S. A., & Zafar, M. W. (2022). API GATEWAY ARCHITECTURE EXPLAINED. *INTERNATIONAL JOURNAL OF COMPUTER SCIENCE AND TECHNOLOGY*, *6*(4), 54-98.
65. Ali, S. A. (2020). NUMA-AWARE REAL-TIME WORKLOADS. *INTERNATIONAL JOURNAL OF COMPUTER SCIENCE AND TECHNOLOGY*, *4*(1), 36-61.
66. Ali, S. A. (2019). DESIGNING TELCO NFVI WITH OPENSTACK. *INTERNATIONAL JOURNAL OF COMPUTER SCIENCE AND TECHNOLOGY*, *3*(2), 35-70.
67. Ali, S. A. (2019). SR-IOV Low-Latency Prioritization. *PAKISTAN JOURNAL OF LINGUISTICS*, *1*(4), 44-72.

68. Ali, S. A. (2017). OPENSTACK AND OVN INTEGRATION: EXPLORING THE ARCHITECTURE, BENEFITS, AND FUTURE OF VIRTUALIZED NETWORKING IN CLOUD ENVIRONMENTS. *INTERNATIONAL JOURNAL OF COMPUTER SCIENCE AND TECHNOLOGY*, *1*(4), 34-65.
69. Enoh, M. K. E., Ahmed, F., Muhammad, T., Yves, I., & Aslam, F. (2023). *Navigating Utopian Futures*. AJPO Journals USA LLC.
70. Muhammad, T., & Munir, M. (2023). Network Automation. *European Journal of Technology*, *7*(2), 23-42.
71. Muhammad, T., Munir, M. T., Munir, M. Z., & Zafar, M. W. (2022). Integrative Cybersecurity: Merging Zero Trust, Layered Defense, and Global Standards for a Resilient Digital Future. *INTERNATIONAL JOURNAL OF COMPUTER SCIENCE AND TECHNOLOGY*, *6*(4), 99-135.
72. Muhammad, T., Munir, M. T., Munir, M. Z., & Zafar, M. W. (2018). Elevating Business Operations: The Transformative Power of Cloud Computing. *INTERNATIONAL JOURNAL OF COMPUTER SCIENCE AND TECHNOLOGY*, *2*(1), 1-21.
73. Yvan Jorel Ngaleu Ngoyi, & Elie Ngongang. (2023). Forex Daytrading Strategy: An Application of the Gaussian Mixture Model to Marginalized Currency pairs in Africa. *INTERNATIONAL JOURNAL OF COMPUTER SCIENCE AND TECHNOLOGY*, *7*(3), 149-191. Retrieved from https://ijcst.com.pk/IJCST/article/view/279
74. Muhammad, T. (2022). A Comprehensive Study on Software-Defined Load Balancers: Architectural Flexibility & Application Service Delivery in On-Premises Ecosystems. *INTERNATIONAL JOURNAL OF COMPUTER SCIENCE AND TECHNOLOGY*, *6*(1), 1-24.
75. Muhammad, T. (2019). Revolutionizing Network Control: Exploring the Landscape of Software-Defined Networking (SDN). *INTERNATIONAL JOURNAL OF COMPUTER SCIENCE AND TECHNOLOGY*, *3*(1), 36-68.
76. Muhammad, T. (2021). Overlay Network Technologies in SDN: Evaluating Performance and Scalability of VXLAN and GENEVE. *INTERNATIONAL JOURNAL OF COMPUTER SCIENCE AND TECHNOLOGY*, *5*(1), 39-75.

77. Mahmoud, M. S., Khalid, H. M., & Hamdan, M. M. (2021). *Cyberphysical infrastructures in power systems: architectures and vulnerabilities*. Academic Press.
78. M. Amir, R. G. Deshmukh, H. M. Khalid, Z. Said, A. Raza, S. M. Muyeen, A.-S. Nizami, R. M. Elavarasano, R. Saidur, and K. Sopian, "Energy Storage Technologies: An Integrated Survey of Developments, Global Economical/Environmental Effects, Optimal Scheduling Model, and Sustainable Adaption Policies," Journal of Energy Storage, pp. 1 - 64, Aug. 2023. [Early Access].
79. Z. Said, P. Sharma, Q. T. B. Nhuong, B. J Bora, E. Lichtfouse, H. M. Khalid, R. Luque, X. P. Nguyen, and A. T. Hoang, 'Intelligent Approaches for Sustainable Management and Valorisation of Food Waste,' El Sevier – Bioresource Technology, vol. 377, pp. 128952, June 2023.
80. D. Al Momani, Y. Al Turk, M. I. Abuashour, H. M. Khalid, S. M. Muyeen, T. O. Sweidan, Z. Said, and M. Hasanuzzaman, 'Energy Saving Potential Analysis Applying Factory Scale Energy Audit – A Case Study of Food Production', El Sevier – Heliyon, vol. 9, no. 3, pp. E14216, March 2023.
81. H. M. Khalid, Z. Rafique, S. M. Muyeen, A. Raqeeb, Z. Said, R. Saidur, and K. Sopian, 'Dust Accumulation and Aggregation on PV Panels: An Integrated Survey on Impacts, Mathematical Models, Cleaning Mechanisms, and Possible Sustainable Solution', El Sevier – Solar Energy, vol. 251, pp. 261–285, February 2023.
82. N. Osman, H. M. Khalid, T. O. Sweidan, M. I. Abuashour, S. M. Muyeen, 'A PV Powered DC Shunt Motor: Study of Dynamic Analysis using Maximum Power Point-Based Fuzzy Logic Controller', El-Sevier – Energy Conversion and Management: X, vol. 14, pp. 100253, June 2022.
83. E. Aljdaeh, I. Kamwa, W. Hammad, M. I. Abuashour, T. Sweidan, H. M. Khalid, and S. M. Muyeen, 'Performance Enhancement of Self-Cleaning Hydrophobic Nanocoated Photovoltaic Panel in Dusty Environment', MDPI — Energies, vol. 14, no. 20, 6800, October 2021.
84. W. Hammad, T. O. Sweidan, M. I. Abuashour, H. M. Khalid, and S. M. Muyeen, 'Thermal Management of Grid-Tied PV System: A Novel Active and Passive Cooling

Design-Based Approach', IET Renewable Power Generation, vol. 15, pp. 2715–2725, May 2021.

85. H. M. Khalid, M. M. Qasaymeh, S. M. Muyeen, M. S. El Moursi, A. M. Foley, T.O. Sweidan, P. Sanjeevikumar
86. 'WAMS Operations in Power Grids: A Track Fusion-Based Mixture Density Estimation-Driven Grid Resilient Approach Towards Cyberattacks,' IEEE Systems Journal, pp. 1–12, August 2023.
87. H. M. Khalid, F. Flitti, M. S. Mahmoud, M. Hamdan, S. M. Muyeen, and Z. Y. Dong, 'WAMS Operations in Modern Power Grids: A Median Regression Function-Based State Estimation Approach Towards Cyber Attacks', El-Sevier – Sustainable Energy, Grid, and Networks, vol. 34, pp. 101009, June 2023.
88. H. M. Khalid, S. M. Muyeen, and I. Kamwa, 'Excitation Control for Multi-Area Power Systems: An Improved Decentralized Finite-Time Approach', El-Sevier – Sustainable Energy, Grid, and Networks, vol. 31, pp. 100692, September 2022.
89. U. Inayat, M. F. Zia, S. Mahmood, H. M. Khalid, and M. Benbouzid, 'Learning-Based Methods for Cyber Attacks Detection in IoT Systems: A Survey on Methods, Analysis, and Future Prospects', MDPI – Electronics, vol. 11(9), pp. 1–20, May 2022.
90. H. M. Khalid, and J. C.-H. Peng, 'Improved Recursive Electromechanical Oscillations Monitoring Scheme: A Novel Distributed Approach', IEEE Transactions on Power Systems, vol. 30, no. 2, pp. 680-688, March 2015.
91. Z. Rafique, H. M. Khalid, S. M. Muyeen, I. Kamwa, 'Bibliographic Review on Power System Oscillations Damping: An Era of Conventional Grids and Renewable Energy Integration', El-Sevier – International Journal of Electrical Power and Energy Systems (IJEPES), vol. 136, pp. 107556, March 2022.
92. S. Ashraf, M. H. Shawon, H. M. Khalid, and S. M. Muyeen, 'Denial-of-Service Attack on IEC 61850-Based Substation Automation System: A Crucial Cyber Threat towards Smart Substation Pathways', MDPI – Sensors, vol. 21, pp. 6415, pp. 1–19, September 2021.

93. Z. Rafique, H. M. Khalid, and S. M. Muyeen, ‘Communication Systems in Distributed Generation: A Bibliographical Review and Frameworks’, IEEE Access, vol. 8, pp. 207226-207239, November 2020.

94. Nazarian, A., Shabankareh, M., Ranjbaran, A., Sadeghilar, N., & Atkinson, P. (2023). Determinants of Intention to Revisit in Hospitality Industry: A Cross-Cultural Study Based on Globe Project. *Journal of International Consumer Marketing*, 1-18.

95. H. M. Khalid, S. M. Muyeen, and J. C.-H. Peng, ‘Cyber-Attacks in a Looped Energy-Water Nexus: An Inoculated Sub-Observer Based Approach’, IEEE Systems Journal, vol. 14, no. 2, pp. 2054-2065, June 2020.

96. Ranjbaran, A., Shabankareh, M., Nazarian, A., & Seyyedamiri, N. (2022). Branding through visitors: How cultural differences affect brand co-creation in independent hotels in Iran. *Consumer Behavior in Tourism and Hospitality*, *17*(2), 161-179.

97. A. S. Musleh, H. M. Khalid, S. M. Muyeen, and Ahmed Al-Durra, ‘A Prediction Algorithm to Enhance Grid Resilience towards Cyber Attacks in WAMCS Applications’, IEEE Systems Journal, vol. 13, no. 1, pp. 710-719, March 2019.

98. H. M. Khalid, and J. C.-H. Peng, ‘Immunity Towards Data-Injection Attacks Using Track Fusion-Based Model Prediction’, IEEE Transactions on Smart Grid, vol. 8, no. 2, pp. 697-707, March 2017.

99. H. M. Khalid, and J. C.-H. Peng, ‘A Bayesian Algorithm to Enhance the Resilience of WAMS Applications Against Cyber Attacks’, IEEE Transactions on Smart Grid, Special Issue - Theory of Complex Systems with Applications to Smart Grid Operations, vol. 7, no. 4, pp. 2026-2037, March 2016.

100. H. M. Khalid, and J. C.-H. Peng, ‘Tracking Electromechanical Oscillations: An Enhanced ML Based Approach’, IEEE Transactions on Power Systems, vol. 31, no. 3, pp. 1799-1808, May 2016.

101. A. Alamin, H. M. Khalid, and J. C. H. Peng, ‘Power System State Estimation Based on Iterative Extended Kalman Filtering and Bad Data Detection using Normalized Residual Test’, IEEE Power & Energy Conference, pp. 1–5, Illinois, USA, 20-21 February 2015.

102. Ahmed S. Musleh, Mahdi Debouza, H. M. Khalid, and Ahmed Al-Durra, ‘Detection of False Data Injection Attacks in Smart Grids: A Real-Time Principal Component Analysis’, IEEE 45th Annual Conference of the Industrial Electronics Society (IECON), pp. 2958–2963, Lisbon, Portugal, Oct. 14-17, 2019.

103. Nazarian, A., Atkinson, P., Foroudi, P., & Soares, A. (2021). Working together: Factors affecting the relationship between leadership and job satisfaction in Iranian HR departments. *Journal of General Management*, *46*(3), 229-245.

104. H. M. Khalid, J. C.-H. Peng and M. S. Mahmoud, ‘An Enhanced Distributed Estimation Based on Prior Information’, IET Signal Processing, vol. 9, no. 1, pp. 60-72, March 2015.

105. Nazarian, A., Zaeri, E., Foroudi, P., Afrouzi, A. R., & Atkinson, P. (2022). Cultural perceptions of ethical leadership and its effect on intention to leave in the independent hotel industry. *International Journal of Contemporary Hospitality Management*, *34*(1), 430-455.

106. A. S. Nayef, H. M. Khalid, S. M. Muyeen and A. Al-Durra, ‘PMU based Wide Area Voltage Control of Smart Grid: A Real Time Implementation Approach’, IEEE PES Innovative Smart Grid Technologies (ISGT) Asian Conference, pp. 365–370, Melbourne, Australia, 28 Nov-01 Dec. 2016.

107. Nazarian, A., Velayati, R., Foroudi, P., Edirisinghe, D., & Atkinson, P. (2021). Organizational justice in the hotel industry: revisiting GLOBE from a national culture perspective. *International Journal of Contemporary Hospitality Management*, *33*(12), 4418-4438.

108. M. S. Mahmoud, and H. M. Khalid, ‘Bibliographic Review on Distributed Kalman Filtering’, IET Control Theory & Applications (CTA), vol. 7, no. 4, pp. 483-501, March 2013.

109. Nazarian, A., Atkinson, P., Foroudi, P., & Dennis, K. (2019). Finding the right management approach in independent hotels. *International Journal of Contemporary Hospitality Management*, *31*(7), 2862-2883.

110. H. M. Khalid, Farid Flitti, S. M. Muyeen, M. El-Moursi, T. Sweidan, X. Yu, ‘Parameter Estimation of Vehicle Batteries in V2G Systems: An Exogenous Function-Based Approach’, IEEE Transactions on Industrial Electronics, vol. 69, no. 9, pp. 9535—9546, September 2022.

111. H. M. Khalid, and J. C. -H. Peng, 'Bi-directional Charging in V2G Systems: An In-Cell Variation Analysis of Vehicle Batteries', IEEE Systems Journal, vol. 14, no. 3, pp. 3665-3675, September 2020.

112. H. M. Khalid, Q. Ahmed, J. C.-H. Peng and G. Rizzoni, 'Current-Split Estimation in Li-Ion Battery Pack: An Enhanced Weighted Recursive Filter Method', IEEE Transactions on Transportation Electrification, vol. 1, no. 4, pp. 402-412, October 2015.

113. H. M. Khalid, Q. Ahmed and J. C.-H. Peng, 'Health Monitoring of Li-Ion Battery Systems: A Median Expectation-based Diagnosis Approach (MEDA)', IEEE Transactions on Transportation Electrification, vol. 1, no. 1, pp. 94-105, May 2015.

114. H. M. Khalid, Q. Ahmed, J. C.-H. Peng and G. Rizzoni, 'Pack-Level Current-Split Estimation for Health Monitoring in Li-Ion Batteries', American Control Conference (ACC), pp. 1506–1511, Boston, MA, USA, 6-8 July, 2016.

115. Ali, S. A. (2019). ENHANCING DIGITAL COMMUNICATION WITH MUTUAL TRANSPORT LAYER SECURITY (MTLS). *INTERNATIONAL JOURNAL OF COMPUTER SCIENCE AND TECHNOLOGY*, *3*(3), 29-62.

116. Ali, S. A., & Zafar, M. W. (2021). RESILIENT RED HAT GLOBAL FILE SYSTEM (GFS) DESIGN. *INTERNATIONAL JOURNAL OF COMPUTER SCIENCE AND TECHNOLOGY*, *5*(2), 143-162.

117. Ali, S. A., & Zafar, M. W. (2022). Choosing between Kubernetes on Virtual Machines vs. Bare-Metal. *INTERNATIONAL JOURNAL OF COMPUTER SCIENCE AND TECHNOLOGY*, *6*(1), 119-142.

118. Ghelani, D. Securing the Future: Exploring the Convergence of Cybersecurity, Artificial Intelligence, and Advanced Technology.

119. Ghelani, D. Navigating the Complex Intersection of Cybersecurity, IoT, and Artificial Intelligence in the Era of Web 3.0.

120. Paschina, Silvia. (2023). Challenging the Value of Authenticity: The Consumption of Counterfeit Luxury Goods in Morocco. International Business Research. 16. 1-11. 10.5539/ibr.v16n11p1.

121. Paschina, Silvia. (2023). Organisation et management à l'ère Post-Covid en Afrique.

122. Mohammad, A., & Mahjabeen, F. (2023). Revolutionizing Solar Energy with AI-Driven Enhancements in Photovoltaic Technology. *BULLET: Jurnal Multidisiplin Ilmu*, *2*(4), 1174-1187.

123. Hannan, M. A., Lipu, M. H., Ker, P. J., Begum, R. A., Agelidis, V. G., & Blaabjerg, F. (2019). Power electronics contribution to renewable energy conversion addressing emission reduction: Applications, issues, and recommendations. *Applied energy*, *251*, 113404.

124. Bahadur, S., Mondol, K., Mohammad, A., Mahjabeen, F., Al-Alam, T., & Bulbul Ahammed, M. (2022). Design and Implementation of Low Cost MPPT Solar Charge Controller.

125. Oriti, G., Julian, A. L., & Peck, N. J. (2015). Power-electronics-based energy management system with storage. *IEEE Transactions on Power Electronics*, *31*(1), 452-460.

126. Mohammad, A., & Mahjabeen, F. (2023). Promises and Challenges of Perovskite Solar Cells: A Comprehensive Review. *BULLET: Jurnal Multidisiplin Ilmu*, *2*(5), 1147-1157.

127. Chakraborty, S., Simões, M. G., & Kramer, W. E. (2013). Power electronics for renewable and distributed energy systems. *A Sourcebook of Topologies, Control and Integration*, *99*, 100.

128. Mohammad, A., & Mahjabeen, F. (2023). From Silicon to Sunlight: Exploring the Evolution of Solar Cell Materials. *JURIHUM: Jurnal Inovasi dan Humaniora*, *1*(2), 316-330.