ABSTRACT

The design, simulation and hardware implementation of a Luo converter designed for renewable energy systems are presented here. An AC supply is used to make the converter steady, but only the sun and wind energies in general supply the main energies to power the converter. An Artificial Neural Network (ANN) is trained with pulse width modulation data to dynamically control the converter and optimize voltage boosting under different environmental and load conditions. This real time adaptive control technique provides effective stabilization of the output voltage, decreases switching losses, and better energy conversion efficiency. This new Luo converter provides better responsiveness, flexibility and energy efficiency compared to alternative power supply converters with fixed gain or PID controllers. The proposed power supply converter is highly suitable for use in electric vehicle (EV) charging stations with renewable energies where advanced energy management and precise control is required for better performance, efficiency and sustainability.

Keywords - Luo converter, renewable energy, PWM, ANN, EV charging.

CHAPTER 1

INTRODUCTION

1.1 HISTORY OF RENEWABLE ENERGY SYSTEMS

Environmental disasters and increasing global energy demands have hastened the move away from traditional fossil fuels and the use of renewable sources. Solar and wind are the most common renewable sources because they are typically available and do not pollute the environment. Solar power systems use PV panels to convert solar energy to electrical energy; wind energy systems use wind turbines to convert the kinetic energy from moving air to electrical energy. These technologies represent significant solutions to problems of climate change and energy security, and governments, industry and researchers all around the world are investing in the implementation and advancement of renewable systems to help reduce carbon emissions and reliance on fossil fuels.

1.2 CHALLENGES OF INTEGRATING RENEWABLE ENERGY

While there are advantages to renewable energy systems, they also pose technical issues, particularly with regard to their ability to integrate to power systems and standalone systems. The largest issue these systems face is intermittency. Solar energy is limited with respect to sunlight, but also varies based on the intensity of sunlight, cloud cover and time of day, with wind energy dependant on wind speed and atmospheric conditions. This intermittency can create power fluctuations, voltage fluctuations, and energy management challenges across the system as a whole.

In order to maintain the stable operation of renewable systems like sensitive loads (i.e. electric vehicle charging stations), there must be power management and control improvements made where such real-time fluctuations support these improvements.

1.3 ROLE OF POWER ELECTRONICS IN RENEWABLE ENERGY SYSTEMS

Power electronics converters (specifically dc-dc converters) are responsible for converting the voltage output from renewable energy sources to usable and reliable levels. The converter will deliver an output voltage to control either loads downstream like batteries, inverters or electric loads. For this reason Luo converters are also a non-isolated DC-DC converter and are therefore well suited for renewable energy systems requiring voltage boosting and bucking when the need arises. The Luo converter exhibits better dynamic response, efficiency and voltage regulation compared to the conventional converters such as Buck or Boost, due to its advance topology and as such is well suited for unpredictable application with very fast changing input conditions like wind and solar energy.

1.4 IMPORTANCE OF SMART CONTROL FOR POWER CONVERTERS

While the Luo Converter offers flexibility on the hardware side, truly efficient operation requires the implementation of smart control algorithms under actual conditions. Standard controllers such as PID provide reasonable performance in steady-state conditions but typically result in poor performance when the converter experiences sudden changes or nonlinear behaviors (e.g. variations in power generation characteristic of renewable systems).

Overall, the emergence of AI-based technologies such as Artificial Neural Networks (ANNs) have begun to take hold in converter control. Subject to specific networks and training, ANN can provide promising results for a data driven and adaptive manner to learn from historical behavior of a system and subsequently predict the best control actions. ANN is used for standard converter applications where the operating conditions are complicated (e.g. nonlinear) and mathematical modeling of the converter behavior can remain uncertain.

CHAPTER 2

LITERATURE REVIEW

1. Title: Luo-Converters Voltage Lift Technique

Authors: Fang Lin Luo

Publication: PESC '98 Record, 29th Annual IEEE Power Electronics Specialists Conference

Summary:

To maximize voltage gain and limit negative parasitic losses from circuit elements, this paper proposed the voltage-lift method. The Luo converters proposed have a distinctive advantage in renewable energy applications specifically, because they have the capacity to provide an elevated voltage output at greater reliability and uniformity. Their small formfactor, coupled with high efficiency, sets them apart in the power converter space.

2. Title: Performance Analysis of Solar Energy Conversion System Using Super-Lift Luo Converter

Authors: P. Elangovan, V. Maheswari, P. Manigandan

Publication: 2020 IEEE ICADEE Conference

Summary:

This study explored the potential benefits of solar technology over a conventional boost converter in order to evaluate the overall performance of a solar conversion system using a Super-Lift Luo Converter (SLLC). The SLLC, compared to normal boost converter technology, provides a more constant output and more voltage lift. The simulation results exhibited the performance decay due to noise was decreased and validated faster speed and torque control to pursue solar-powered performance; thus validating that SLLC is a feasible converter for solar alternative energy applications.

3. Title: Simulation and Implementation of Super Lift Luo Converter

Authors: Josily Jose, B. Jayanand

Publication: 2013 International Conference on Renewable Energy and Sustainable Energy (ICRESE)

Summary:

A PI controller was used to improve the dynamic response of a Super-Lift Luo Converter with geometric voltage gain to their application in battery charging and EV power. The Super-Lift Luo Converter improves voltage gain of the converter hardware and decreased non-linearities as seen through software simulation and hardware verification.

4. Title: Analysis and Design of Superlift Luo Boost Converter

Authors: K. Sarasvathi, K. Divya

Publication: 2018 4th ICEES Conference

Summary:

The Super-Lift Luo Converter with voltage gain by suitable geometry and positive output is the core of this paper. This topology is promising for renewable energies, because it yields greater output voltages than standard converters, according to a set of simulations using MATLAB/Simulink.

5. Title: Analysis of a Modified Positive Output Luo Converter and Its Application to Solar PV System

Authors: Chaitanya Pansare, Shailendra Kumar Sharma, Chinmay Jain, Rakesh Saxena

Publication: 2017 IEEE Industry Applications Society Annual Meeting

Summary:

This research showed that a re-lift structure was an adapted double Luo converter in order to double the voltage gain. The simulation results show that this modified Luo converter also has better efficiency as well as power delivery when applied to solar PV systems that are working continuously conductive mode.

6. Title: Modeling and Simulation Analysis of PV Fed Cuk, Sepic, Zeta, and Luo DC-DC Converters

Authors: Deepak, Rupendra Kumar Pachauri, Yogesh K. Chauhan

Publication: Gautam Buddha University, India

Summary:

This comparison study can make a contribution in selecting the most appropriate converter for the interconnection of solar energy by providing the size and characteristics of the paths provided for variety of isolated and non-isolated DC-DC converters and their output characteristics in terms of resistive loads. This study evaluates Cuk, Sepic, Zeta, and Luo converters. The converters will be analyzed using MATLAB/Simulink.

7. Title: Performance Analysis of ANN Based DC To DC Converter

Authors: Priya Thakur, Dr. Nagendra Tripathi, Dr. Heena Mishra

Publication: IJERA, Vol. 13, Issue 2, February 2023

Summary:

A DC-DC boost converter that is appropriate for microgrid systems and is controlled using ANNs is introduced in the study with a new control architecture. The ANN demonstrated a developmental advantage over traditional PI control relative to changing loads and was capable of improved voltage regulation according to changing conditions after it had been trained with data from MPC models.

8. Title: An Ultra High Step-Up DC-DC Converter Based on the Boost, Luo, and Voltage Doubler Structure

Authors: Tohid Rahimi et al.

Publication: IEEE Access

Summary:

This paper has outlined a high-gain hybrid converter topology that utilizes boost, Luo, and voltage doubler structures. This topology is ideal for renewable energy systems that need low power high efficient converters since simulations and 100W hardware testing were able to achieve efficiency of about 90%.

9. Title: Design and Implementation of Luo Converter for Renewable Application

Authors: G. Bharani, M. Elango, U. Harshavarshini, G. Karthick, S. Dineshkumar

Publication: 2023 9th ICEES, IEEE

Summary:

This paper offers a design of a Luo converter meant for solar energy with a primary goal of low ripple and high conversion efficiency as well as possibilizing it in renewable energy systems due to its high regulation of voltage. Our results of simulations validate the steady state output voltages.

10. Title: Performance Analysis of Luo-Converter for Photovoltaic Application

Authors: Malek Guizani et al.

Publication: 2018 SSD Conference, IEEE

Summary:

This paper includes a comparison of Boost and Luo converter topologies for PV systems. Luo converters have superior output quality and higher voltage gain, in particular the Positive Output Super-Lift and Voltage-Lift converters, making Luo converters a good option for grid-connected PV applications.

11. Title: Luo-Converters: A Series of New DC-DC Step-Up (Boost) Conversion Circuits

Author: Fang Lin Luo

Publication: 2nd Int. Conf. on Power Electronics and Drive Systems, IEEE

Summary:

The self-lift, re-lift, and multi-lift Luo converter configurations are discussed in this study. These converters are advantageous in embedded and renewable applications because they have high voltage gain, have low ripple, and are modular and compact with high efficiency.

12. Title: Improving Solar Energy Conversion Efficiency through Luo Converter Enhanced by Artificial Neural Network and Cloud Integration

Authors: B. Marisekar et al.

Publication: 2024 8th ICISC, IEEE

Summary:

The authors present a new solar conversion configuration with an ANN-based controller and cloud-based monitoring. The ANN's ability to modify parameters in real-time provides intelligent and reliable energy management, together with a cloud connection provides remote monitoring and control of the equipment for a stable output.

13. Title: Design of DC–DC Luo Converter for Solar Applications using MATLAB/SIMULINK

Authors: Shanthi T et al.

Publication: 2023 ICAECA Conference, IEEE

Summary:

In this paper, the Luo converter with closed-loop PI control has been integrated within a solar energy system. Simulation results verify the effectiveness of the Luo converter as a constant solar power source and AC support for an inverter, where the output voltage has remained constant with low ripple.

14. Title: Design and Implementation of Voltage-lift Luo Converter with PID Control for Solar Power Systems

Authors: Paramasivam K et al.

Publication: 2023 ICAECA Conference

Summary:

To reduce input ripple and enhance efficiency a voltage-lift Luo converter with PID control is reported in this work. MATLAB/SIMULINK has high voltage stability and conversion efficiency for stand-alone solar battery charging systems.

CHAPTER 3

PROBLEM IDENTIFICATION AND METHODOLOGY

3.1 EXISTING METHODOLOGY

At present, renewable energy-powered electric vehicle charging stations use the same energy conversion applications as conventional direct current to direct current converters: the greater buck, the boost, and buck-boost converters, as well as a static controller with a linear or PID (Proportional-Integral-Derivative) controller. The charging stations use mostly wind energy or solar energy and receive an auxiliary energy source of AC power at times to support continuous charging.

The following components are generally part of the traditional design:

1. **Solar Panel:** Panels are usually fitted with MPPT (Maximum Power Point Tracking) techniques to maximize solar energy, therefore making solar panels the main source of energy.
2. **Wind turbines:** Wind power is sometimes combined with solar power to increase efficiency in cases with intermittent sunny days.
3. **DC to DC Converters:** These devices regulate the renewable sources voltages and current to be the appropriate level for the EV battery.
4. **Controllers:** Energy storage controllers are static controllers such as PID or other linear controllers, including controlling the power conversion process.

3.2 PROBLEMS WITH THE EXISTING SYSTEM

1. **Low Adaptability:** Conventional PID controllers are not capable of dealing with the variation in conditions with the environment and load conditions.
2. **Wasteful use of energy:** Using fixed control techniques leads to greater energy loss and ineffectiveness in the energy conversion in real-time basis.
3. **Inefficient Management of Complex Power Dynamics: Conventional** converters cannot manage the concurrent presence multiple renewable sources reliably.

4. **Limited Flexibility for Load Variation:** Inflexible controllers cannot accommodate the degrading variation of the EV charging load.
5. **Increased Switching Losses:** Non-adaptive systems suffer far greater loss, while have variation in their renewables inputs.

3.3 PROBLEM STATEMENT AND OBJECTIVE OF THE PROJECT

3.3.1 PROBLEM STATEMENT:

To create an intelligent, adaptable, and efficient power conversion system employing an Artificial Neural Network (ANN) controlled Luo Boost Converter for renewable energy-powered EV charging applications.

3.3.2 OBJECTIVE:

The aim of this research is to design and implement a Luo converter controlled with an artificial neural network (ANN), specifically for use in electric vehicle charging stations driven by renewable energy sources. The converter will adjust the output voltage in response to rapid fluctuations in renewable solar and wind energy influx, the output voltage will maintain charging voltage adequately under unpredictable environmental & load conditions, ensuring efficient energy conversion.

6. The goals are to develop a Luo converter which suitable for renewable energy connections while being optimized for efficiency in step-up and step-down voltage regulations.
7. To implement an Artificial Intelligence (ANN) based system that adapts to changes in load demand and environmental variables
8. To illustrate the advantages of using ANN-controlled Luo converters where efficiencies and performance exceed those of traditional converter topologies.
9. To provide better options for EV charging stations which are based on renewable energy in order to ensure sustainable development with efficient energy management.

3.4 METHODOLOGY – PLAN OF EXPERIMENTS

The methodology employed in this project includes the development, simulation, and experimental validation of an efficient and an adaptive approach to control a Luo Boost Converter using an ANN-based controller supplied with renewable energy for EV charging stations.

The sequence of tasks undertaken includes:

Literature Review:

There was an evaluation of existing literature around DC-DC Converters (Luo Converter), ANN controllers, and challenges related to the integration of renewable energy sources.

System Design:

Identifying the energy sources: Solar panel and wind turbine as renewable inputs.

Design of Luo Boost Converter with an optimised voltage lifting solution.

ANN Controller development:

Train an ANN model based on the PWM duty cycle and frequency relative to the input voltage.

Utilising TensorFlow to train the model and optimise.

Store the trained ANN model and scaled values for hardware integration.

Simulation:

Model the complete system in MATLAB/Simulink.

Simulate the effects of solar irradiance and wind speed fluctuations at dynamic loads.

Assess the performance of the converter with and without ANN control.

Hardware Prototype:

Build the Luo converter circuit from the existing list of MOSFET, inductors, capacitors and diodes.

Communicate with the trained ANN model from Arduino through serial communication for real control.

Use PWM-based switching with dynamic adjustment based on the sensed voltage.

Testing and Validation:

Through an analysis of the benefits of PID-controlled systems over traditional PID-controlled systems, and by comparison all metrics which include output voltage levels, changing inputs, efficiency, and switching losses.

This process will ensure that I have gone through everything theoretical and practical to validate the proposed methodology.

CHAPTER 4

DESIGN AND IMPLEMENTATION METHODOLOGY

4.1 PROPOSED SYSTEM

In this chapter, we present the full design and development process of the ANN controlled Luo Boost Converter controlled by a renewable energy-based EV charging station. The system includes multiple energy sources: solar, wind and a backup AC supply. The intelligent neural network manages the renewable energy and adaptively regulates the output voltage. We conduct simulation and hardware evaluation of the systems performance based on some of the factors that can change in the environment.

4.2 DIAGRAMMATIC REPRESENTATION OF SYSTEM

The proposed block diagram of “Optimized Voltage Boosting in Renewable Energy Systems: ANN-Controlled Luo Converter for EV Charging” is shown below

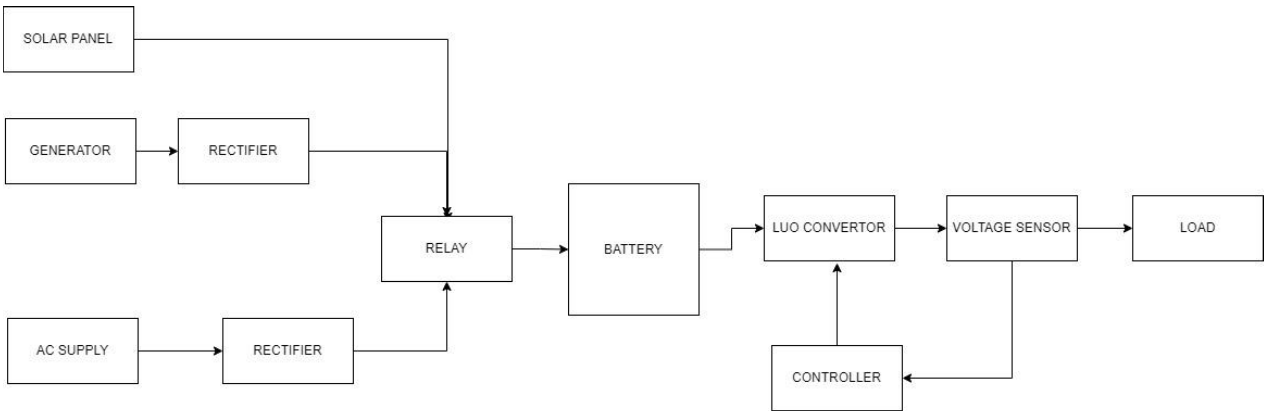

Figure 4.1: **Diagrammatic Representation of the suggested system**

4.2.1 AN EXPLANATION OF SYSTEM ARCHITECTURE:

The setup includes three main energy sources: the solar panels, the wind turbines and AC auxiliary source. The combination of these energy sources is formulated in DC form and supplied to a Luo Boost Converter which will up-convert the voltage to charge EVs. The most important part of the system is the

ANN controller, which generates is the best possible PWM signals for the converter's switching device to be operated.

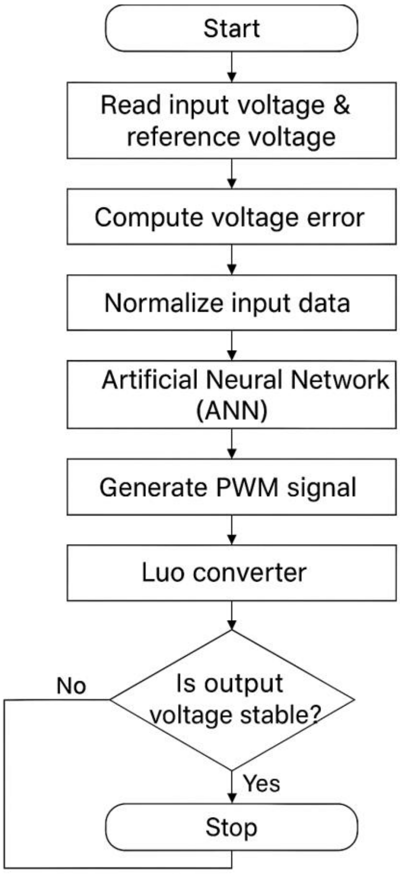

Figure 4.2 Flowchart of ANN-Controlled Luo Converter Operation

4.3 WORKING OF SUGGESTED SYSTEM:

The first operation of the systems is taking solar and wind generated power, both are variable power sources due to ambient conditions. The second part of the operation allows for an additional AC source (in place for the two sources), to provide supporting power, when energy from the wind and solar have degraded to zero output. After the output is processed, there are DC outputs available, from the Luo Boost Converters voltage-lift process will convert the output sufficient enough to recharge electric cars. We implemented an ANN-based controller which collects and examines global environmental data to manipulate the duty cycle of the PWM control signal for identifying unwanted energy as such. The implementation of this controller confirmed that adjusting the converter in real time (as previously identified) is suitable for accommodating changing surrounding energy production. We employed an intelligent controlled system, therefore controlling renewable energy source interruption, reduced losses in switching, and improved charge delivery efficiency as well. When we realised the converted output to the EV charging station, the system showed that the system was operating with satisfactory stable output voltage whilst there were dynamic source inputs.

4.3.1 SCHEMATIC REPRESENTATION OF THE LUO CONVERTER:

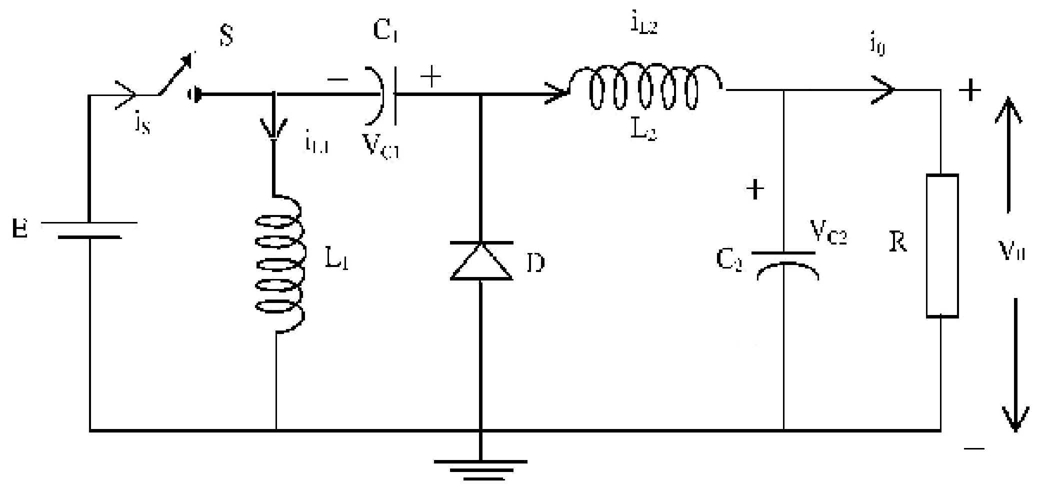

Figure 4.3 Schematic Diagram Depicting the Luo Converter Topology

The Luo converter is a high-performance DC-DC converter which employs the voltage-lift concept. After the input capacitor connected to the DC power supply, the inductor stores energy when the switching MOSFET is in the on state. Upon switch-off, a fast-recovery diode can direct the current path to transfer the supervisory energy stored in the inductor to the output.

Where the power-lifting is concerned, the output voltage is lifted gradually at very little loss by a secondary diode and capacitor configuration. The diode also lifts the voltage when the MOSFET is switched off by transferring the inductive energy into the output capacitor and load.

4.3.2 MATHEMATICAL MODELING OF THE LUO BOOST CONVERTER

Luo boost converter is a high-gain DC to DC converter configuration that provides high DC output voltage from a low DC input voltage by using an inductor and voltage collector switch. The converter's electrical behavior and design parameters are explained by the following equations.

Key Equations:

1. **Voltage Gain Equation:**

$$Vout = \frac{Vin(1 + D) \times n^2}{1 - D}$$

1. D: The switching signal's duty cycle;
2. n: The ratio of the linked inductor's turns;
3. Vout: the voltage at the voltage;
4. Vin: the voltage at the input

1. **Inductor Voltage Equation:**

$$VL1 = Vin - VC1 - Vf1$$

1. VC1: The value of voltage across capacitor C1
2. VL1: Voltage across the linked inductor's first winding
3. Vf1: Primary side diode forward decrease in voltage

1. **Output Voltage from Voltage Multiplier**:

$$Vout = 2^n \times VC2$$

1. VC2: The voltage across the multiplier circuit's last capacitor
2. n: The multiplier's number of stages or turns

3. **Inductor Current Equation:**

$$\frac{dL1}{dt} = (Vin - Vout)/L1$$

1. IL1: Inductor current (primary winding)

2. L1: Inductance value

1. Capacitor Voltage Equations:

$$\frac{dVC1}{dt} = -\frac{IL1}{C1}$$

$$\frac{dVC2}{dt} = -\frac{Iout}{C2}$$

1. C1, C2: Capacitance values

2. Iout: Output load current

These formulas serve as the analytical foundation for:

1. Developing component values (inductor, capacitor, and diode ratings);
2. Targeting output voltage by optimizing duty cycle and transformer ratio;
3. And Forecasting system dynamics under ANN-PID-based control.

The performance and stability of the suggested converter are verified using this mathematical model during the simulation and hardware implementation stages.

4.4 ARTIFICIAL NEURAL NETWORK (ANN) BASED CONTROLLER ARCHITECTURE

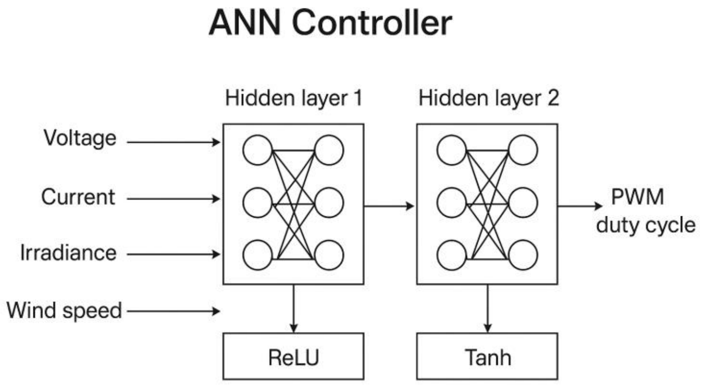

Fig 4.4 ANN Controller Block Diagram

The core of the adaptive control strategy is a trained Artificial Neural Network (ANN) model designed to generate optimal PWM signals based on real-time input voltage data. The ANN development followed these steps:

1. **Data Generation:** A dataset of voltage vs. PWM frequency and duty cycle values was generated programmatically for training purposes.
2. **Data Preprocessing:** Inputs and outputs were normalized using MinMaxScaler to improve learning efficiency.
3. **Model Structure:** A sequential neural network with two hidden layers was designed:
    1. Hidden Layer 1: 10 neurons with ReLU activation
    2. Hidden Layer 2: 10 neurons with Tanh activation
    3. Output Layer: Linear activation for PWM frequency and duty cycle
4. **Training:** The model was trained using the Adam optimizer and MSE loss function over 200 epochs with batch size 16.

5. **Export:** The trained model and scaling parameters were saved using joblib and TensorFlow for deployment on hardware.

4.5 SIMULATION SETUP OF SUGGESTED SYSTEM

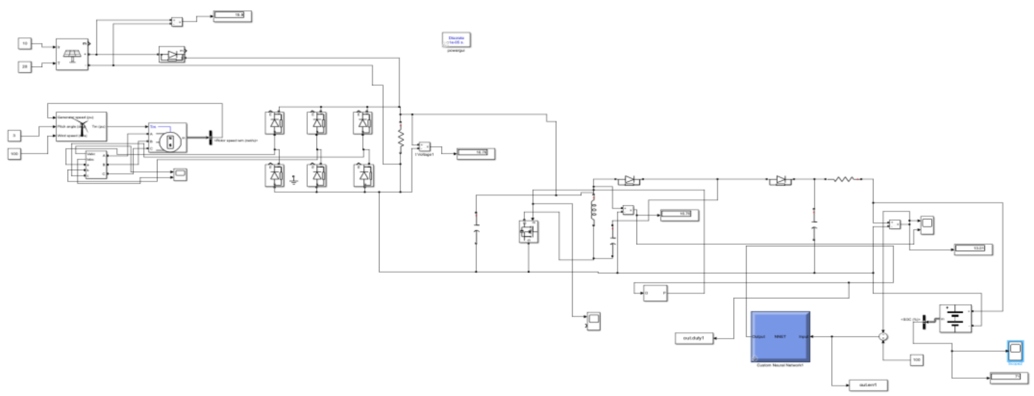

Figure 4.5 MATLAB Simulation Model of ANN Controlled Luo Converter for EV Charging

This simulation models a comprehensive hybrid renewable energy system designed for electric vehicle (EV) charging, integrating both solar and wind power sources. The photovoltaic (PV) array receives solar irradiance and cell temperature as input variables, dynamically generating electrical energy.

A diode is connected in series to prevent reverse current flow, ensuring safe and efficient operation. At the same time, a wind turbine subsystem takes wind speed, pitch angle, and generator speed as inputs to generate torque to drive a Permanent Magnet Synchronous Machine (PMSM) to be acting as generator. A 3-phase voltage and current (VI) measurement block is used to monitor the PMSM's output, while a bus selector extracts rotor speed data for feedback control.

The combined power from these sources is then regulated by a Luo Boost DC-DC converter, which uses a high-speed MOSFET for voltage elevation based on the voltage-lift technique. An RLC filter is included to reduce high-frequency switching noise and output voltage ripple. A custom-trained Artificial Neural

Network (ANN) acts as the intelligent control core, dynamically adjusting PWM frequency and duty cycle based on real-time voltage readings.

These PWM signals are used to control the MOSFET switching behavior for optimal performance. The final regulated output is directed to a battery system that simulates EV charging, thereby validating the system's capability to deliver efficient, stable, and adaptive power conversion under variable environmental conditions.

4.6 HARDWARE SETUP OF SUGGESTED SYSTEM

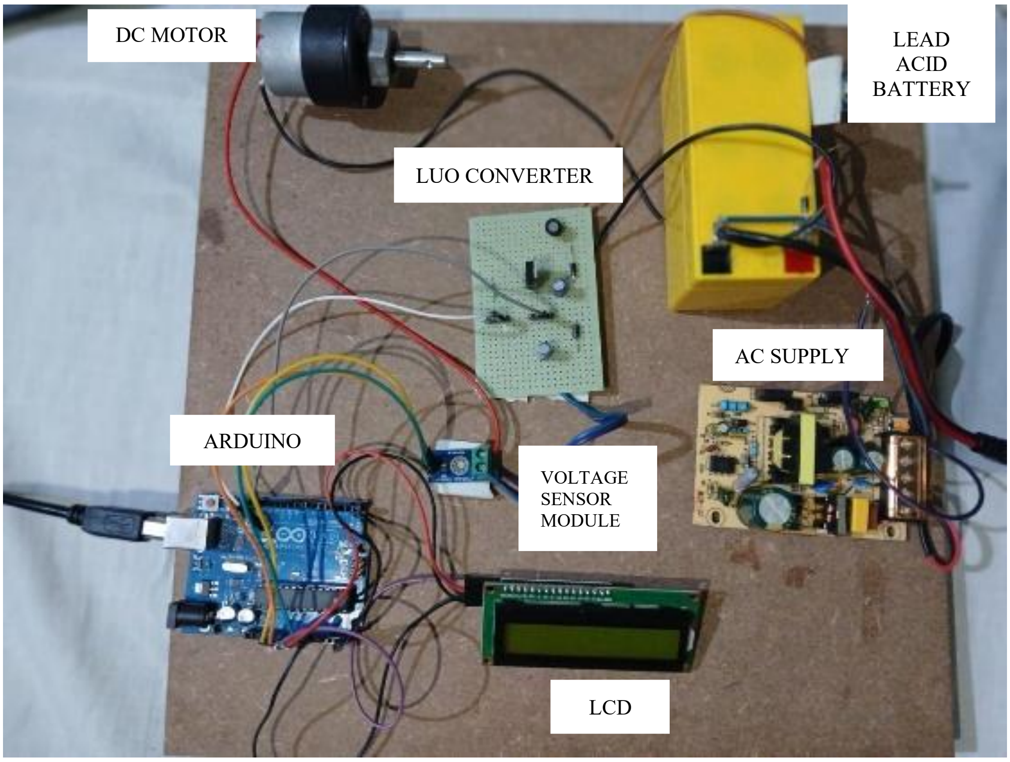

Figure 4.6 Prototype Implementation of Luo Boost DC to DC Converter

Using discrete electrical components, the Luo Boost the DC-to-DC Converter prototype replicates the traditional Luo converter topology on a dotted board. This modular setup includes one inductor, two high-capacitance capacitors, two fast-recovery diodes, and a power MOSFET, all configured to demonstrate the voltage-lift operation characteristic of the Luo converter.

The hardware implementation facilitates the observation of step-up conversion behavior, where energy is cyclically stored in the inductor during the MOSFET's conduction phase and subsequently transferred to the output through the capacitors and diodes during the non-conduction phase. A straightforward duty cycle pulse width modulation (PWM) signal from an external source power the MOSFET, enabling it to swiftly flip its high frequency and track the converter's output voltage.

This involves real time adjustments levelling off any voltage change that is profitably detected and will eventually not let the unexpected change in output voltage negatively change the input voltage or load of the system. Using a perforated/dotted or 'whatever you want to call it' board to develop at this level allows this level of flexibility and accessibility required during prototyping as it allows alterations to be made quickly to circuit connections, promptly changed or replaced of exacting elements of a circuit, or simply to add other technology, such as, a sensor or microcontroller, to the experiment while testing. A physical prototype can be an important step for proving a theoretical design to establish if it meets operational parameters and simulating tangible renewable energy applications such as EV charging systems, etc.

4.6.1 HARDWARE SETUP TRAINED WITH ANN

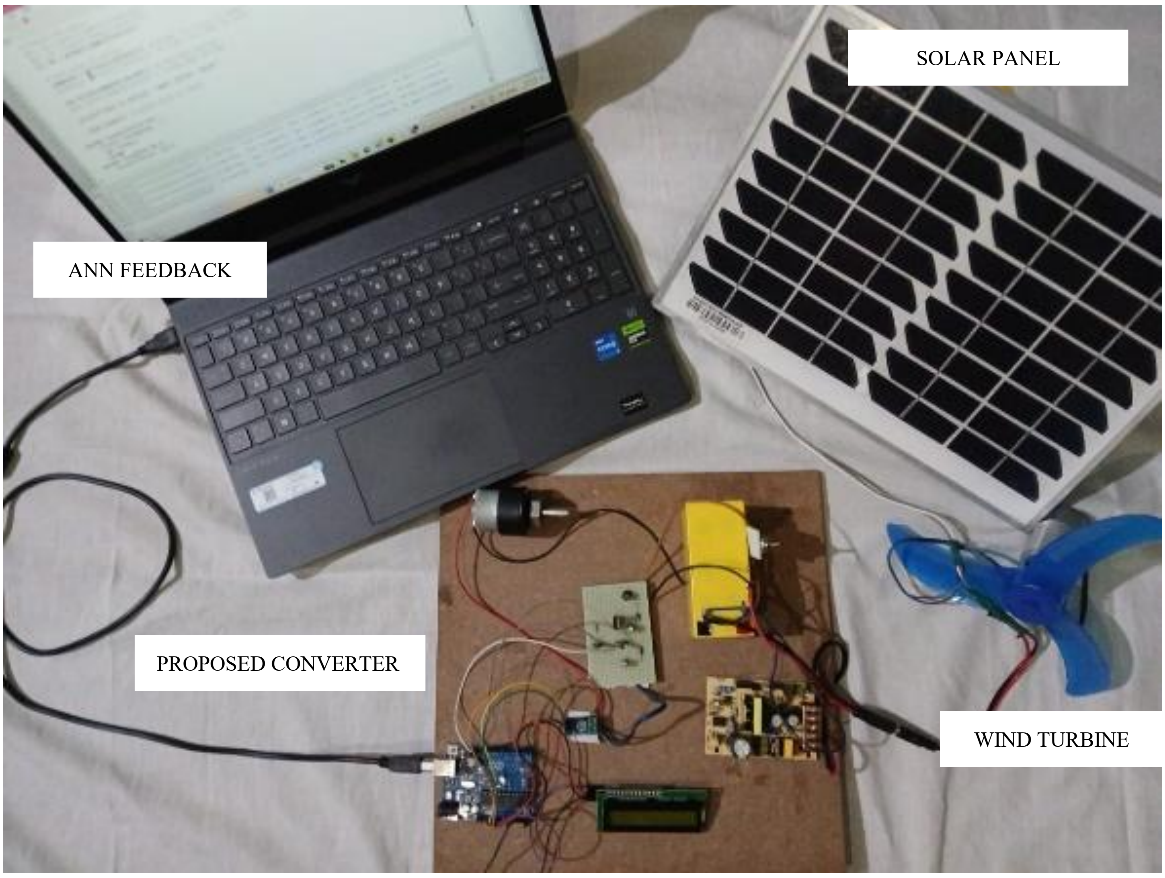

Figure 4.7 Hardware Setup Trained with ANN

A Python-trained ANN (artificial neural network) model is integrated with the hardware system. The ANN is trained on a dataset comprising PWM signal characteristics specifically frequency and duty cycle values—and their corresponding output performance metrics. This trained model is then used to optimize the switching control of the MOSFET in the Luo Boost Converter for efficient voltage regulation. The ANN outputs the ideal PWM parameters in real-time to adapt to varying input conditions, enhancing system stability and dynamic response. The trained model is interfaced with the hardware setup for intelligent control and improved converter performance.

To bring ANN control into real-time hardware, the following integration was done:

1. **Communication:** Serial communication between Python (running ANN model) and Arduino via USB.

2. **PWM Update Protocol:** ANN-generated frequency and duty cycle values were parsed and sent as formatted serial strings (e.g., F1xxxx\nD1xx\n) to Arduino.

3. **Microcontroller Configuration:**

    1. Timer1 used for high-resolution PWM on Pin 9

    2. Timer0 used for secondary PWM output (if needed)

    3. Voltage sensor data read via analog input to monitor real-time input voltage

The Arduino adjusted the PWM output dynamically based on incoming ANN values, ensuring voltage stability and minimal switching losses.

4.7 HARDWARE REQUIREMENT

This Section discusses the hardware components used in this project,

1. Arduino (ATMEGA 328P)
2. Solar Panel
3. Wind
4. Voltage Sensor module
5. Capacitor
6. Inductor
7. MOSFET
8. Diode
9. Resistor
10. Battery

11. Motor
12. LCD

4.7.1. ARDUINO (ATMEGA 328P)

Figure 4.8 Arduino

The ATmega328/P microcontroller, which is based on the Atmel AVR® core, has 32 general purpose registers that are directly coupled to the ALU and a rich instruction set, enabling quick and effective execution. It has a 6-channel 10-bit ADC, 22 I/O lines, 32KB of In-System Programmable Flash, 1KB EEPROM, 2KB SRAM, three Timer/Counters with PWM, USART, SPI, and I2C, and several power-saving modes for low power usage and fast startup. Adjacent Key Suppression® technology and Atmel's QTouch® library provide capacitive touch sensing. A bootloader or SPI can be used to reprogram the device's Flash memory because Atmel's higher-density non-volatile memory technology allows for this.

Pin diagram of ATMEGA328

A comprehensive set of tools for developing programs and systems, such as C compilers, macro assemblers, program debuggers and simulators, in-circuit emulators, and evaluation kits, are available for the ATmega328/P. The diagram below

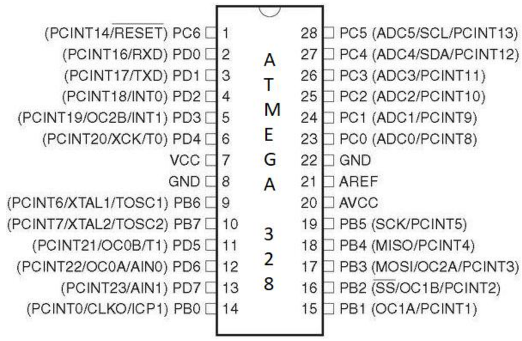

Figure 4.9 Pin diagram of ATMEGA328

4.7.2 LIQUID CRYSTAL DISPLAY (LCD):

Figure 4.10 LCD Display

When sufficient voltage is applied to an LCD, the liquid crystal molecules align in a specific direction, allowing light to rotate through a polarizer and highlight the desired characters. The LCD operates on a +5V supply with a maximum transient of 10mV, and proper adjustment of the voltage at pin 3 ensures good contrast. The module should not be removed from a live circuit, and proper isolation is needed to prevent stray voltages that can cause display flickering. LCDs are lightweight, thin, and consume low power, making them ideal for long-duration use. Since they do not emit light, backlighting is required for visibility in the dark. LCDs are durable, have a wide temperature range, and must be properly initialized before use, commonly displaying information like blood group and blood glucose levels.

4.7.3 VOLTAGE SENSOR MODULE:

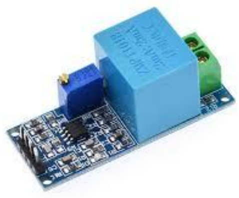

Figure 4.11 Voltage Sensor Module

The straightforward and incredibly helpful Voltage Detection Sensor Module reduces any input voltage by a factor of five using a potential divider. This enables us to monitor voltages higher than what a microcontroller can sense via its analog input pin. For instance, you can measure a voltage up to 25V using an analog input range of 0V to 5V. Additionally, this module has handy screw terminals for quick and safe wire connections.

The internal circuit diagram of the Voltage Sensor Module is given below.

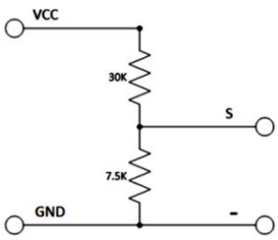

Figure 4.12 Circuit Diagram for Voltage Sensor Module

Connecting an Arduino (or other microcontroller) to a voltage sensor is easy. Connect the voltage sensor screw terminals to the VCC and GND of the voltage source that needs to be measured. Connect the voltage sensor S and - (GND) to the Arduino's analog pin and GND pin, respectively.

The formula for input and output voltage is

Vin = Vout * (R2/(R1+R2)).

Here, Vout = (analogvalue * 5 / 1024) and R1 = 30K ohm and R2 = 7.5K ohm.

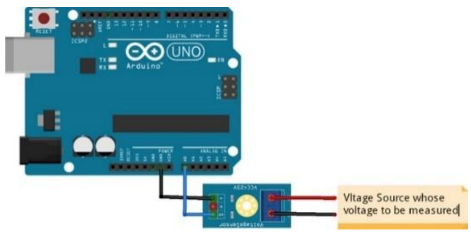

Figure 4.13 Working of Voltage Sensor Module

4.7.4 LEAD ACID BATTERY (12 V)

Figure 4.14 Lead Acid Battery (12 V)

The 12V lead-acid battery utilized in this project is chosen for its capacity to harness and deliver energy for the Luo Boost Converter and the load connected. It is reliable and continues to supply or deliver energy in a steady manner, particularly in renewable energy, which is why it is chosen for its deep-cycle characteristics that allow for repeated charges and discharges. The rating of 12V is appropriate for the converter and how it would connect to the other components of the system. Its capacity, cycle life, and efficiency of energy storage should guarantee steady delivery or performance during variable power from solar or wind energy sources.

4.7.5 CAPACITOR

The project utilizes capacitors which are rated to charge and filter voltage in the Luo Boost Converter circuit, as well as to mitigate the voltage ripple. Capacitances are going to be selected for charging the circuit and filtering the high frequency noise from the circuit that produces harsh voltage level transitions and ringing. Decisions on selecting capacitors will be based on the capacitor capacitance's rating, the voltage rating and equivalent series resistance (ESR). When using the converter, it is important to more accurately select capacitors for sustained and consistent voltage output and good energy storage capability.

Figure 4.15 Capacitor

4.7.6 MOSFET (METAL OXIDE SEMICONDUCTOR FILED EFFECT TRANSISTOR)

The MOSFET (Metal-Oxide-Semiconductor Field-Effect Transistor) that has been adopted in this project was selected for its effectiveness in switching the signal in the Luo Boost Converter. An MOSFET acts as a fast switch to regulate the power transfer through the circuit. The MOSFET is determined according to specified voltage ratings and continuous current rating to allow minimum conduction losses and fast switching cycle times. The MOSFET is critical to the efficiency of the converter by minimizing power dissipation and increasing the overall reliability of the system. Drain-source voltage (Vds), current ratings (Id) and gate threshold voltage (Vgs) will be defined depending on the final selection of the MOSFET to be used.

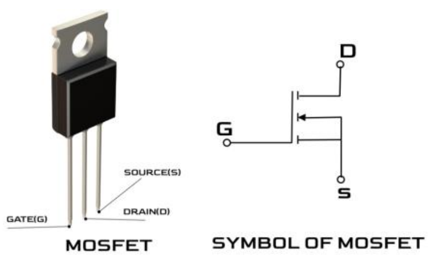

Figure 4.16 MOSFET

4.7.7 DIODE

The PN diode that is used in this project will be effective in the Luo Boost Converter circuit for rectification. The diode is responsible for allowing current in one direction and blocking current in the reverse direction. Without the diode, the Luo Boost Converter would not function properly. The diode selected for this project depends on its voltage and current limitation in a forward bias (current) direction to ensure the system is stable with minimal losses. Ratings for forward voltage, reverse current, and peak repetitive reverse voltage can be specified once a model of the diode is selected.

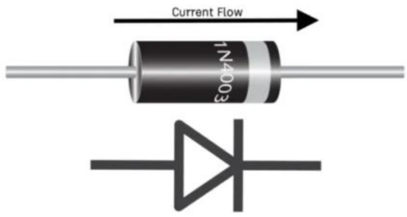

Figure 4. 17 Diode

4.7.8 MOTOR

The motor in this project, a 12V DC motor, is specifically made for operation at 12V and delivers consistent performance in numerous applications. It is selected because it is efficient and appropriate for systems that need moderate power output, like renewable energy-based systems. It is perfect for powering mechanical loads in applications such as electric vehicles or other automation systems.

Figure 4.18 DC Motor

4.7.9 SOLAR PANEL

A solar panel is designed to change solar energy into electricity with photovoltaic (PV) cells. The solar panel in our project is rated with a power of 10 Wp at an operation voltage of 12 V, maximum rated current of 0.54 A, a VOC of 21.5 V, and ISC of 0.50 A with a tolerance of ±3%. This information is useful when considering long term operation in any renewable energy system.

Figure 4.19 Solar Panel

4.7.10 WIND

The generator is converting the wind energy into electrical energy available and utilized by simple components of the blades mounted on a center hub with a generator. Wind flows over the blades which causes the blades to turn due to their aerodynamic characteristics that transform the wind's kinetic energy into mechanical energy. The turning runs the generator converting mechanical movement into electrical energy. The design of the blades, material, and size defines the efficiency of the system and optimizes the amount of energy or power extracted from a range of wind velocities.

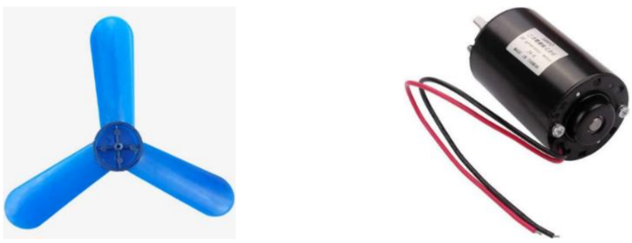

Figure 4.20 Wind Turbine and Blade

4.7.11 INDUCTOR

The inductor used in this project has 1000 μH inductance, and peak DC resistance of 1.0 Ω, and rated current capacity of 400mA DC, which all make it a suitable candidate for storage and transfer of energy in the Luo Boost Converter.

Figure 4.21 Inductor

4.7.12 RESISTOR

Since some circuit elements are resistive, the resistor chosen for this project was chosen to minimize power dissipation and guarantee steady operation. This led to an increase in system efficiency because the circuit was unable to control the required circuit conditions based on the current and voltage levels.

Figure 4.22 Resistor

4.8 SOFTWARE DESCRIPTION

4.8.1. ARDUINO DEVELOPMENT ENVIRONMENT

The Arduino IDE is what you will use to write, compile, and upload your code to an Arduino-compatible board. It consists of a text editor, menus, a toolbar, host terminal and message area.

1. **Writing Sketches**

Programs created for Arduino that are stored with the ino extension (which used to be de in previous IDE versions) are called sketches. Basic features like cut, copy, paste, search, and replace are all available in the IDE. While the console shows outputs, including error messages, the message box provides feedback on saving and exporting. Quick access to validate, upload, generate, unlocked, and store sketches, as well as to launch the Serial Monitor to monitor them is provided by the toolbar.

2. **Sketchbook**

The Integrated Development Environment uses a default directory called the Sketchbook to store user-created sketches. This location can be changed from the Preferences dialog.

3. **Tabs and Multiple Files**

Projects can be organized into multiple files, each represented by tabs. Supported file types include. ino, .c, .cpp, and .h.

4. **Uploading Sketches**

Users must choose a suitable motherboard and serial interface from the Tools panel prior to uploading. Uploading uses the Arduino bootloader, which enables code transfer without additional hardware. The process is often automatic with modern boards, while older boards may require a manual reset.

5. **Libraries**

Libraries extend the functionality of Arduino by adding support for various hardware and software features. They can be imported from the Sketch > Include Library menu and may increase the memory usage of the sketch.

4.8.2. MATLAB DEVELOPMENT ENVIRONMENT

MATLAB (Matrix Laboratory) is a high-performance software designed for matrix computations, data analysis, and algorithm development. It integrates computation, visualization, and programming in a user-friendly environment.

6. Basic Features

MATLAB works primarily with matrices and arrays. It provides functions for data manipulation, numerical analysis, and algorithm development. Its powerful scripting language supports both small-scale (quick tasks) and large-scale (full applications) programming.

7. Starting and Quitting

MATLAB can be started via the desktop icon (Windows). To exit, select Exit MATLAB or type quit in the Command Window.

1. MATLAB Desktop Components

1. Command Window: Execute commands and run scripts.
2. Editor/Debugger: Create and debug .m files.
3. Workspace Browser: View and manage current session variables.
4. Current Folder: Shows files in the active directory.
5. Command History: Logs previously executed commands.

6. Help System

The Help Browser gives access to MATLAB documentation and tutorials. Users can search for functions or topics using the Help Navigator.

1. Toolboxes

Toolboxes are add-on libraries that provide functions for specialized tasks such as:

1. Signal and image processing
2. Control systems
3. Machine learning

4. Neural networks

5. Simulation and modelling

1. Graphics and Visualization

MATLAB offers robust 2D and 3D plotting capabilities. It allows the creation of interactive plots, animations, and graphical user interfaces (GUIs).

1. Matrix Manipulation

MATLAB's core strength is its ability to efficiently handle and compute with matrices. Basic operations include:

1. Addition, subtraction, multiplication

2. Transposition, inversion

3. Eigenvalue and SVD computations

1. Programming and Scripting

MATLAB allows creating scripts and functions using control flow statements (if, for, while), data structures (arrays, cells, structs), and object-oriented programming. It also supports integrating external programs (e.g., C or FORTRAN) via APIs.

2. External Program Integration

Using commands like!, users can run system-level programs from within MATLAB, allowing for automation and multi-software workflows.

1. Saving and Loading Workspaces

1. Use save to store the current session variables in .mat files.

2. Use load to retrieve previously saved data.

4.9 CODE FOR TRAINING ANN:

```
import pandas as pd

import numpy as np

import tensorflow as tf

from tensorflow import keras

from sklearn.model_selection import train_test_split

from sklearn.preprocessing import MinMaxScaler

import joblib

voltages = np.linspace(0, 24, 500)  # 0V to 24V

frequencies = 100 + (voltages * (500 - 100) / 24)  # Mapping 100 Hz to 10kHz

duty_cycles = 5 + (voltages * (20 - 5) / 24)  # Mapping 5% to 80%

# Create DataFrame

data = pd.DataFrame({'Voltage': voltages, 'Frequency': frequencies, 'DutyCycle': duty_cycles})

data.to_csv("pwm_data.csv", index=False)  # Save dataset

# Load Dataset

df = pd.read_csv("pwm_data.csv")

X = df[['Voltage']].values  # Input: Voltage

y = df[['Frequency', 'DutyCycle']].values  # Output: Frequency & Duty Cycle

# Normalize Data

scaler_x = MinMaxScaler()

scaler_y = MinMaxScaler()
```

```
X_scaled = scaler_x.fit_transform(X)
y_scaled = scaler_y.fit_transform(y)
# Save Scalers
joblib.dump(scaler_x, "scaler_x.pkl")
joblib.dump(scaler_y, "scaler_y.pkl")
# Train-Test Split
X_train, X_test, y_train, y_test = train_test_split(X_scaled, y_scaled, test_size=0.2,
random_state=42)
# Build ANN Model
model = keras.Sequential([
    keras.layers.Dense(10, activation="relu", input_shape=(1,)),
    keras.layers.Dense(10, activation="relu"),
    keras.layers.Dense(2, activation="linear")  # Output: Frequency & Duty Cycle])
model.compile(optimizer="adam", loss="mse", metrics=["mae"])
# Train Model
model.fit(X_train, y_train, epochs=200, batch_size=16, validation_data=(X_test,
y_test))
# Save Model
model.save("ann_pwm_model.h5")
print("Model trained and saved successfully!")
import pandas as pd
import numpy as np
```

```
import tensorflow as tf
import serial
import time
import joblib  # For loading scalers
# Load trained ANN models
model1 = tf.keras.models.load_model("ann_pwm_model.h5")  # First ANN Model
# Load scalers
scaler_X1 = joblib.load("scaler_X.pkl")
scaler_y1 = joblib.load("scaler_y.pkl")
# Set the correct COM port for Arduino
arduino_port = "COM3"  # Change based on your system
baud_rate = 9600
try:
    ser = serial.Serial(arduino_port, baud_rate, timeout=1)
    time.sleep(2)  # Allow Arduino to reset
except serial.SerialException:
    print("Error: Could not open serial port. Check the connection.")
    exit()
print("Serial connection established!")
# Function to predict PWM values using Model 1
def predict_pwm1(voltage):
    voltage_scaled = scaler_X1.transform(np.array([[voltage]]))
```

```
    pred_scaled = model1.predict(voltage_scaled)
    pred = scaler_y1.inverse_transform(pred_scaled)
    frequency, duty_cycle = pred[0]
    return int(frequency), int(duty_cycle)
# Main loop to read voltage values and send PWM settings to Arduino
vv=0
kk=0
while True:
    try:
        # Example: Read V1 and V2 dynamically (Replace with actual input method)
        data = ser.readline().decode().strip()
        values = data.split(',')
        if len(values) == 2:
            vv, kk = values
            print(vv)
        # Predict PWM values
        #F1, D1 = predict_pwm1(V1-float(vv))
        #F2, D2 = predict_pwm2(V2-float(kk))
        F1, D1 = predict_pwm1(float(vv))
        # Send values to Arduino
        command1 = f"F1{F1}\nD1{D1}\n"  # Format: F1 (Freq), D1 (Duty)
        #command2 = f"F2{F2}\nD2{D2}\n"  # Format: F2 (Freq), D2 (Duty)
```

```
        ser.write(command1.encode())  # Send PWM1 settings
        #ser.write(command2.encode())  # Send PWM2 settings
        print(f"Sent to Arduino - PWM1: {F1}Hz, {D1}%")
        time.sleep(1)  # Adjust delay as needed
    except KeyboardInterrupt:
        print("\nStopping...")
        ser.close()
        break
    except Exception as e:
        print(f"Error: {e}")
```

ARDUINO CODE:

```
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
// Define LCD Address (change if needed)
LiquidCrystal_I2C lcd(0x27, 16, 2);
// Define PWM Pins
#define PWM1 9   // PWM output on Pin 9 (Timer1)
#define PWM2 5   // PWM output on Pin 5 (Timer0)
// Define Analog Input
#define ANALOG_IN_PIN A0
// Floats for ADC voltage & Input voltage
float adc_voltage = 0.0;
```

```
float in_voltage = 0.0;
// Floats for resistor values in voltage divider
float R1 = 30000.0;
float R2 = 7500.0;
// Float for Reference Voltage
float ref_voltage = 5.0;
// Integer for ADC value
int adc_value = 0;
void setup() {
  pinMode(PWM1, OUTPUT);
  pinMode(PWM2, OUTPUT);
  pinMode(A0, INPUT);
  pinMode(A1, INPUT);
  Serial.begin(9600);
  // Initialize LCD
  lcd.begin();
  lcd.backlight();
  lcd.setCursor(0, 0);
  lcd.print("Initializing...");
  // Configure Timer1 (Pin 9 - Fast PWM)
  TCCR1A = (1 << COM1A1) | (1 << WGM11);  // Fast PWM, non-inverting
  TCCR1B = (1 << WGM13) | (1 << WGM12) | (1 << CS10); // No prescaler
```

```
  ICR1 = 15999; // Default 1kHz frequency
  OCR1A = ICR1 / 2; // 50% Duty Cycle
  // Configure Timer0 (Pin 5 - Fast PWM)
  TCCR0A = (1 << COM0B1) | (1 << WGM01) | (1 << WGM00); // Fast PWM,
non-inverting
  TCCR0B = (1 << CS01); // Prescaler 8 (Default ~976 Hz)
  OCR0B = 127; // 50% Duty Cycle
  lcd.clear();
}
void loop() {
  // Read the Analog Input
  adc_value = analogRead(ANALOG_IN_PIN);
  // Determine voltage at ADC input
  adc_voltage  = (adc_value * ref_voltage) / 1024.0;
  // Calculate voltage at divider input
  in_voltage = adc_voltage * (R1 + R2) / R2;
  // Display Voltage on LCD
  lcd.setCursor(0, 0);
  lcd.print("Voltage: ");
  lcd.print(in_voltage, 2);
  lcd.print(" V  "); // Extra spaces to clear old values
  // Read Serial Commands for PWM Control
```

```
  if (Serial.available()) {
    String input = Serial.readStringUntil('\n');
    input.trim();
    Serial.print(in_voltage);
Serial.print(",");
Serial.print(in_voltage);
    Serial.println();
    if (input.startsWith("F1")) { // Set Frequency for PWM1 (Pin 9 - Timer1)
      int freq1 = input.substring(2).toInt();
      if (freq1 >= 100 && freq1 <= 10000) {
        ICR1 = (16000000 / freq1) - 1;
      } //else //Serial.println("Invalid Frequency! Range: 100-10k Hz.");
    }
    else if (input.startsWith("F2")) { // Set Frequency for PWM2 (Pin 5 - Timer0)
      int freq2 = input.substring(2).toInt();
      if (freq2 >= 100 && freq2 <= 5000) {
        int prescaler = (freq2 > 2500) ? 1 : 8; // Auto-select prescaler
        OCR0B = (freq2 > 2500) ? (16000000 / (freq2 * 2) - 1) : (2000000 / (freq2 *
2) - 1);
      } //else //Serial.println("Invalid Frequency! Range: 100-5k Hz.");
    }
```

```
    else if (input.startsWith("D1")) { // Set Duty Cycle for PWM1
      int duty1 = input.substring(2).toInt();
      if (duty1 >= 0 && duty1 <= 100) {
        OCR1A = (ICR1 * duty1) / 100;
      }//else //Serial.println("Invalid Duty! 0-100%.");
    }
    else if (input.startsWith("D2")) { // Set Duty Cycle for PWM2 (Pin 5 - Timer0)
      int duty2 = input.substring(2).toInt();
      if (duty2 >= 0 && duty2 <= 100) {
        OCR0B = (255 * duty2) / 100;
      } //else //Serial.println("Invalid Duty! 0-100%.");
    }
    //else //Serial.println("Invalid Input! Use 'F1xxxx' (PWM1), 'F2xxxx' (PWM2),
'D1xx', 'D2xx'.");
  }
  delay(500);
}
```

CHAPTER 5

RESULTS AND DISCUSSION

5.1 SIMULATION RESULTS

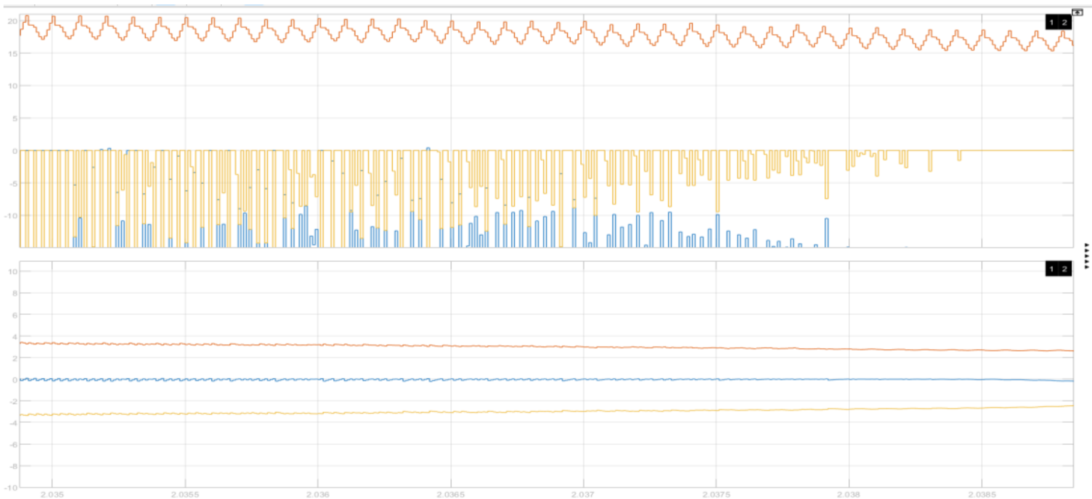

Figure 5.1 llustrates the voltage and current characteristics in a 3-phase system

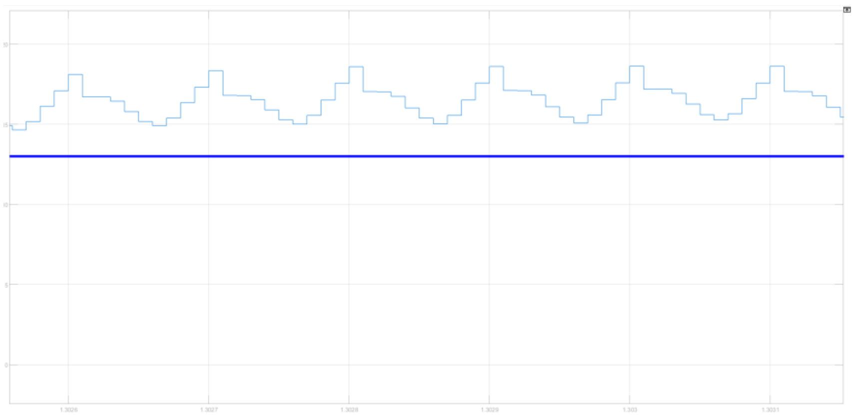

Figure 5.2 Shows the input and output characteristics of LUO converter

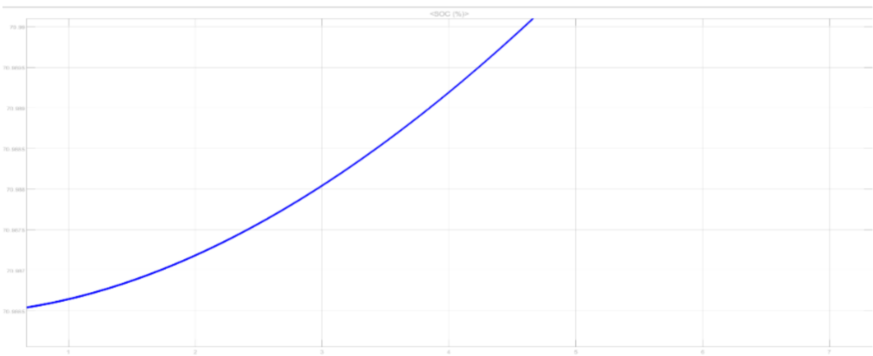

Figure 5.3 Shows the EV Battery SOC

5.2 HARDWARE RESULTS

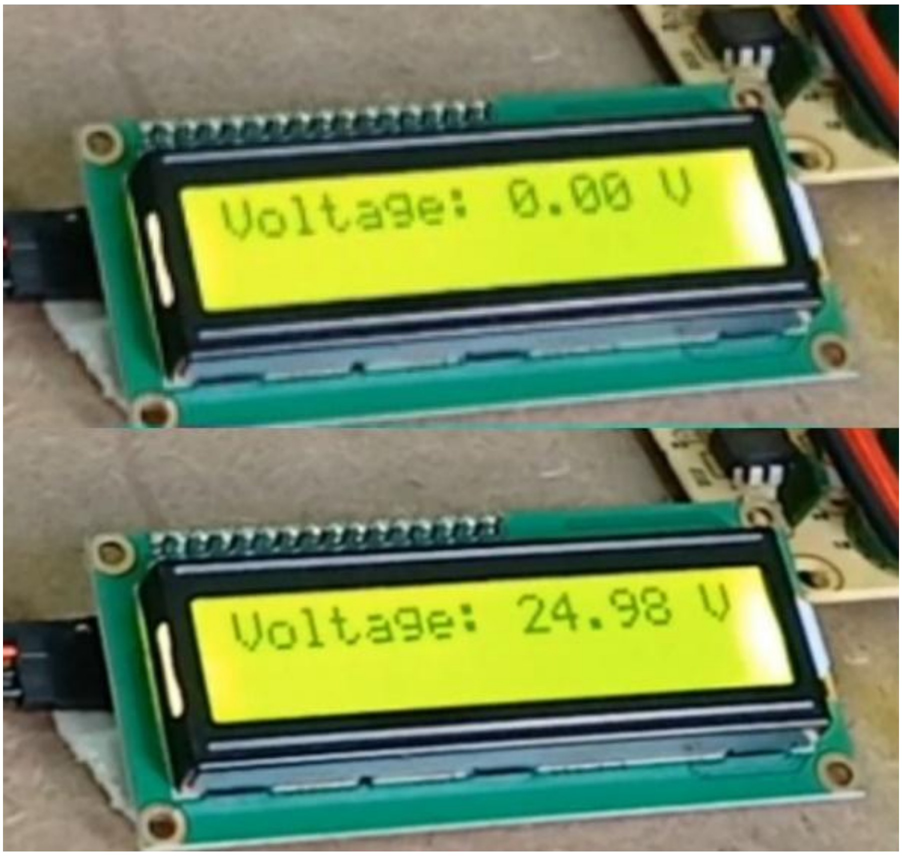

Figure 5.4 Hardware Result of Luo Boost Converter under Solar Input Conditions

The hardware setup demonstrates the performance of the Luo Boost Converter when powered by a 12V solar panel. Without any load connected, the converter effectively boosts the input to approximately 24V, showcasing its no-load voltage gain. When a load is connected, the output voltage varies based on the load condition, dynamically adjusting to provide stable boosted output. This confirms the converter's ability to efficiently step up voltage from solar input for practical use, such as charging batteries or powering EV systems.

CHAPTER 6

CONCLUSION AND FUTURE SCOPE

6.1 CONCLUSION

The suggested Hybrid Renewable Energy-Based EV Charging Station successfully integrates solar, wind, and auxiliary AC sources with a Luo Boost DC-DC Converter controlled by an Artificial Neural Network (ANN)-PID based control mechanism. This combined system presents a highly adaptive, intelligent, and energy-efficient solution specifically suited for contemporary EV infrastructure requirements. The strength of this system is that it's able to respond dynamically to fluctuating environmental conditions—be it changing solar irradiance, wind speeds, or grid availability. The ANN controller, which is optimized for real-time converter output, provides stable voltage delivery with reduced switching losses and increased overall power conversion efficiency.

There are especially used in off-grid and semi-urban areas where the stabilty of the grid may be mediocre. The system also enables smart grid capabilities with intelligent demand response and energy sharing within the network. The modular and compact approach of these power systems allows for scalability and flexibility across multiple levels of applications, from residential EV chargers to community-scale energy hubs. The infusion of AI controlled use of renewable energy, high-efficiency power electronics, everyday programming of demand response, matches current trends for sustainable energy and climate resilience and adds real value to collective global goals like carbon neutrality and decentralized energy access.

6.2 FUTURE SCOPE

3. **IoT and AI Integration:** Connect Arduino with IoT platforms (Blynk, Ubidots, ThingSpeak) for remote sensor monitoring and use MATLAB for intelligent predictions, fault detection, and automation**.**

4. **Advanced Data Analysis:** Use MATLAB's libraries for deep analysis and visualization of Arduino-collected data.

5. **Real-Time Monitoring and Control:** Implement closed-loop systems where MATLAB processes data and controls Arduino devices dynamically.

6. **Wireless Communication:** Employ Wi-Fi, Bluetooth, Zigbee, or LoRa modules for remote data transfer from Arduino to MATLAB.

7. **Embedded System Prototyping:** Simulate and test complete embedded systems in MATLAB/Simulink before Arduino deployment.

8. **Education and Research:** Offer a low-cost platform for learning and research in electronics, robotics, and AI.

9. **Industry 4.0 Applications:** Enable smart automation and predictive maintenance by integrating Arduino with MATLAB analytics.

10. **GUI Development:** Create user-friendly GUIs using MATLAB App Designer to control and monitor Arduino systems easily.

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