BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY
DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

EEE 316 (Power Electronics Laboratory)

Final Project Report

Section: C1 Group: 08

INDUSTRIAL POWER CONTROL BY INTEGRAL CYCLE SWITCHING

Course Instructors:

Ashikur Rahman Jowel, Lecturer
Azazul Islam, Adjunct Lecturer

Signature of Instructor: ______________________________

Academic Honesty Statement:

IMPORTANT! Please carefully read and sign the Academic Honesty Statement, below. Type the student ID and name, and put your signature. *You will not receive credit for this project experiment unless this statement is signed in the presence of your lab instructor.*

"In signing this statement, We hereby certify that the work on this project is our own and that we have not copied the work of any other students (past or present), and cited all relevant sources while completing this project. We understand that if we fail to honor this agreement, We will each receive a score of ZERO for this project and be subject to failure of this course."

Signature: ______________________________

Full Name: Md. Hasan Newaz
Student ID: 1906135

Signature: ______________________________

Full Name: Md. Asif Kabir
Student ID: 1906153

Signature: ______________________________

Full Name: Tamim Hasan Bhuiyan
Student ID: 1906154

Signature: ______________________________

Full Name: Md. Shipon Hossain
Student ID: 1906155

1 Abstract

The proposed project is designed to implement integral cycle switching for the precise control of AC power in linear loads, such as those found in electric furnaces, particularly heaters. Integral cycle switching entails the selective removal of complete AC cycles or specific portions thereof from the signal. To achieve this, we employ a microcontroller belonging to the ATmega328 family programmed in C language. The microcontroller's task is to ensure that upon the application of the AC signal to the load, the actual time-averaged voltage at the load remains proportionally lower than the complete signal.

To facilitate this, a comparator is incorporated for zero-crossing detection, and its output is fed to the microcontroller as an interrupt. Subsequently, the microcontroller responds to these interrupts by generating precise triggering pulses. These generated pulses serve as the driving force for opto-isolators which, in turn, are responsible for triggering the TRIAC. Consequently, the integral cycle switching is effectively implemented in accordance with the input conditions interfaced with the microcontroller.

To validate the output, a lamp is utilized in this system. This meticulous approach to integral cycle switching holds potential for applications demanding fine control over AC power delivery to linear loads.

2 Introduction

Phase-controlled switching is commonly used to regulate the speed of single-phase induction motors. However, this method tends to introduce significant high-order harmonics into the system. Alternatively, integral cycle control can be employed, but it introduces sub-harmonics in the power line.

To address these issues, a novel approach is proposed: discontinuous phase-controlled switching. This technique combines both phase control and integral-cycle switching to achieve voltage control. Precise voltage adjustments and step-wise voltage changes are achieved through the former and latter methods, respectively.

In the case of rotor fan-type loads, the performance of this proposed controller is notably enhanced when applied specifically to control the main winding voltage. However, for constant-torque loads, traditional voltage controllers have limited speed control capabilities. In such scenarios, the distinct sub-harmonics introduced by the integral-cycle controller are harnessed. These sub-harmonics compel the rotor to lock at desired sub-synchronous speeds. So, various types of motors can operate seamlessly over a broad range and achieve near-sub-synchronous speeds under aerated conditions for constant-torque loads. This innovative approach holds promise for optimizing motor control in different operational scenarios.

3 Design

3.1 Problem Formulation

The project aims to develop a power control system for industrial applications that utilizes integral cycle switching techniques to regulate power without introducing harmful harmonics into the electrical grid. The formulation of this problem can be summarized as follows:

3.1.1 Identification of Scope

The project scope encompasses the design, development, and implementation of a power control system using integral cycle switching. It includes the study of harmonic generation in industrial power systems and the creation of a solution that ensures efficient power regulation while mitigating harmonic distortion. The scope also covers testing, validation, and potential applications in industrial settings.

3.1.2 Literature Review

The literature review examines existing research on industrial power control, integral cycle switching (ICS), and harmonic distortion mitigation:

1. Industrial Power Control: Traditional methods often introduce harmonics, impacting efficiency and equipment lifespan.

2. Integral Cycle Switching (ICS): ICS minimizes harmonics by adjusting conduction angles, showing promise in various applications.

3. Harmonic Distortion: Nonlinear loads and switching operations lead to harmonic distortion, affecting equipment and energy costs.

4. Existing Solutions: Passive/active filters and control algorithms address harmonics but have limitations.

5. Research Gaps: A cost-effective and adaptable ICS-based power control solution is needed for industrial settings.

6. Project Objectives: The project aims to develop an ICS-based power control system, addressing existing limitations, and improving industrial power quality.

3.1.3 Formulation of Problem

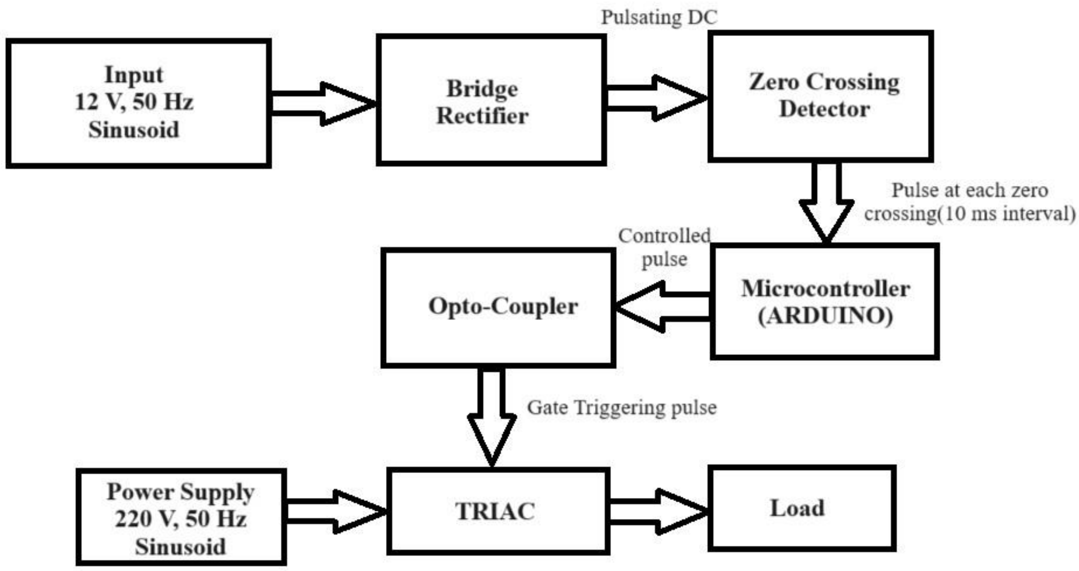
The project seeks to address the challenge of achieving precise industrial power control using integral cycle switching while avoiding the generation of disruptive harmonics in the electrical system. This problem arises from the need for efficient power regulation in industrial settings without compromising power quality and equipment performance.

3.1.4 Analysis

This phase involves a comprehensive assessment of the proposed industrial power control system's design. It includes evaluating the system's architecture, component selection, and integration to ensure it effectively implements integral cycle switching while minimizing harmonic generation. Additionally, considerations for scalability, cost-effectiveness, and adaptability to various industrial environments are key aspects of the design analysis.

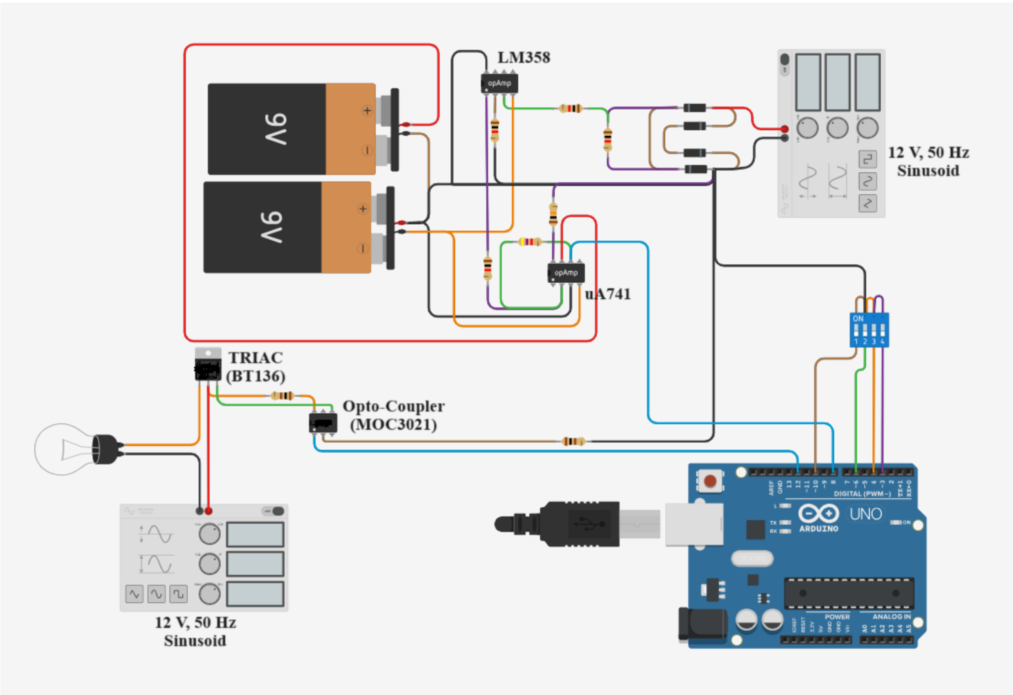
3.2 Design Method:

The following flow graph denotes how our project functions:

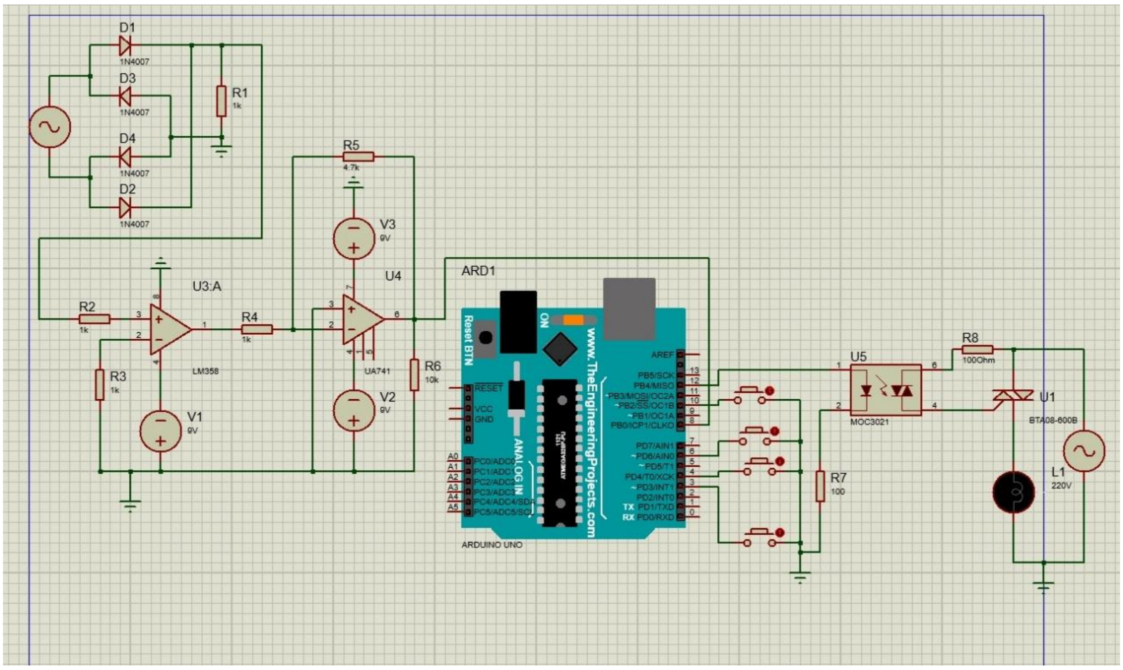


Firstly, we will take a AC signal of 12V magnitude that will be passed through a Bridge Rectifier. The pulsating DC output of the rectifier is fed to a zero crossing detector which will give a pulse when the pulsating DC signal crosses zero voltage level. The zero crossing detector provides its output to the microcontroller ARDUINO. We set a ARDUINO program in such a way that the user can manually control how many cycles of the output will remain ON and OFF. Suppose, if the user presses the first push button, then one cycle will remain ON. If the user presses the second push button, then two cycle will remain ON. In such a way, we programmed for four cycle with the help of four push button. According to the push button pressed, the microcontroller will keep the pulse for a particular period of time and rest of the pulses will cut out. The output pulse from microcontroller is used to trigger the gate of TRIAC switch. A opto-coupler is placed in between microcontroller and TRIAC to separate the control part of the project from the power part. According to the pulse triggering at gate, TRIAC will turn ON and desired cycles will pass to the load from power supply.

3.3 Circuit Diagram



3.4 Simulation Model



3.5 Full Source Code of Firmware

```
const int inputPin3 = 3;
const int inputPin4 = 4;
const int inputPin6 = 6;
const int inputPin10 = 10;
const int outputPin = 12;

void setup() {
  pinMode(inputPin3, INPUT_PULLUP);
  pinMode(inputPin4, INPUT_PULLUP);
  pinMode(inputPin6, INPUT_PULLUP);
  pinMode(inputPin10, INPUT_PULLUP);
  pinMode(outputPin, OUTPUT);
}

void loop() {
  // Check if inputPin3 is HIGH
  if (digitalRead(inputPin3) == LOW) {
    digitalWrite(outputPin, HIGH); // Set output to HIGH
    delay(20);                     // Keep it HIGH for 20 ms
    digitalWrite(outputPin, LOW);  // Set output to LOW
    delay(60);                     // Keep it LOW for 60 ms
  }
  // Check if inputPin4 is HIGH
  else if (digitalRead(inputPin4) == LOW) {
    digitalWrite(outputPin, HIGH); // Set output to HIGH
    delay(40);                     // Keep it HIGH for 40 ms
    digitalWrite(outputPin, LOW);  // Set output to LOW
    delay(40);                     // Keep it LOW for 40 ms
  }

  else if (digitalRead(inputPin6) == LOW) {
    digitalWrite(outputPin, HIGH); // Set output to HIGH
    delay(60);                     // Keep it HIGH for 60 ms
    digitalWrite(outputPin, LOW);  // Set output to LOW
    delay(20);                     // Keep it LOW for 20 ms
  }
  // Check if inputPin10 is HIGH
  else if (digitalRead(inputPin10) == LOW) {
    digitalWrite(outputPin, HIGH); // Set output to inputPin2's
state
  }
  // If none of the conditions are met, set the output to LOW
  else {
    digitalWrite(outputPin, LOW);
  }
}
```

Table: Source Code for the main program

4 Implementation

4.1 Description

This is the INDUSTRIAL POWER CONTROL BY INTEGRAL CYCLE SWITCHING circuit.

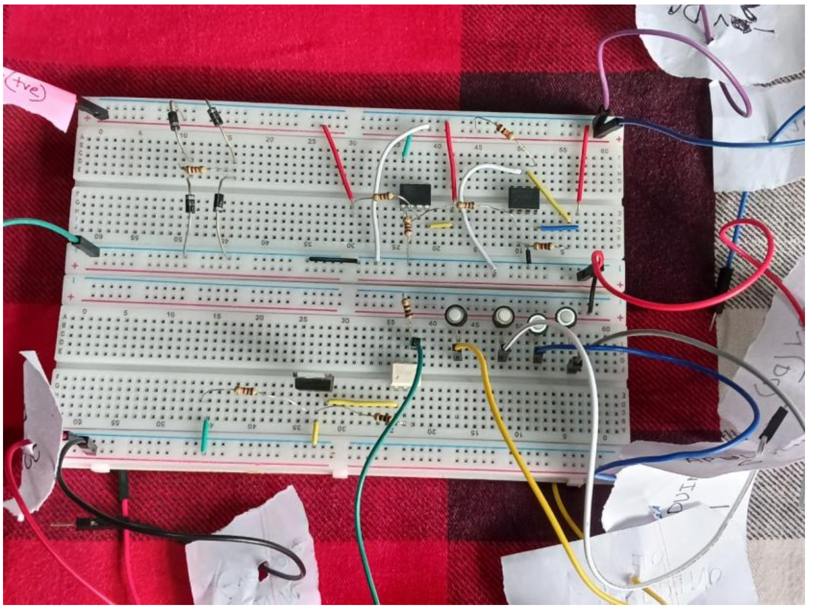
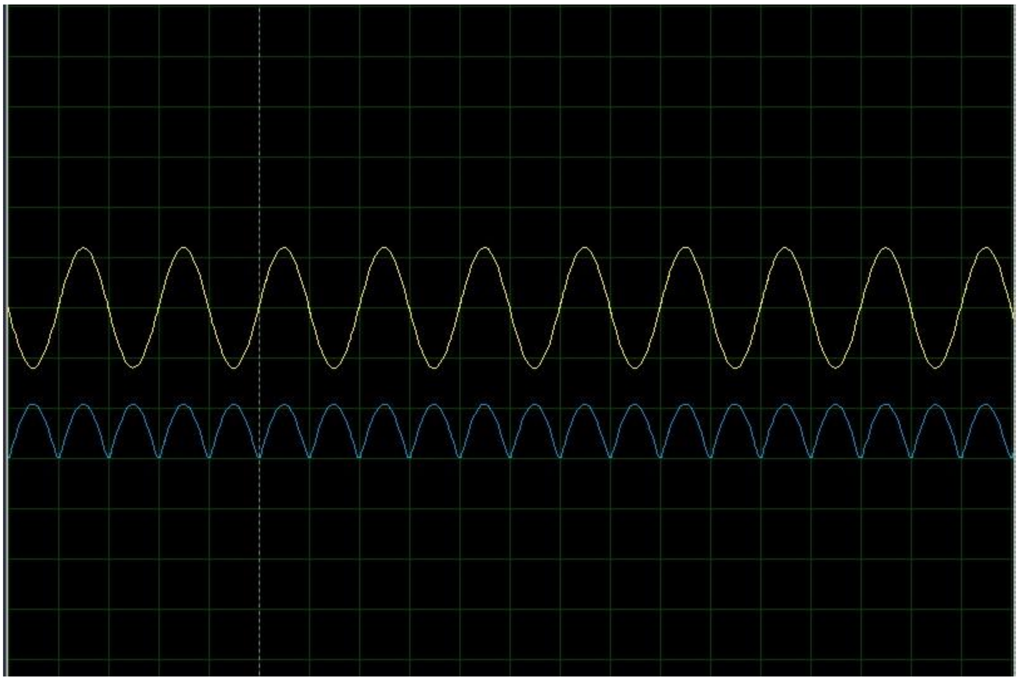


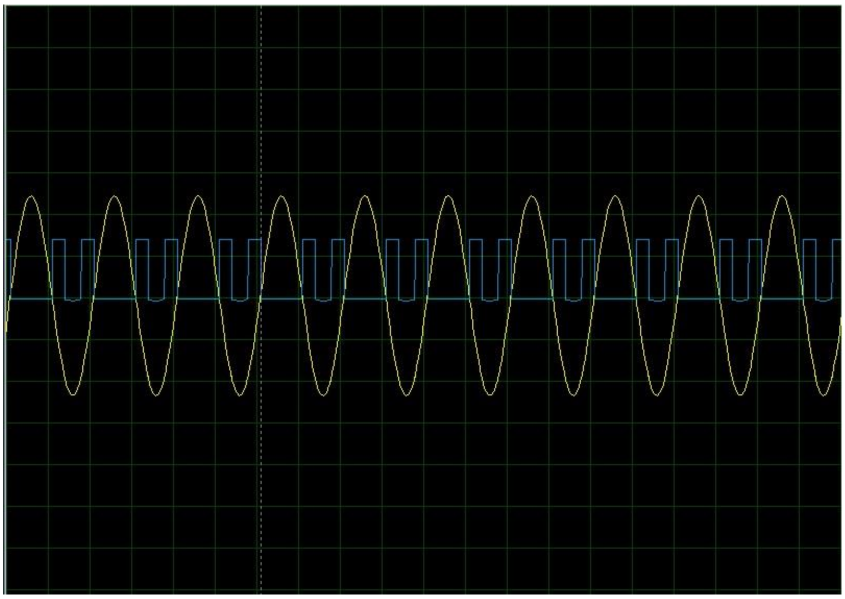
Figure: Implementation of Design

4.2 Experiment and Data Collection

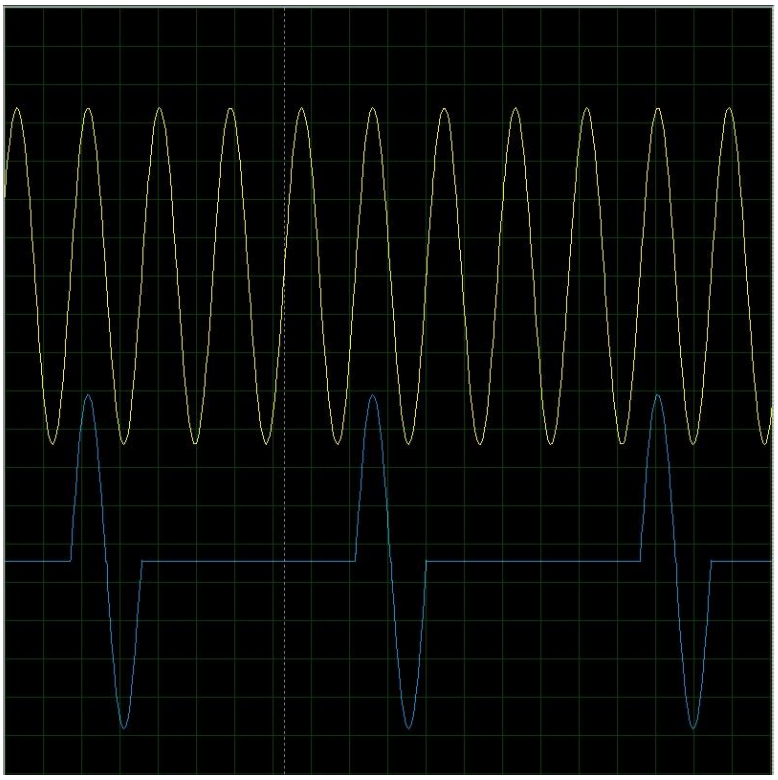
Input vs Pulsating DC (Input-Yellow, Pulsating DC-Blue)



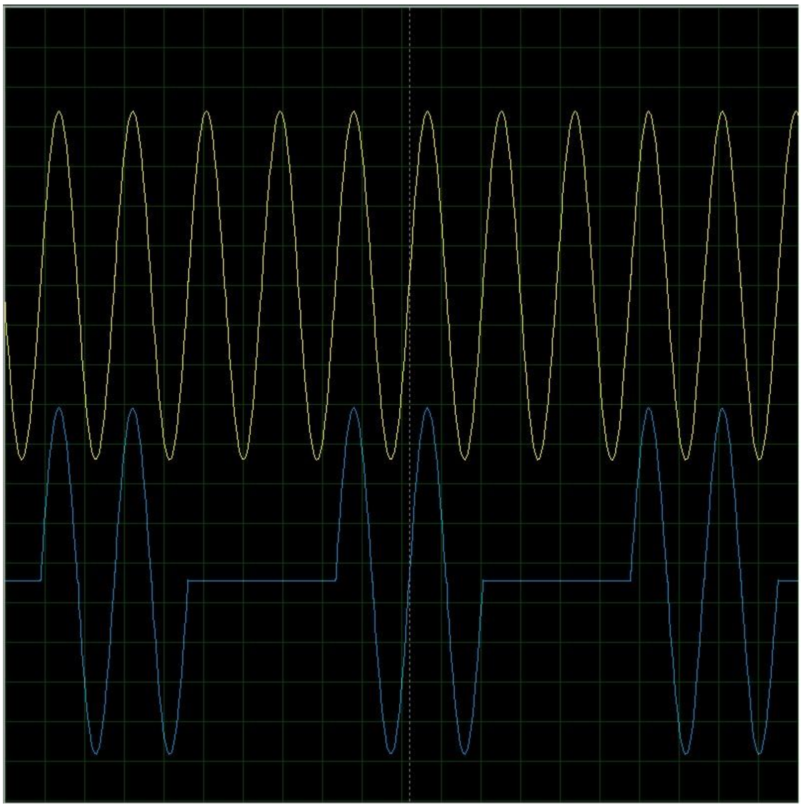
Input vs Zero Crossing Detector Output (Input-Yellow, Zero Crossing-Blue)



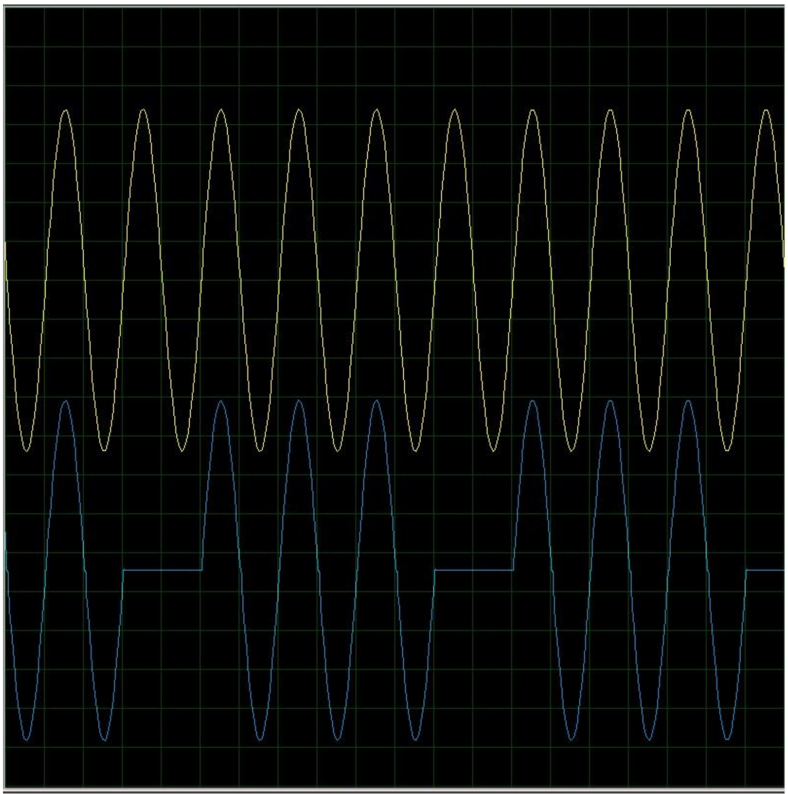
Power Supply vs Output (1 cycle ON, 3 cycle OFF)



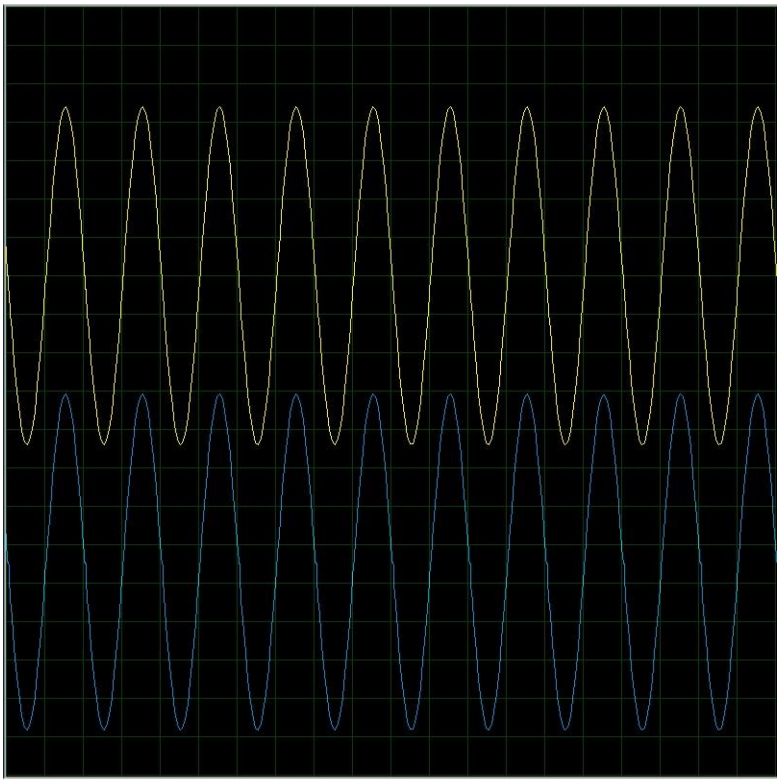
Power Supply vs Output (2 cycle ON, 2 cycle OFF):



Power Supply vs Output (3 cycle ON, 1 cycle OFF):



Power Supply vs Output (4 cycle ON):



4.3 Data Analysis

We have performed the project both in hardware and software (Proteus Simulation). We received an expected output of desired cycle time ON – OFF from both the software simulation and hardware implementation. However, a little bit of noise arrives while performing the project in hardware.

5 Design Analysis and Evaluation

5.1 Novelty

The originality of this project lies in its innovative approach to industrial power control. By utilizing integral cycle switching (ICS) to regulate power without introducing harmful harmonics, this project addresses a critical need in industrial settings:

1. Unique Harmonic Mitigation: The project's focus on harmonic mitigation through ICS sets it apart from conventional power control methods. It offers a novel solution to a persistent problem in industrial environments.

2. Adaptability: The project aims to design a system that is adaptable to diverse industrial scenarios, a feature often lacking in existing solutions. This adaptability is a novel approach to achieving efficient power control.

3. Cost-Effectiveness: By combining the advantages of ICS with an emphasis on cost-effectiveness, this project offers a unique value proposition. It aims to provide a practical solution that aligns with the financial constraints of industrial operations.

4. Comprehensive Approach: The project covers the entire spectrum from design and development to implementation, making it a holistic solution for industrial power control. This comprehensive approach distinguishes it from narrow-focused research endeavors.

In summary, the originality of this project lies in its innovative application of integral cycle switching to address harmonic issues in industrial power control. It combines adaptability, cost-effectiveness, and a holistic approach to offer a unique and valuable contribution to the field.

5.2 Design Considerations

5.2.1 Considerations to public health and safety

Ensuring public health and safety is paramount in any project, particularly one involving industrial power control. Here are the key considerations to address:

i) Electrical Safety: Implement stringent safety measures to prevent electrical hazards, including electrical shock, short circuits, and fire. Ensure compliance with industry standards and regulations for electrical systems.

ii) Hazardous Materials: If the project involves the use of hazardous materials, handle and store them in accordance with safety protocols. Provide adequate training and protective equipment for personnel working with these materials.

iii) System Failures: Develop safeguards to minimize the risk of system failures that could disrupt industrial processes and compromise safety. Implement backup power systems or fail-safe mechanisms where necessary.

iv) Emergency Response: Establish clear emergency response procedures and provide training to project personnel. Ensure the availability of fire extinguishers, first-aid kits, and emergency shutdown protocols.

v) Environmental Impact: Consider the environmental impact of the project, especially in terms of emissions, chemical waste, and noise pollution. Mitigate these effects to protect public health and the environment.

vi) Occupational Health: Prioritize the health and safety of workers involved in the project. This includes providing proper personal protective equipment (PPE), addressing ergonomic concerns, and monitoring workplace conditions.

vii) Noise Control: Industrial power control systems can generate significant noise. Implement noise control measures to protect the hearing health of workers and nearby residents.

viii) Community Awareness: Communicate with the local community about the project's potential impacts, safety measures, and emergency contact information. Address any concerns or questions from the community.

By carefully addressing these considerations throughout the project's lifecycle, you can help ensure the public health and safety of both workers and the surrounding community. Additionally, collaboration with safety experts and relevant authorities can provide valuable guidance and oversight.

5.2.2 Considerations to environment

Environmental considerations are essential in any project, especially one involving industrial power control. Here are key aspects to address:

i) Emissions Reduction: Implement measures to minimize emissions of pollutants, greenhouse gases, and other harmful substances into the atmosphere. Consider energy-efficient technologies and clean energy sources to reduce the project's carbon footprint.

ii) Waste Management: Develop a comprehensive waste management plan to handle any hazardous or non-hazardous waste generated during the project. Prioritize recycling and responsible disposal methods.

iii) Resource Conservation: Strive to optimize resource use by reducing energy and water consumption. Implement energy-efficient equipment and processes to minimize the project's environmental impact.

iv) Noise Mitigation: Implement noise control measures to minimize the project's impact on the acoustic environment. This is especially important if the project is located in a residential area.

v) Biodiversity Preservation: If the project site is near natural habitats, take steps to preserve local biodiversity. Avoid disrupting ecosystems, and consider reforestation or habitat restoration if necessary.

vi) Water Management: If the project involves water use, employ sustainable water management practices, such as recycling or reusing water, to reduce consumption and minimize environmental impact.

vii) Compliance with Environmental Regulations: Ensure strict compliance with all environmental regulations, permits, and approvals. Regularly monitor and report environmental parameters as required by authorities.

viii) Environmental Impact Assessment (EIA): Conduct a thorough

environmental impact assessment to identify potential environmental risks and develop mitigation strategies. This assessment should involve experts in ecology, air quality, and water quality, among others.
ix) Sustainability Practices: Integrate sustainability principles into the project's design and operation. Consider lifecycle assessments and eco-friendly materials when feasible.
By addressing these environmental considerations, the project can minimize its impact on the environment, preserve natural resources, and ensure compliance with environmental regulations. Environmental stewardship should be an integral part of project planning and execution.

5.2.3 Considerations to cultural and societal needs

Respecting cultural and societal needs is crucial for the successful implementation of any project, including one related to industrial power control. Here are key considerations:

i) Cultural Sensitivity: Be aware of and respect the cultural heritage of the project's location. Engage with local communities and cultural experts to understand any cultural sensitivities, sacred sites, or historical significance associated with the project area.

ii) Community Engagement: Establish open and transparent communication channels with local communities. Listen to their concerns, needs, and suggestions related to the project. Address community questions and provide regular updates on project developments.

iii) Employment Opportunities: Consider the project's impact on local employment. Explore opportunities to hire local residents and provide training and skill development programs to benefit the community.

iv) Infrastructure Development: Evaluate the potential for infrastructure improvements that could benefit local communities. For example, if the project requires road upgrades or utility expansions, ensure that these improvements are mutually beneficial.

v) Environmental and Health Impacts: Assess and address any potential environmental or health impacts that may disproportionately affect nearby communities. Implement mitigation measures to protect the well-being of residents.

vi) Public Safety: Prioritize the safety of the public, including nearby residents and workers. Implement safety measures and emergency response plans to address potential hazards.

vii) Noise and Air Pollution: Minimize noise and air pollution that could disrupt the quality of life for local communities. Implement noise-reduction measures and consider air quality controls.

viii) Crisis Communication: Develop a crisis communication plan that includes strategies for addressing unexpected events or disruptions and informing the public promptly and accurately.

ix) Cultural Resource Protection: If the project site is known to contain cultural or archaeological resources, work with experts to protect and preserve these resources during construction and operation.

x) Community Benefits: Explore opportunities for the project to provide lasting benefits to the community, such as funding for local schools, healthcare facilities, or other social infrastructure.

By carefully addressing these cultural and societal considerations, the project can build positive relationships with the local community, enhance its social license to operate, and contribute to the overall well-being and development of the area. It is essential to approach the project with sensitivity and a commitment to meeting the needs and expectations of all stakeholders.

5.3 Investigations

5.3.1 Literature Review

Our investigation begins with a thorough literature review, delving into existing research to understand the landscape of industrial power control, integral cycle switching, and harmonic distortion mitigation. This crucial step lays the foundation for our project, ensuring that we build upon established knowledge and identify gaps that our research can address.

5.3.2 Experiment Design

The heart of our investigation lies in the design of experiments. We meticulously plan and structure our experiments to test the effectiveness of integral cycle switching in real-world industrial scenarios. This involves selecting appropriate equipment, defining variables, and ensuring the experiments are representative of the challenges industrial settings pose.

5.3.3 Data Analysis and Interpretation

After conducting experiments, we shift our focus to data analysis and interpretation. This phase involves processing and evaluating the data collected during experiments. Our aim is to draw meaningful conclusions, assess the performance of integral cycle switching, and identify any necessary adjustments or improvements to our power control system. This data-driven approach guides our project's development and ensures its effectiveness in mitigating harmonic distortions while regulating industrial power.

5.4 Impact Assessment

5.4.1 Assessment of Societal and Cultural Issues

In this assessment, we evaluate the project's impact on the local society and culture, emphasizing:

Community Engagement: We engage with local communities to understand their concerns and needs, fostering open communication throughout the project.

Cultural Sensitivity: We respect and protect cultural heritage, consulting with experts to identify and preserve any culturally significant sites.

Infrastructure Development: We assess the potential for infrastructure improvements that can benefit both the project and the local community.

Environmental and Health Impacts: We evaluate potential impacts on the environment and public health, implementing mitigation measures to safeguard communities.

Public Safety: We prioritize safety for residents and workers, implementing safety measures and emergency response plans.

Noise and Air Pollution: We aim to minimize noise and air pollution to maintain a high quality of life for local communities.

Crisis Communication: We develop a comprehensive communication plan to inform the public promptly in case of unexpected events.

Community Benefits: We explore opportunities to provide lasting benefits to the community, such as funding for social infrastructure.

Long-Term Sustainability: We assess how the project can contribute positively to the community's well-being beyond its initial phases.

This assessment ensures that the project aligns with societal and cultural needs, fostering positive relationships with local communities and contributing to their well-being.

5.4.2 Assessment of Health and Safety Issues

In this assessment, we prioritize the health and safety of all project stakeholders by:

Electrical Safety: Implementing strict measures to prevent electrical hazards, ensuring compliance with safety standards.

Hazardous Materials: Safely handling and storing hazardous materials, providing proper training and protective equipment.

System Failures: Developing safeguards against system failures that could disrupt operations and compromise safety.

Emergency Response: Establishing clear emergency response procedures, providing essential safety equipment, and conducting personnel training.

Environmental Impact: Mitigating emissions, chemical waste, and noise pollution to protect public health and the environment.

Occupational Health: Prioritizing worker health and safety through proper training, ergonomic considerations, and workplace monitoring.

Noise Control: Implementing measures to reduce noise pollution and protect the hearing health of workers and nearby residents.

Community Awareness: Engaging with the local community to address safety concerns, provide information, and address questions.

Regulatory Compliance: Ensuring strict adherence to safety and environmental regulations, permits, and approvals.

Testing and Inspection: Conducting rigorous testing and inspections to identify and rectify safety issues before full-scale implementation.

This assessment ensures that health and safety considerations are integrated into all aspects of the project, safeguarding the well-being of workers, the public, and the environment.

5.4.3 Assessment of Legal Issues

This assessment focuses on identifying and addressing legal considerations associated with the project, including:

Regulatory Compliance: Ensuring that the project adheres to all relevant local, state, and federal laws, regulations, and permits.

Contracts and Agreements: Reviewing and managing contracts with suppliers, contractors, and stakeholders to protect the project's legal interests.

Intellectual Property: Protecting any intellectual property rights associated with project innovations or technology developments.

Environmental Compliance: Ensuring compliance with environmental laws, including permits and approvals related to emissions, waste management, and land use.

Occupational Health and Safety Laws: Adhering to laws and regulations governing workplace safety and worker protections.

Land Use and Zoning: Ensuring that the project complies with land use regulations, zoning laws, and property rights.

Intellectual Property and Patents: Protecting any intellectual property created during the project through patents, trademarks, or copyrights.

This assessment helps identify legal risks and compliance requirements, allowing the project to proceed with confidence within the bounds of the law.

5.5 Sustainability and Environmental Impact Evaluation

In this comprehensive assessment, we diligently scrutinize the project's sustainability and environmental footprint. Our primary focus is on resource efficiency, where we seek to minimize resource consumption by adopting energy-efficient technologies and promoting responsible material use. Emissions reduction is another critical aspect, as we are committed to implementing measures that curtail emissions, pollutants, and greenhouse gases, contributing to a cleaner environment. Waste management is approached systematically, with plans for responsible waste handling, recycling, and environmentally sound disposal practices. Additionally, our dedication extends to the preservation of local biodiversity and ecosystems, ensuring that our project operates harmoniously with natural surroundings. We're also proactive in exploring opportunities for the project to benefit the local community, both economically and socially. Regulatory compliance is non-negotiable; we rigorously adhere to environmental regulations and obtain all necessary permits. Sustainability principles are deeply embedded in our project's DNA, with a focus on practices that ensure our operations are environmentally responsible, now and into the future. This holistic evaluation underscores our commitment to minimizing environmental impact and fostering sustainability, creating a positive legacy for both the community and the environment.

5.5. Individual Contribution of Each Member

1906135: Component management and testing the project.

1906153: Planning, circuit design and software implementation.

1906154: Microcontroller algorithm building.

1906155: Circuit building in breadboard and testing.

5.6 Mode of Team Work

In person collaboration and also via online meeting.

5.7 Log Book of Project Implementation

Date	**Milestone achieved**	**Individual Role**	**Comments**
08-08-23	Planning	All of us	Successfully done
12-08-23	Buying components	1906154, 1906135	Successfully done
14-08-23	Schematic	1906153	Successfully done
20-08-23	Circuit Building	1906155	Successfully done
30-08-23	Code Building	1906154	Successfully done
04-09-23	Circuit Simulation	1906153	Successfully done
07-09-23	Main circuit design and Testing	1906135, 1906155	Successfully done

6 Communication

6.1 Executive Summary

We can control the power by using integral cycle switching. We understand how to remove cycle from main input. We get output without any distortion. This model also reduces the harmonic content while controlling the power and since we are providing zero cross switching so the probability of sparking is also reduced. The setup can also be used to control the speed of induction motor or fan.

6.2 User Manual

The project is pretty straight forward to use for the users. The user will require to connect the 220 V single phase supply in the appropriate jumper. There are four push buttons in the breadboard. The user can push the buttons in accordance of his/her desired no. of cycle to be kept ON.

6.3. Problems We Faced

- We tried to use 8015 series Microcontroller, but we failed to upload code here.
- We used a circuit to make a zero-crossing detector but it didn’t work.
- Because of using high voltage some of our component burnt.
- Output voltage from our MC(Arduino) was very low for which we need some change in the circuit

6.4 Overcoming the Problems

- We shifted to Arduino Uno (MC) to implement the gate pulse.
- We have designed a new circuit for zero-crossing detector.
- We will work with low voltage for safety
- We have changed the gain value to get proper output.

7.1 Project Management and Cost Analysis

Components	Quantities	Price
Diodes (1N4007)	4 pieces	16 Tk.
Resistors (1kΩ)	5 pieces	5 Tk.
Resistors (100 Ω)	2 pieces	2 Tk.
Resistors (10 kΩ)	1 piece	1 Tk.
Op-Amp (LM358)	1 piece	10 Tk.
Op-Amp (uA741)	1 piece	15 Tk.
ARDUINO UNO	1 piece	700 Tk.
Push Buttons	4 pieces	20 Tk.
Opto-Coupler (MOC3021)	1 piece	40 Tk.
TRIAC (BT136)	1 piece	24 Tk.
Lamp	1 piece	60 Tk.
Breadboard	2 pieces	130 Tk.
Jumpper Connectors		50 Tk.
Total		980 Tk

8 Future Work

The world is becoming autonomous. By automating this project, efficiency can be increased. This can be done by using a sensor programmed with the microcontroller. Once the sensor receives the data, the cycle switching automatically takes place. We can make an automatic temperate control using this method. Temperature sensor senses the temperature and when the temperature goes beyond the set limit, the intensity will be controlled by using the cycle switching method.

9 References

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• *Distortion in power system by Lundquist Johan. IEEE STD 519-1992, wikipedia.*

• *Integral energy power quality centre by Vic Smith.*

• *Solid state relay user's guide by Omron*