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Mitigation of Short Duration Power Quality Issues in Power System by Using STATCOM

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ABSTRACT: In today's power systems, ensuring reliable and high-quality electricity supply is paramount. Short-duration power quality issues pose significant challenges, leading to voltage sags, swells, and flickers, which can disrupt operations and damage equipment. To address these challenges, the use of Static Synchronous Compensators (STATCOMs) has emerged as a promising solution. This paper investigates the effectiveness of STATCOMs in mitigating short-duration power quality issues in power systems. Through comprehensive analysis and simulations, the paper demonstrates the capability of STATCOMs to swiftly regulate voltage fluctuations and maintain system stability during transient disturbances. Furthermore, the paper discusses key design considerations and control strategies for integrating STATCOMs into power systems for effective mitigation of short-duration power quality issues. Overall, this research contributes to advancing the understanding and implementation of STATCOM technology for enhancing power system reliability and quality.

KEYWORDS: FACTS, STATCOM, Reactive Power Compensation, Voltage Stability.

I. INTRODUCTION

In recent years, power quality issues have become a significant concern in power systems worldwide, posing challenges such as voltage sags, swells, and flickers. These issues not only affect the reliability and stability of the grid but also impact the performance of sensitive loads, leading to financial losses and potential equipment damage.

In modern power systems, maintaining high-quality power supply is crucial for ensuring efficient operation and reliability. However, short-duration power quality issues such as voltage sags, swells, and flicker can occur due to various factors including sudden load changes, faults, and the integration of renewable energy sources. These disturbances can lead to equipment malfunction, production losses, and customer dissatisfaction.

To address these challenges, the Static Synchronous Compensator (STATCOM) has emerged as a promising solution. STATCOM is a voltage source converter-based flexible AC transmission system (FACTS) device capable of rapidly injecting reactive power into the system to regulate voltage and improve power quality. Its fast response time and ability to control voltage magnitude and phase angle make it suitable for mitigating short-duration power quality issues. Throughout this project report, we will delve into the fundamental principles of STATCOM operation, its integration into power systems, and its effectiveness in mitigating various power quality issues. Additionally, we will analyse case studies and simulation results to provide a comprehensive understanding of STATCOM's performance under different operating conditions.

By the end of this presentation, it is my hope that you will gain valuable insights into the practical application of STATCOM for enhancing power system reliability and mitigating short duration power quality issues. Without further ado, let us embark on this journey to explore the transformative potential of STATCOM in ensuring a stable and resilient power supply for the future.

This paper aims to explore the application of STATCOM for mitigating short-duration power quality issues in power systems. It will discuss the operating principles of STATCOM, its advantages over traditional compensation methods, and its effectiveness in mitigating voltage sags, swells, and flicker. Additionally, practical implementation considerations and case studies demonstrating the effectiveness of STATCOM in real-world power systems will be presented.

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By leveraging the capabilities of STATCOM, power system operators can enhance the reliability and stability of their networks, minimize equipment damage, and improve customer satisfaction. Furthermore, integrating STATCOM into power systems aligns with the growing emphasis on smart grid technologies and Sustainable energy solutions.

In response to these challenges, the utilization of advanced technologies like STATCOM has emerged as a promising solution. STATCOM, as a flexible and fast-acting reactive power compensator, offers dynamic voltage support and reactive power control, effectively mitigating power quality disturbances in real-time.

Statement of the Problem and Purpose: Old electromechanical devices used to control electrical networks were slow to respond and had limited operation due to wear. They struggled to continuously manage power flows efficiently. To address the shortcomings of traditional control methods, FACTS devices have emerged, offering improved control over various parameters of the electrical grid (like phase shift, voltage, and impedance). This enables better management of power transmission, voltage stability, and the ability to approach thermal limits of transmission lines, ultimately enhancing the efficiency and reliability of electrical systems.

Significance of the Study :The importance of this work is to find a good solution for improving voltage control and managing reactive power in electricity transmission networks. This is done by using FACTS devices, specifically STATCOM (Static Synchronous Compensator), which helps in adjusting voltage levels and balancing power flow more effectively.

Research Questions :
1. How can we create a model of the electrical system to make reactive power compensation and voltage control better using STATCOM?
2. Where should we place STATCOM to make reactive power compensation and voltage control work best?
3. Which software should we use to analyse this?

II. LITERATURE REVIEW

Researchers from various regions have explored reactive power compensation and voltage control in power systems, yielding valuable insights. In 2016, Nilesh et al. recommended using a static VAR compensator (SVC) to enhance transfer capability in power systems. They utilized variable shunt susceptance and Newton-Rapson load flow analysis with an IEEE-39 bus system, demonstrating the importance of SVC placement for improving transfer capability.
In 2013, Chandrakanth et al. applied a STATCOM to regulate voltage and power flow in a lengthy transmission line. They experimented with STATCOM placement at different points along the line and employed pulse width modulation for controller circuitry. Their simulations showed that the middle of the transmission line was the optimal location for the STATCOM.

Meenakshi and Abdul investigated the performance of a synchronous compensator (STATCOM) with conventional control connected to a 33 kV grid. They aimed to reduce grid burden by compensating for reactive power demanded by loads.

Power electronics equipment called STATCOM is been used in systems to regulate voltage and improve power quality. STATCOM can swiftly and precisely meet the grid's reactive power needs as a shunt-connected react Energy device. It is a useful tool for preserving a stable and dependable power supply system because of its capacity to provide quick and accurate reactive power correction. STATCOMs use insulated gate bipolar transistors (IGBTs) and capacitors to generate reactive power in response to changes in the grid voltage, helping to maintain a stable voltage profile and improve the power factor. They are increasingly being used in modern power systems due to their Capability of providing precise with the fast-acting reactive Energy compensation, high efficiency, and small size.

[1] Shubham O. Shewatkar explained "Design of Adaptive PI Controller of STATCOM for Voltage Stability" In power system voltage stability is consider as the main parameter for that purpose Statcom is used Improving the voltage stability. Many controls scheme is used designing of FACTS devices here mainly focus on adaptive PI control scheme for better performance. Main objective is to make itself adjusting control according to changing condition because performance of STATCOM decreases as operating condition changes. So, with this approach the control parameters of PI controller are self-adjusted under different operating condition.

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[2] Hendri Masdi explained "the Energy system different faults are occurs due unbalanced system or due to sudden change in load like voltage sag, voltage swell, interruption, de offset, so that reduction in voltage cannot be tolerated by sensitive equipment like PLC. Adjustable speed drives, robotics etc. so that many uncontrollable devices are used to reduce the power quality issues. Capacitor banks, UPS, parallel feeders are used to reduce these issues. Due to the unpredictable reactive power correction, this device cannot eliminate PQ difficulties. The amount of land needed is reduced, and energy storage devices take the role of capacitors. Reactive current may be sustained at low voltage via Statcom.

[3] Rahul Chaturvedi and Prof. Alka Thakur explained "A Review D-STATCOM Voltage Regulation Systems". Every large-scale company, factories required and high power. Quality but due to some problems quality of power gets reduces which can directly affect on products. Currently many Statcom studies that balanced system 3-phase 3-wire. This uses an Insulated Gate Bipolar Transistor VSI with a 10 kilo Hz frequency and to compensate for reactive power. For improved operation, adaptive control technology is used.

Definition of Key Terms:-
FACTS: FACTS stands for Flexible Alternating Current Transmission Systems, defined by IEEE as systems in AC transmission that use power electronics and static controllers to enhance control over electrical networks and increase line transmission capacity. FACTS technology isn't limited to one device but includes a range of devices integrated into electrical networks to improve power flow control and line capacity.
STATCOM : STATCOM, or Static Synchronous Compensator, is a shunt device within the FACTS family. It's a modern technology utilizing devices like GTO and IGBT. STATCOM can manage active power flow, regulate voltage, and enhance dynamic stability of transmission systems by controlling the injection of reactive power at its connection point. Typically installed in parallel with the line, STATCOM is mainly used for providing reactive power compensation to support voltage.
Reactive Power Compensation: Reactive power compensation involves managing reactive power to enhance the performance of AC power systems. Typically, it deals with addressing issues related to load and providing support for voltage levels.
Voltage Stability: Voltage stability refers to a power system's ability to maintain acceptable voltage levels at each bus or point in the system, both during normal operations and after encountering disturbances. Normally, the voltage in a power system remains stable, but when disturbances like faults occur, the voltage can become unstable, leading to a gradual and uncontrolled decrease in voltage. Voltage stability is sometimes called load stability because it affects the ability of the system to handle varying loads.

III. PROPOSED DESIGN

The proposed work's block diagram, as shown in Figure , illustrates the system comprising a single-phase AC source and a load where voltage regulation is required. Feedback from the output voltage (Vtg) and output current (I) is utilized by the controller to monitor voltage, current, and the phase angle between voltage and current via zero crossing detectors.

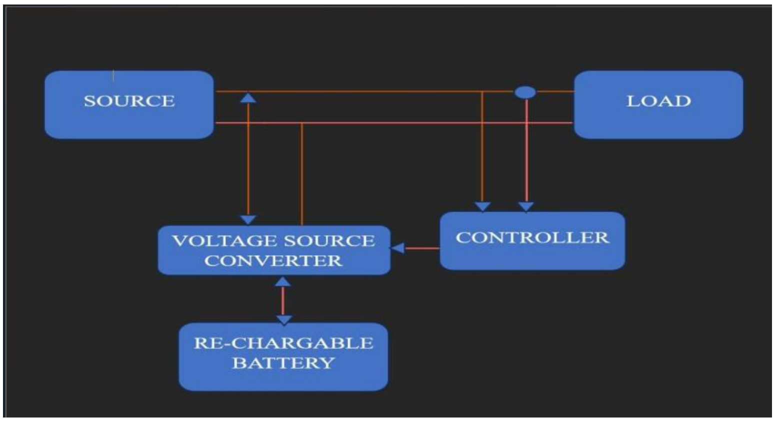

FIGURE 1: Block diagram of the proposed system

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In further detail, for developing the system, various components such as sensors, semiconductor devices, filter capacitors, and controllers are carefully selected. Sensors are chosen to accurately measure voltage and current levels in the system. Semiconductor devices, like transistors or thyristors, are employed for controlling the flow of power and regulating voltage. Filter capacitors help in smoothing out fluctuations in voltage or current. Controllers, such as microcontrollers or digital signal processors (DSPs), are used to process feedback information and adjust the system parameters accordingly for effective voltage regulation and control of current flow. Each component selection is crucial for ensuring the system operates efficiently and meets the desired performance objectives.

IV. REQUIRED COMPONENTS

ARDUINO UNO:
Arduino is an open-source, programmable circuit board built on simple hardware and software. It is centered around the ATmega328. The device includes 14 digital input/output pins, 6 analog inputs, a USB port, a power jack, an ICSP header, and a reset button. To power the board, connect it to a laptop via USB cable or plug in an ACDC power source.

VOLTAGE SENSOR LV- 25
The voltage sensor thus selected for project work is LV-25 voltage sensor.
The key specifications of this sensor are:

- Voltage sensing range: 10 – 500V
- Supply voltage: 12 – 15
- Excellent accuracy
- Very good linearity
- Low thermal drift
- Low response time
- High bandwidth
- High immunity to external interference
- Low disturbance in common mode.

CURRENT SENSOR LA-25:
The current sensor shown in fig shall be selected for sensing currents up to 10A and frequencies up to 2KHz. Therefore, current sensor LA- 25 is selected for hardware development.

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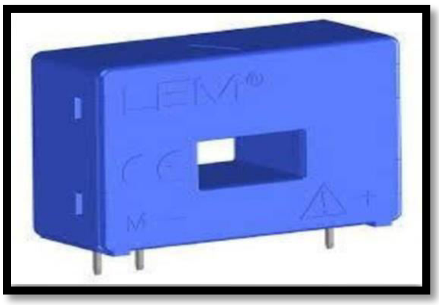

TRANSFORMER :
As shown in figure the transformer is proposed to develop the prototype model of STATCOM at 48V voltage level. Hence it is necessary to step down the 230V single phase AC supply to 24V/48V level. The load demand is taken to be 250VA. Hence the required transformer is selected with following specifications
Voltage:230/24V Current: 5A

IGBT AND DRIVER:
The IGBT is shown in figure selection is based on its working voltage and current of the load circuit. The system is being developed for 48V, 250VARload. Hence the inverter components shall be capable of handling this voltage and current safely.
The voltage rating of selected IGBT shall be at least three time the maximum working voltage.

V. FLOWCHART

1.OPENLOOP MODE

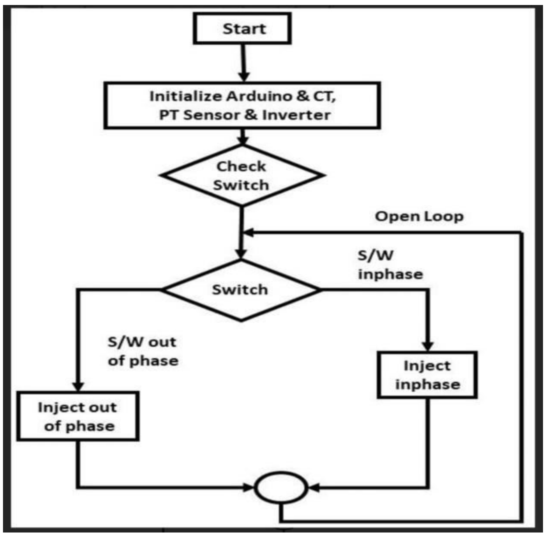

FIGURE 1 : process flow for open loop configuration

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2.CLOSED LOOP MODE

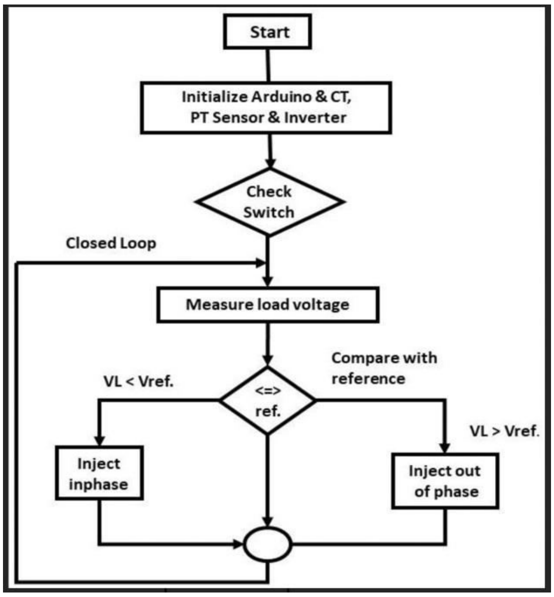

FIGURE2: Process flow for closed loop configuration

APPLICATION

Various applications and utilization in different contexts:

1.Voltage Sag Mitigation:

- Explanation of voltage sags and their impact on power quality.
- How STATCOM can quickly inject reactive power to mitigate

2.Voltage Swell Mitigation:

- Definition and causes of voltage swells.
- Role of STATCOM in absorbing excess reactive power during voltage swells.

3.Voltage Flicker Mitigation:

- How STATCOM can provide dynamic voltage support to reduce flicker.

4.Voltage Unbalance Mitigation:

- Explanation of voltage unbalance and its effects.
- Utilizing STATCOM to balance voltage levels in a power system.

5.Load Compensation:

- Discussion on load variations and their impact on power quality.
- Utilizing STATCOM to provide reactive power compensation and stabilize system voltage.

6.Fault Ride-Through Capability:

- Explanation of fault events and their effects on power systems.
- Role of STATCOM in maintaining system stability and voltage support during faults.

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7.Grid Integration of Renewable Energy:

- Overview of challenges in integrating renewable energy sources into the grid.
- How STATCOM can provide voltage and reactive power support to manage fluctuations from renewables.

8.**Transmission Line Voltage Control:**

- Importance of voltage control in transmission lines.
- Utilizing STATCOM for voltage regulation and maintaining system stability.

9.Power System Resilience :

- Importance of resilience in power systems against disturbances.
- Role of STATCOM in enhancing power system resilience through rapid voltage support.

VI. IMPLEMENTATION

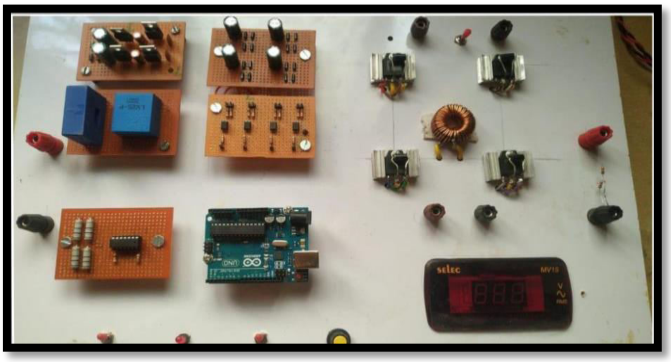

FIGURE 3: Prototype Model 24V&48V STATCOM

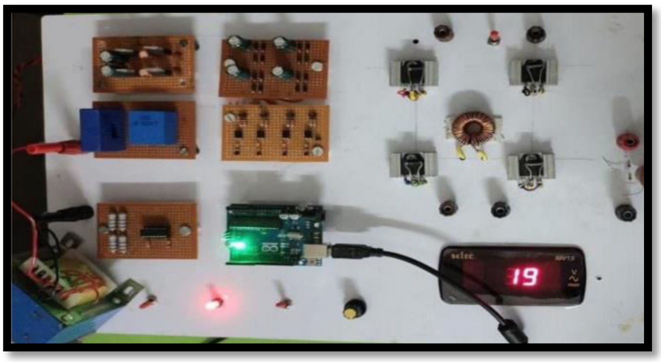

FIGURE 4 Uncompensated (Voltage sag)

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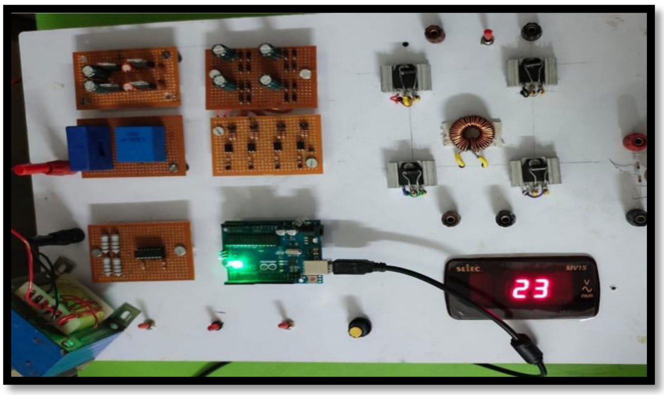

FIGURE5 :Compensation of voltage sag

VII. RESULT

OBSERVATION TABLE (24V OPERATION)

Sr No	Load	Voltage without compensation	Voltage with compensation
1.	100 ohm	21v	24
2.	100 ohm	20v	23
3.	200 ohm	19v	24
4.	200 ohm	20v	24
5.	300 ohm	17v	23
6.	500 ohm	16v	24

Above table presents observations on voltage sag occurrences resulting from the introduction of additional load into the system. Under normal operating conditions, the system maintains stable voltage levels. However, when a 100-ohm resistive load is added, the system experiences a voltage drop from 18V to 19V. To address this voltage drop, the STATCOM assumes a pivotal role by compensating for the decrease in voltage through voltage addition to the system. The table delineates the contrast between uncompensated and compensated voltage levels under various load conditions, showcasing the effectiveness of STATCOM in voltage regulation.

OBSERVATION TABLE (48V OPERATION)

Sr. No.	Load	Voltage without compensation	Voltage with compensation
1.	100 ohm	40v	46v
2.	100 ohm	41v	47v
3.	200 ohm	42v	48v
4.	200 ohm	43v	47v

Table provides insights into voltage sag occurrences resulting from the introduction of additional load into the system. Operating within a 48V system, under normal conditions, stable voltage levels are maintained. However, upon the addition of a 100-ohm resistive load, the system experiences a voltage drop from 42V to 44V. Here, the STATCOM assumes a crucial role, compensating for the voltage drop by adding voltage to the system. The table delineates the disparity between uncompensated and compensated voltage levels across various load conditions, underscoring the vital role of STATCOM in voltage regulation within the 48V system.

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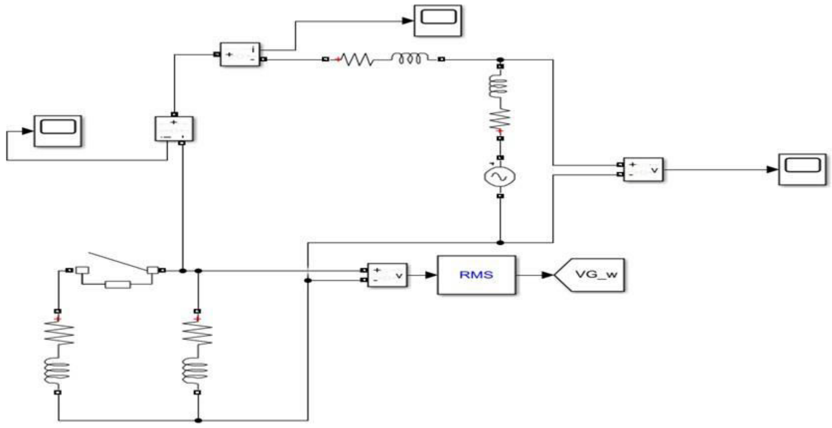
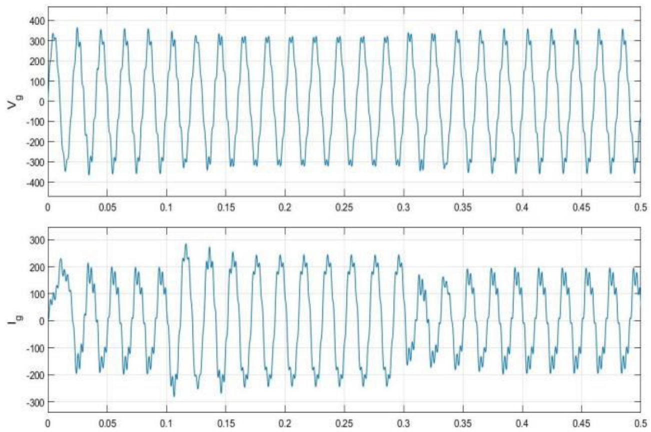
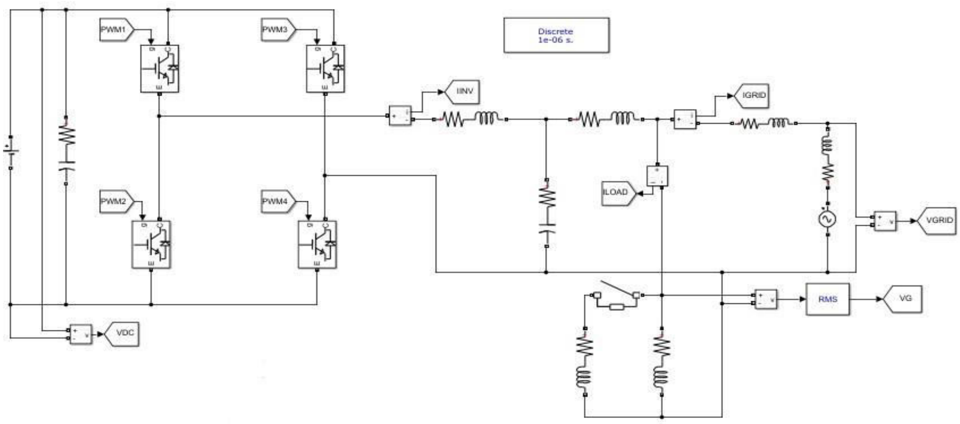
Simulation-
I] Without Statcom-





II] With Statcom-



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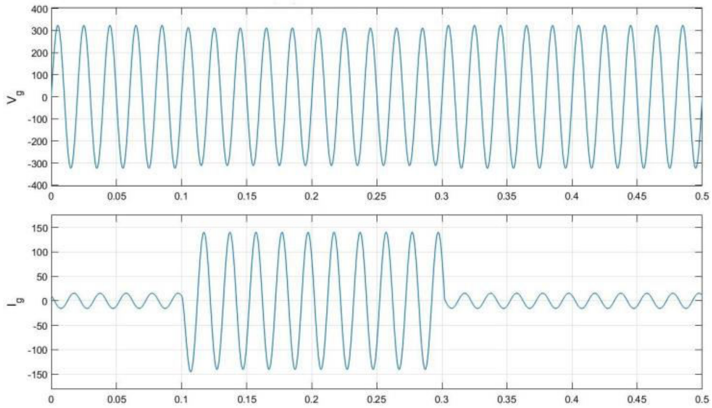

VIII. CONCLUSION

In conclusion, this research has highlighted the critical role of STATCOM in mitigating short-duration power quality issues within power systems. Through comprehensive analysis and simulation studies, it has been demonstrated that STATCOM offers effective voltage support and reactive power compensation, thereby enhancing the stability and reliability of the power grid.

The findings of this study underscore the significance of deploying STATCOM as a viable solution for addressing transient voltage fluctuations, voltage sags, and other power quality disturbances. Moreover, the integration of advanced control algorithms further enhances the performance and flexibility of STATCOM, making it a versatile tool for power system operators.

As we move towards a future characterized by increasing electrification and renewable energy integration, the importance of maintaining high-quality power supply cannot be overstated. By embracing technologies such as STATCOM, utilities can ensure optimal power delivery while minimizing disruptions and improving overall system resilience.

However, it is essential to recognize that successful implementation of STATCOM requires careful consideration of various factors, including system configuration, control strategies, and economic feasibility. Continued research and development efforts are warranted to further refine and optimize STATCOM applications, enabling its widespread adoption in modern power systems.

This research contributes to the ongoing discourse on power quality enhancement and provides valuable insights into the role of STATCOM in addressing short-duration power quality issues. By leveraging the capabilities of STATCOM, we can pave the way for a more robust and efficient power.

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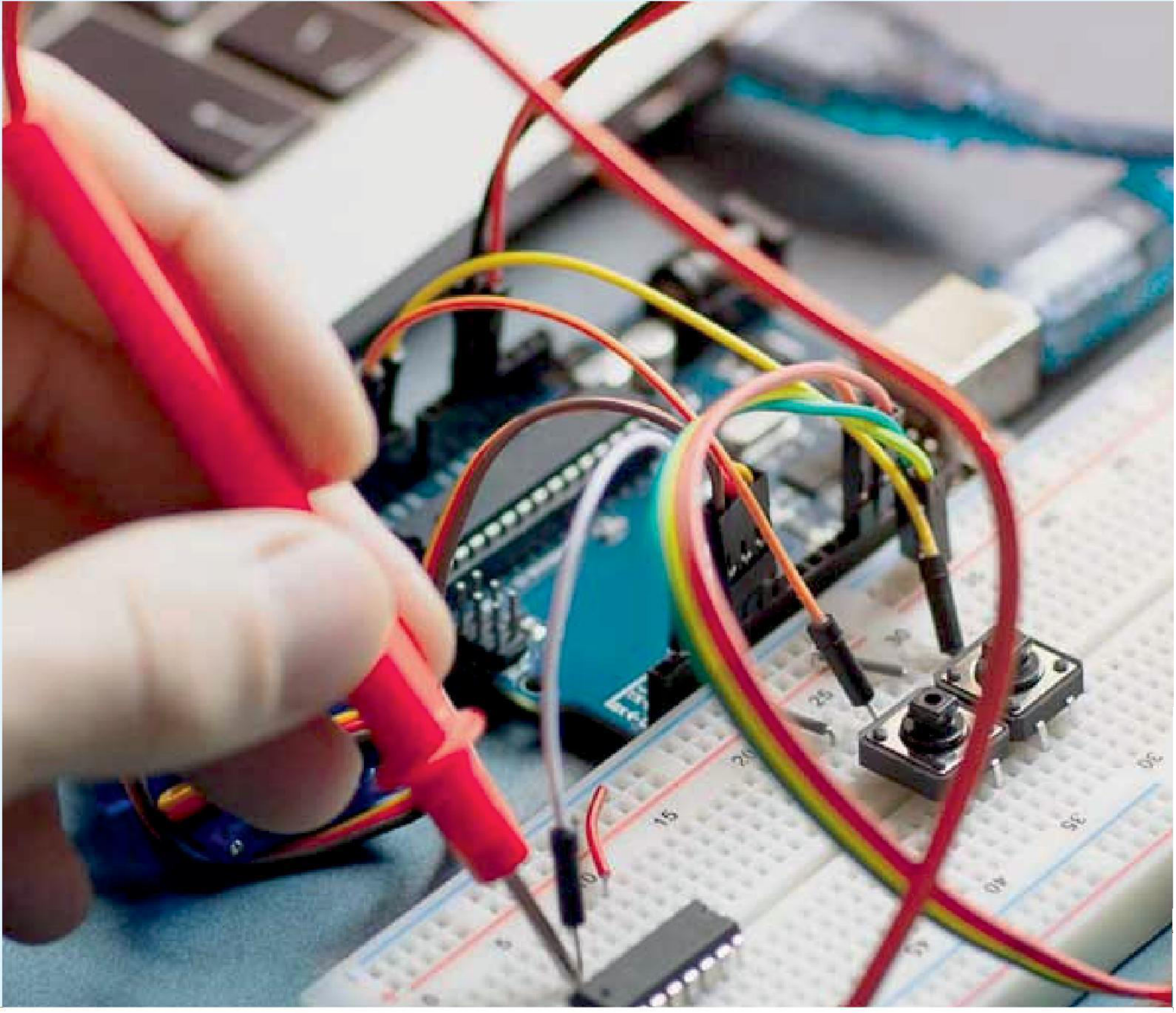

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