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Analysis of Power Quality Issues Related to EV Charging Station

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ABSTRACT: The sector of transport is being electrified because to rising worries about pollution and energy consumption, as well as technological breakthroughs in batteries. As a new technology, electric cars are still trying to find their niche. Its many benefits include less pollutant that contributes to climate change, less fuel use, and simplicity of use. Since chargers function as electric-electronic converters, power quality issues may arise while charging electric vehicles (EVs). More and more people are driving electric vehicles, which brings up concerns about how these vehicles may affect the electricity system and its quality. Power balancing and the effect of charging an electric car on voltage, current, and total harmonic distortion are the primary topics covered in this article. This research presents and analyses power quality concerns in EV charging stations based on monitoring data. Various chargers' harmonic current emissions are studied. The purpose of this study is to examine how the loads placed on the distribution network by electric vehicle charging stations affect reliability indices, power losses, voltage stability, and economic losses. This article uses Proteus simulations to examine the effects of EVs on the electricity distribution network.

KEYWORDS: EV Station, Power Quality, NC Loads, Stability, THD.

I. INTRODUCTION

The suitability of electrical power supplied by the utility to the power consumer is measured by power quality (PQ). Problems with utility service continuity, transient voltages and currents, and fluctuations in voltage magnitude can all result from low PQ, making it an important factor to consider. One of the main causes of poor power quality is harmonic distortion. We have three hypotheses that we are trying to test with this study. First, we postulated that distribution feeders might be affected by the power quality problems caused by electric vehicle charging, due to the fact that EV charge controllers are nonlinear loads and EVs consume a lot of power. Two, we also postulated that different stages of an electric vehicle's charging cycle would cause the charge controller's total harmonic distortion (THD) to vary over time. Thirdly, we postulated that an upper limit on the number of electric vehicle charging stations that could be linked to a single feeder would be imposed by the cumulative effects of several charge controllers on the same feeder, which would lead to distortion higher than that of any one charge controller.

Electric vehicle (EV) charging loads have a negative effect on power system operating characteristics, which has been noted with the widespread revival of EVs. Electric vehicle charging station loads have a negative effect on the power distribution network. Problems with dependability, voltage instability, lower reserve margins, higher peak load demand, and reduced reserve capacity are all outcomes of the rapid charging stations' heavy charging demands. Additionally, the utility's penalty for the power system's declining performance is an important consideration.

The purpose of this study is to examine how the loads placed on the distribution network by electric vehicle charging stations affect reliability indices, power losses, voltage stability, and economic losses. This project uses Proteus simulations to examine the effects of EVs on the electricity distribution network. When the distribution transformer is overloaded with electric vehicle chargers, this project shows the voltage profile, harmonics, and losses that occur.

II. POWER QUALITY

How closely an actual supply system resembles an ideal one is conveyed by the Power Quality of that system. All linked loads should operate satisfactorily and efficiently if the system's Power Quality is excellent. Operating costs and the establishment's impact on carbon emissions will be negligible. The performance of the electrical institution will deteriorate, loads connected to it will fail or have a shortened lifetime, and power quality will be bad overall. Due to low power quality, the operating costs and carbon footprint of the establishment will be considerable, and/or it may not be possible to operate at all. Any problem with the energy network that leads to a financial loss is an example of poor power quality. The word "power quality" might imply something quite different to people. The principle of powering & grounding sensitive measurement equipment in an optimum way suited for the equipment is defined as power quality according to IEEE1100, the standard of the Institute of Electrical & Electronic Engineers. When there are more power quality concerns, all electrical equipment are more likely to malfunction or fail. Whether it's a computer, printer, generator, transformer, electric motor, home appliance, or piece of communication gear, the electrical machine is there. All of these equipment have an undesirable reaction to power quality difficulties, the severity of which depends on the nature of the problems. Power quality may be described as the set of electrical constraints that enable a piece of equipment to operate in its aggregated manner without significant loss of lifespan or performance. This description might be simpler and more to the point. The two qualities that we usually want from the lifetime and performance of an electrical equipment are provided by this definition. An issue with quality may arise if there is a power-related disadvantage that compromises either attribute. Given this definition of force excellence, this section serves as an introduction to the other fundamental terminology related to power quality. The definitions of the words are included in enclosures wherever they are needed to clarify anything. Here we break out the role of power quality factors in an electrical system.

The word "power quality" is simple, but it depicts a separate problem that might arise in every network that supplies electricity, and it is also subjective. What constitutes "good" or "bad" power is according to the user. If the device works as expected, the user will think the power is OK. People worry that the electricity will be terrible if the equipment breaks down too soon or doesn't work as it should. All depends on how the power user sees it. Power quality could exist in a variety of grades or levels between these two extremes. If you want to fix power quality concerns once and for all, you need start by learning what they are.

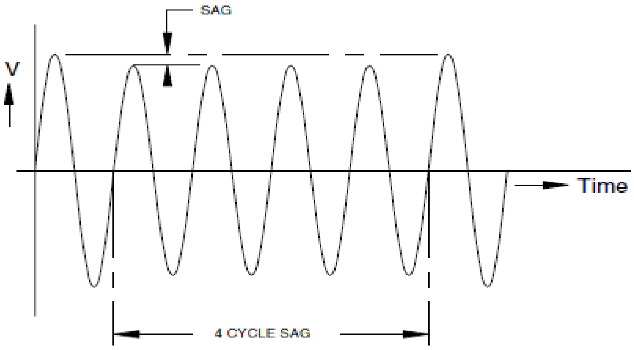


Fig1: Voltage sag

Voltage spikes and dips are caused by low-frequency phenomena known as power frequency disturbances. They could be created by a power system's switching activities or by a power outage. As far as electrical equipment's vulnerability is concerned, the outcomes are same. Distortions like ringing, notching, and impulse are caused by transients, which are short- lived, rapid occurrences in power systems. Factors that affect power frequency disturbances are distinct from those that cause transient energy to be transmitted down power lines, subsequently dissipated, and passed to other electrical circuits. When a power system experiences harmonics, it distorts the waveform at low frequencies. It adds harmonic components to the frequency spectrum. Power system components and functioning are negatively impacted by current and voltage harmonics. Interactions between harmonics and power system characteristics (R, L, and C) can have disastrous results in some cases. Research on power quality is more complicated when it comes to the idea of bonding and grounding. There are three main justifications for grounding. The primary goal of grounding in the United States is to ensure safety, as stated in the National Electrical Code (NEC). Voltage spikes and dips are caused by low-frequency phenomena known as power frequency disturbances. They could be created by a power system's switching activities or by a power outage. As far as electrical equipment's vulnerability is concerned, the outcomes are same. Distortions like ringing, notching, and impulse are caused by transients, which are short- lived, rapid occurrences in power systems. Factors that affect power frequency disturbances are distinct from those that cause transient energy to be transmitted down power lines, subsequently dissipated, and passed to other electrical circuits. When a power system experiences harmonics, it distorts the waveform at low frequencies. It adds harmonic components to the frequency spectrum. Power system components and functioning are negatively impacted by current and voltage harmonics. Interactions between harmonics and power system characteristics (R, L, and C) can have disastrous results in some cases. Research on power quality is more complicated when it comes to the idea of bonding and grounding. There are three main justifications for grounding. The National Electrical Code (NEC) mandates safety grounding in the United States, which is the primary goal of grounding.

The below Fig shows the Power quality issue

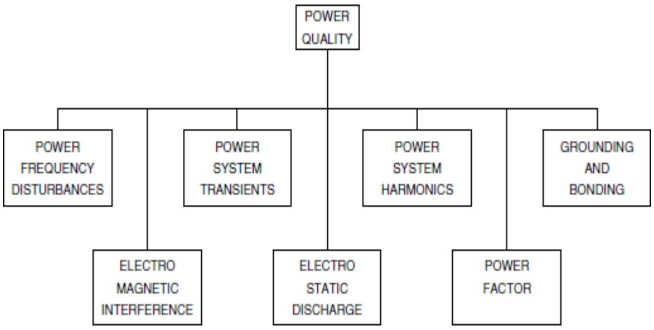


Fig2: Power quality issue

Second, bonding and grounding provide a low-impedance channel for the fault current to flow, which the power source's protective device may use to isolate the faulty circuit in the event of a ground fault. The establishment of a ground connection plane is the third justification for grounding electrically sensitive equipment. Here we have what is called the Signal Reference Ground (SRG).According to the SRG Both the facility and the user may have different preferences when it comes to the setting. The SRG can't exist in a vacuum. A whole ground system is created when it is linked to the facility's safety ground. When electric and magnetic fields interact with sensitive electronic circuits and devices, this phenomenon is known as electromagnetic interference (EMI). EMI occurs at very high frequencies. When compared to power level electrical transients and disturbances, the procedure for attaching electromagnetic interference (EMI) to vulnerable equipment is distinct. As we will see later on, specialised methods are necessary to mitigate the impacts of electromagnetic interference (EMI). Interactions between transmitted or radiated radio frequency fields with communication devices or private information are known as radio frequency interference (RFI). Although the two phenomena are distinct, it is useful to include RFI in the category of EMI.

III. EV CHARGING TECHNOLOGIES

The elements influencing the development of charging technologies are depicted in the figure. One other thing to keep in mind: the technology that is accepted is also determined by the charging site.

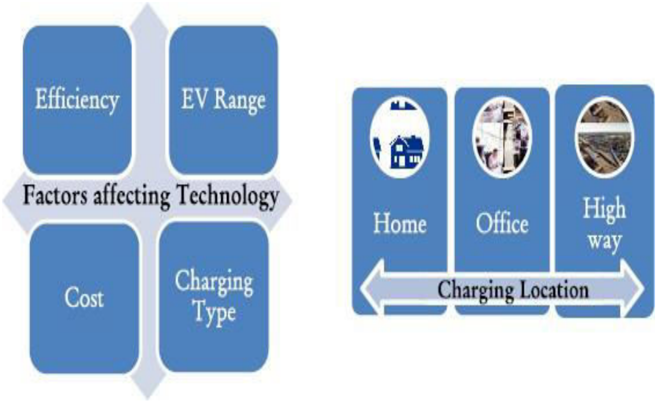
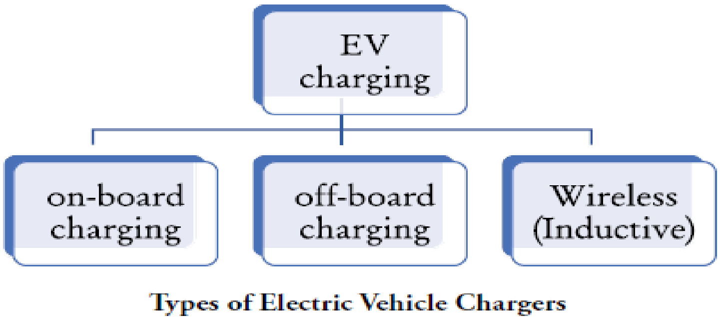


Fig3: Factors that decides charging technologies

This section has been divided into four main categories that will be considered in the following sections:
I. Types of EV charging technologies
II. Types of EV charging systems and processes
III .Grid infrastructure required for EV charging stations
Software environment at charging station, DISCOM control centre and consumer

IV. TYPES OF EV CHARGING TECHNOLOGIES

In order for electric vehicles to advance in various ways (in terms of efficiency, EV range, prices, etc.), advancements in battery system technology are essential. Techniques and skills for charging and discharging also matter. To make EVs more usable and popular, they should be adapted to various settings (at home, at the office, on roads, etc.) and tailored to drivers' requirements. There are two main types of electric vehicle charging: on-board and off-board. This design enables both bidirectional power flow and unidirectional power flow, meaning that both approaches may be used to charge the EV battery in the grid and pump electricity back into the grid. The figure depicts the standard configuration of an electric vehicle's on- board & off-board charging infrastructure.



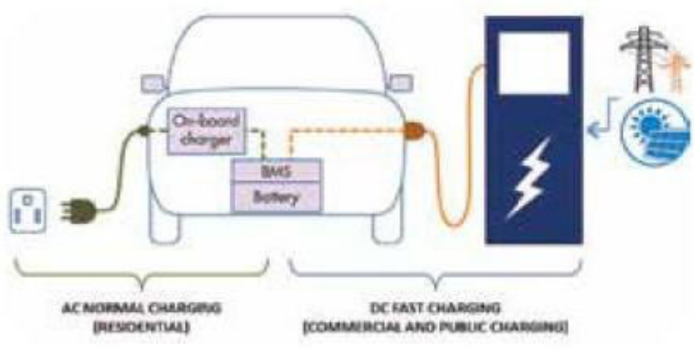


Fig4: On-board and Off-board charging topology of EV

There aren't enough electric vehicle charging outlets nowadays. Two distinct kinds of charging stations are now in use. charge stations in both public and private spaces. While a small number of public charging stations have been installed in various places, the vast majority of stations are privately owned. The rate of charging at these private stations is greater. The components of an EVCS, as shown in the figure, are a rectifier, a converter, and a transformer. The basic components of an electric vehicle charger are a rectifier and a converter.

Evaluating the effects of EVs is necessary since EV loads are growing at a rapid pace. The following figure illustrates the effect on the power system of widespread EV adoption. Smart grid infrastructure, a transportation system with fewer greenhouse gas emissions, and widespread use of electric vehicles all have their advantages However, the consequences for the power network architecture are substantial and detrimental.

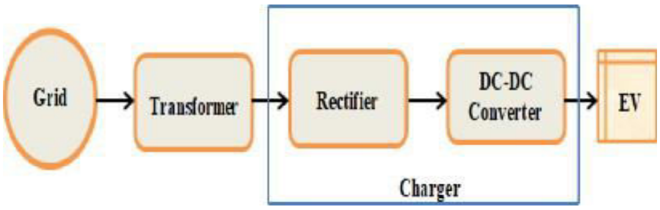


Fig5: Block diagram of an Electric Vehicle Charging Station

V. SYSTEM DESCRIPTION

The proposed system is designed for real-time monitoring and analysis of power quality parameters.

5.1 POWER SUPPLY

Provides a stable and regulated DC voltage required for the proper operation of all system components.Converts AC mains supply into DC using rectifier, filter, and voltage regulator circuits**.**Ensures constant voltage output despite input fluctuations, protecting sensitive devices like the microcontroller and sensors.Plays a critical role in maintaining **system** reliability and accuracy during continuous operation

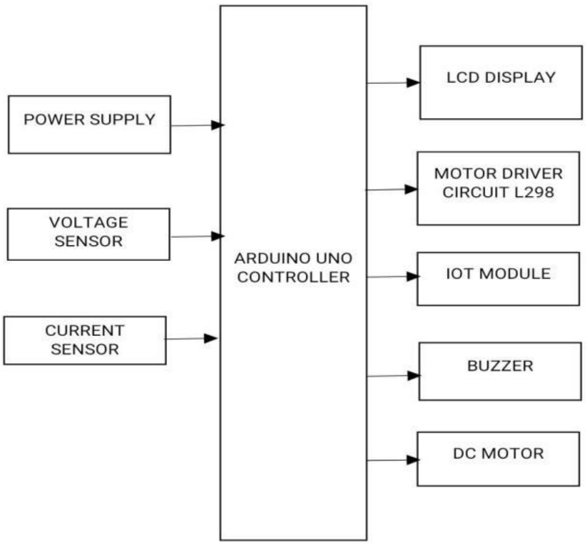


Fig6: Block diagram

5.2 VOLTAGE SENSOR

Used to measure the instantaneous and RMS voltage of the supply system. Converts high voltage levels into a scaled-down analog signal suitable for Arduino input. Enables detection of voltage variations such as sag, swell, and fluctuations**.** Essential for analyzing power quality disturbances and maintaining system safety.

Fig7: Voltage sensor

5.3 CURRENT SENSOR

Measures the load current flowing through the circuit in real time. Works based on principles such as Hall Effect or shunt resistance**.** Provides an analog signal proportional to current, which is processed by the microcontroller. Helps in identifying overcurrent conditions, load changes, and harmonic currents.

Fig8: Current sensor

5.4 ARDUINO UNO

Acts as the central processing unit of the system. Receives analog signals from voltage and current sensors and converts them into digital values using an **inbuilt** ADC (Analog-to-Digital Converter)**.**Executes programmed algorithms to calculate parameters like voltage, current, and power quality indices**.** Controls output devices such as LCD display, buzzer, and IoT module. Ensures real-time data processing and system coordination

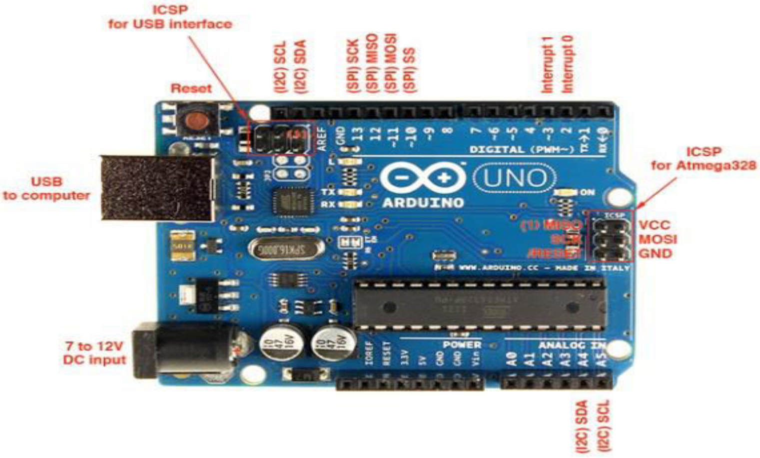


Fig9: Arduino UNO

5.5 LCD DISPLAY

Displays real-time electrical parameters such as voltage,
current, and system status. Provides a user-friendly interface for local monitoring without requiring external devices. Operates using standard communication protocols like 4-bit or 8-bit mode**.** Helps users quickly identify normal and abnormal operating conditions.

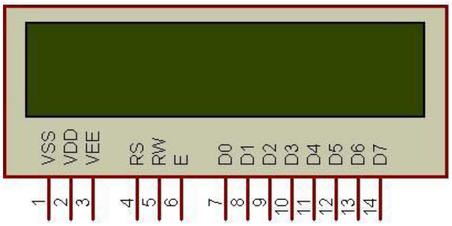


Fig10: Liquid crystal Display

5.6 MOTOR DRIVER (L298)

Used to control the operation of the DC motor, which acts as a variable load. Functions as an interface between Arduino and the motor, handling higher current requirements. Allows control of motor speed and direction using PWM signals. Protects the microcontroller from high current and voltage spikes.

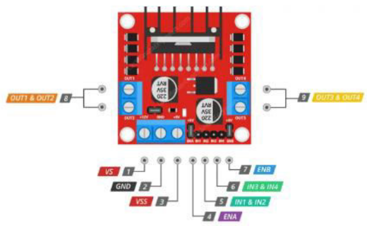


Fig11: L298N

5.7 IoT MODULE

Enables wireless communication between the system and cloud platforms. Transmits real-time data such as voltage, current, and alerts for remote monitoring and analysis. Commonly uses modules like ESP8266 or ESP32 with Wi-Fi capability. Supports development of smart monitoring systems and data logging applications.

Fig12: Node MCU ESP32

5.8 BUZZER

Acts as an alerting device to indicate abnormal conditions. Activated when parameters exceed predefined limits such as overvoltage, overcurrent, or system faults. Provides an instant audible warning, improving system safety and response time. Simple yet effective component for fault indication.

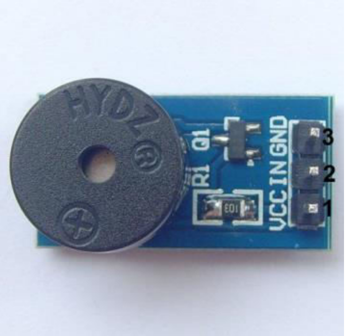


Fig13: Buzzer

5.9 DC MOTOR

Used as a simulated load to replicate real-world electrical demand conditions. Helps in analyzing system behavior under varying load conditions. Load variation can be controlled to study power quality issues such as voltage drop and current increase. Essential for testing and validating system performance.

VI. WORKING PRINCIPLE

The working principle of the proposed system is based on monitoring and controlling the EV battery charging process to ensure safety and efficiency. Initially, the power supply provides regulated DC power to the system, and the battery begins charging through an AC-DC conversion circuit. The voltage and current sensors continuously measure the battery parameters and send the data to the Arduino Uno controller. The controller processes these values to monitor battery condition and estimate the State of Charge (SOC). The measured data is displayed on the LCD and also transmitted to the cloud using the IoT module for remote monitoring. Based on the sensor inputs, the system automatically controls charging by disconnecting the supply using a relay when the battery is fully charged or if any abnormal condition like overvoltage, overcurrent, or overheating occurs. Additionally, the buzzer provides alerts for fault conditions, ensuring safe and reliable operation of the EV charging system.

VII. ANALYSIS METHODS

7.1 TOTAL HARMONIC DISTORTION(THD)

$$THD = \frac{\sqrt{V_2^2+V_3^2+V_4^2+\cdots+V_n^2}}{V_1}$$

- Measures distortion in voltage waveform
- Higher THD → Poor power quality

For Current THD

$$THD_I = \frac{\sqrt{I_2^2+I_3^2+I_4^2+\cdots+I_n^2}}{I_1}$$

7.2 RMS VALUE CALCULATION

$$V_{rms} = \sqrt{\frac{1}{T}\int_0^T v^2(t)\,dt}$$

$$I_{rms} = \sqrt{\frac{1}{T}\int_0^T i^2(t)\,dt}$$

- Represents effective value of AC signal
- Important for power calculations

7.3 REAL,REACTIVE AND ,APPARENT POWER

Real Power (P) $P = VI\cos\phi$

Reactive Power (Q) $Q = VI\sin\phi$

Apparent Power (S) $S = VI$

7.4 POWER FACTOR (PF)

$PF = P/S = \cos\phi$

- Indicates efficiency of power usage
- Low PF → High losses

7.5 HARMONIC DISTORTIONN FACTOR(DF)

$$DF = \frac{1}{\sqrt{1+THD^2}}$$

7.6 CREST FACTOR (CF)

CF = Vpeak / Vrms

- Indicates waveform distortion
- High CF → Presence of spikes

7.7 FORM FACTOR(FF)

FF = Vrms / Vavg

- Used to analyze waveform shape

7.8 VOLTAGE REGULATION

%VR = Vno-load - Vfull-load / Vfull-load * 100

- Shows voltage variation under load

7.9 VOLTAGE UNBALANCE FACTOR (VUF)

VUF = Vnegative / Vpositive * 100

- Important for three-phase systems

7.10 FREQUENCY DEVIATION

Δf = f_actual – f_rated

- Indicates system stability

7.11 HARMONIC CURRENT CALCULATION

$$I_h = \sqrt{I_2^2 + I_3^2 + I_4^2 + \cdots + I_n^2}$$

7.12 ACTIVE POWER WITH HARMONICS

P = ∑ n = 1∞VnIncosϕn

7.13 TOTAL APPARENT POWERWITH HARMONICS

S = Vrms × Irms

7.14 DISPLACEMENT POWER FACTOR (DPF)

DPF =cosϕ1

7.15 TRUE POWER FACTOR

PFtrue = P / Vrms * Irms

7.16 INSTANTANEOUS POWER

p(t) = v(t) · i(t)

7.17 ENERGY CONSUMPTION

E = P × t

7.18 LOAD FACTOR

Load Factor = Average Load / Maximum load

VIII. RESULT AND DISCUSSION

The experimental analysis of the proposed power quality monitoring system under varying load conditions clearly demonstrates the significant impact of EV charging stations on electrical network performance. As the load increases, a noticeable reduction in supply voltage is observed, indicating voltage sag conditions, especially during peak demand and fast charging scenarios. Simultaneously, the current drawn by the system increases non-linearly due to the presence of power electronic converters, leading to higher stress on distribution components. The harmonic analysis reveals that Total Harmonic Distortion (THD) rises considerably with increased loading, with dominant lower-order harmonics such as the 3rd and 5th contributing heavily to waveform distortion. This results in overheating of equipment, reduced efficiency, and potential malfunction of sensitive devices. Additionally, the power factor is found to degrade as load increases, mainly due to reactive power consumption and harmonic currents, which further increases transmission losses. The system also exhibits minor voltage fluctuations and flicker effects during rapid switching conditions, affecting power stability. The real-time monitoring system based on Arduino Uno successfully captures and processes all these parameters with good accuracy and response time, providing continuous updates through the LCD display and IoT module. The results confirm that without proper mitigation techniques such as filtering and smart load management, EV charging infrastructure can adversely affect overall power quality. Therefore, the study highlights the necessity for advanced monitoring systems and corrective measures to ensure stable and efficient operation of modern power systems integrated with EV charging stations.

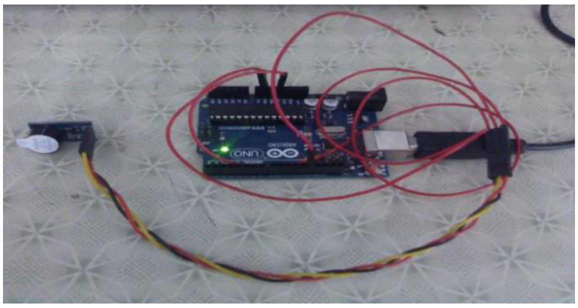


Fig14: Testing Results

IX. CONCLUSION

In this study, the impact of EV charging stations on power quality has been thoroughly analyzed, highlighting key issues such as harmonic distortion, voltage variations, and power factor degradation caused by non-linear charging loads. The experimental results show that as the load increases, there is a significant rise in Total Harmonic Distortion (THD), along with a noticeable drop in voltage and power factor, which can affect the stability and efficiency of the electrical distribution system. The proposed Arduino-based monitoring system successfully measures and displays real-time electrical parameters, proving to be a cost-effective and reliable solution for power quality analysis. Overall, the findings emphasize the need for proper mitigation techniques, including harmonic filters and smart charging strategies, to ensure stable, efficient, and reliable operation of EV charging infrastructure in modern power systems. Furthermore, the integration of IoT technology enhances the capability of remote monitoring and data analysis, enabling better decision-making and system management. The study also indicates that continuous monitoring can help in early detection of faults and prevent long-term damage to electrical equipment. In addition, implementing advanced control techniques can significantly improve power factor and reduce harmonic levels. The results obtained from this system can be further utilized for developing intelligent energy management systems. Finally, this work provides a strong foundation for future research in smart grid integration and sustainable EV charging solutions.

REFERENCES

[1] M. H. J. Bollen, Understanding Power Quality Problems: Voltage Sags and Interruptions, New York, NY, USA: IEEE Press, 2000.
[2] A. Emadi, Y. J. Lee, and K. Rajashekara, “Power electronics and motor drives in electric, hybrid electric, and plug-in hybrid electric vehicles,” IEEE Transactions on Industrial Electronics, vol. 55, no. 6, pp. 2237–2245, Jun. 2008.
[3] IEEE Standard 519-2014, IEEE Recommended Practice and Requirements for Harmonic Control in Electric Power Systems, IEEE, 2014.

[4] N. Mohan, T. M. Undeland, and W. P. Robbins, Power Electronics: Converters, Applications, and Design, 3rd ed., Hoboken, NJ, USA: Wiley, 2003.

[5] R. C. Dugan, M. F. McGranaghan, S. Santoso, and H. W. Beaty, Electrical Power Systems Quality, 3rd ed., New York, NY, USA: McGraw-Hill, 2012.

[6] J. Arrillaga and N. R. Watson, Power System Harmonics, 2nd ed., Chichester, U.K.: Wiley, 2003.

[7] S. Singh and B. Singh, “Power quality issues in electric vehicle charging stations,” International Journal of Electrical Power & Energy Systems, vol. 95, pp. 15–23, Feb. 2018.

[8] M. Yilmaz and P. T. Krein, “Review of charging power levels and infrastructure for plug-in electric and hybrid vehicles,” IEEE Transactions on Power Electronics, vol. 28, no. 5, pp. 2151–2169, May 2013.

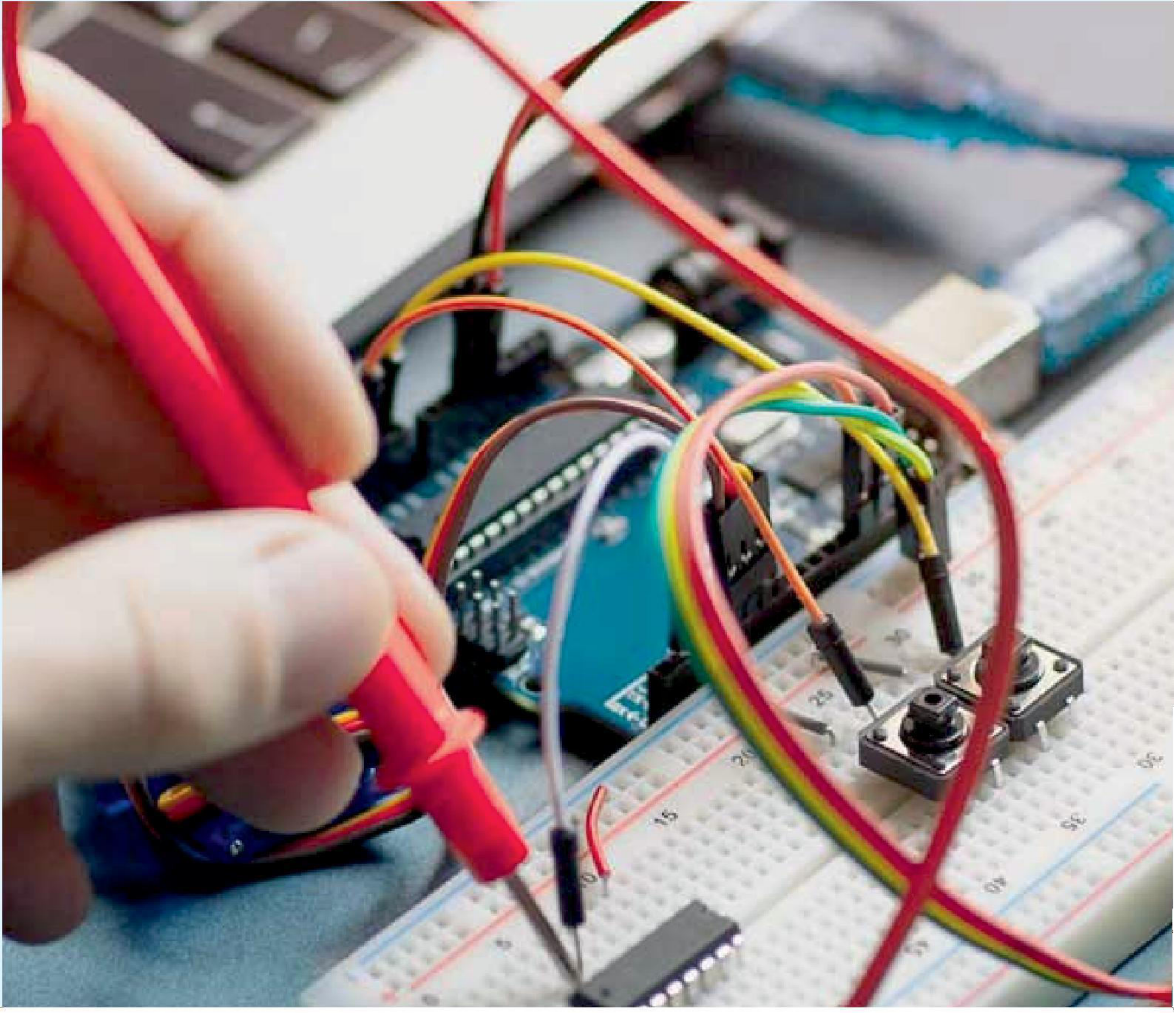
[9] T. G. Habetler, “Analysis of power quality impacts of electric vehicle charging,” IEEE Industry Applications Magazine, vol. 25, no. 2, pp. 45–52, Mar.–Apr. 2019.

[10] B. K. Bose, Modern Power Electronics and AC Drives, Upper Saddle River, NJ, USA: Prentice Hall, 2002.

[11] C. Sankaran, Power Quality, Boca Raton, FL, USA: CRC Press, 2002.

[12] H. Akagi, “New trends in active filters for power conditioning,” IEEE Transactions on Industry Applications, vol. 32, no. 6, pp. 1312–1322, Nov.–Dec. 1996.

[13] S. Williamson, A. Khaligh, S. Oh, and A. Emadi, “Impact of plug-in hybrid electric vehicles on distribution networks,” IEEE Power Engineering Society General Meeting, 2009.



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