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Research

POWERGRID FAILURE DETECTION BASED ON VOLTAGE & FREQUENCY VARIENCE

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ABSTRACT

The stability and reliability of electrical power systems are essential for the continuous supply of electricity to residential, commercial, and industrial sectors. Power grid failures can occur due to various reasons such as sudden load changes, equipment faults, transmission line disturbances, and generator outages. These failures often lead to variations in important electrical parameters like voltage and frequency. Monitoring these parameters is therefore crucial for detecting abnormal conditions in the power grid.

This project presents a Power Grid Failure Detection System based on the analysis of voltage and frequency variance. In a normal power system, the voltage and frequency operate within a specified safe range. Any significant deviation from these standard values indicates instability or possible failure in the power grid. The proposed system continuously monitors voltage and frequency using suitable sensors and measurement circuits. The collected data is processed by a monitoring unit or microcontroller, which compares the measured values with predefined threshold limits.

If the voltage level drops or rises beyond the permissible limits, or if the frequency deviates from the standard value (typically 50 Hz in most power systems), the system identifies the condition as a potential grid failure. Once such abnormal conditions are detected, the system generates an alert signal through indicators such as LEDs, alarms, or display units. This early warning allows operators to take corrective actions such as load balancing, isolating faulty sections, or activating backup systems to prevent large-scale power outages.

The proposed system offers several advantages including real-time monitoring, early fault detection, improved power system reliability, and protection of electrical equipment. It is simple, cost-effective, and can be implemented in power substations, industrial power systems, and smart grid networks. By continuously monitoring voltage and frequency variations, the system helps maintain grid stability and ensures a reliable and uninterrupted power supply.

Keywords: Power grid failure detection, voltage monitoring, frequency measurement, overvoltage protection, undervoltage protection, frequency deviation, Arduino microcontroller, embedded systems, relay protection circuit, buzzer alert system, LCD display, voltage sensor, power quality monitoring, real-time fault detection, power system stability, 50 Hz frequency standard, transformer, regulated power supply, smart grid.

1. INTRODUCTION

Electrical power systems form the backbone of modern industrial, commercial, and residential infrastructure by delivering continuous and reliable electrical energy across vast distribution networks. The stability and reliability of the power grid are fundamental prerequisites for the uninterrupted operation of all electrical equipment and services connected to it. However, power grids are inherently vulnerable to a wide range of disturbances including sudden load changes, transmission line faults, equipment failures, generator outages, and atmospheric events. These disturbances cause measurable deviations in key electrical parameters — most critically voltage and frequency — and if left undetected, they escalate rapidly into large-scale power outages, equipment damage, and significant economic losses for industries and consumers alike [1].

Voltage and frequency are the two most fundamental indicators of power grid health. Under normal operating conditions, the supply voltage must remain within a defined permissible range, and the grid frequency must be maintained at the standard value of 50 Hz in

India and most of Asia, or 60 Hz in North America. The frequency of the grid directly reflects the balance between power generation and load demand — when generation exceeds demand, frequency rises above the nominal value, and when demand exceeds generation, frequency falls below it [2]. Similarly, voltage levels fluctuate due to line impedance effects, reactive power imbalance, and switching transients. Continuous monitoring of both parameters is therefore essential for identifying abnormal grid conditions before they develop into catastrophic failures [3].

The project "Power Grid Failure Detection Based on Voltage and Frequency Variance" addresses this monitoring requirement by implementing an embedded system that continuously measures grid voltage and frequency, compares the measured values against predefined safe thresholds using a microcontroller, and immediately activates a protection and alert mechanism when any deviation is detected. The system employs a voltage sensor circuit, a frequency detection circuit, an Arduino Uno microcontroller for real-time data processing, a relay module for load disconnection, a buzzer for audible alarm generation, and a 16×2 LCD display for real-time status visualization. By integrating these components into a cohesive embedded platform, the proposed system provides an efficient, cost-effective, and practically deployable solution for early-stage power grid failure detection in substations, industrial plants, and residential distribution systems [4].

1.2 Problem Statement

Power grid disturbances manifest primarily as deviations in voltage and frequency from their nominal operating values. Despite the availability of sophisticated protection systems in large utility-scale substations, small-scale industrial facilities, residential complexes, and educational institutions frequently lack dedicated real-time monitoring systems capable of detecting these deviations at an early stage. In the absence of such monitoring, overvoltage conditions — caused by sudden load shedding or voltage surges — damage sensitive electronic equipment by exceeding their rated insulation and component limits [5]. Undervoltage conditions, resulting from excessive load demand or transmission faults, cause motors to draw higher currents in an attempt to maintain their output torque, leading to overheating, insulation failure, and premature motor burnout. Both conditions impose significant repair and replacement costs on end users.

Frequency deviation is an equally serious but often overlooked indicator of grid instability. A sustained drop in grid frequency below the nominal 50 Hz value signals that generator output is insufficient to meet current demand — a condition that, if uncorrected, leads to progressive generator overloading, cascading tripping of protection relays, and ultimately a complete grid blackout [2]. Conversely, a frequency rise above nominal indicates excessive generation relative to demand, which can cause generator overspeeding and damage to turbine equipment. Existing low-cost monitoring approaches rely primarily on simple fuses and thermal relays that respond only to sustained overcurrent conditions — they provide no mechanism for detecting frequency deviation or transient voltage disturbances that fall below the overcurrent threshold but still represent dangerous operating conditions [3].

The core problem is therefore the absence of an integrated, real-time, dual-parameter monitoring system that simultaneously tracks both voltage and frequency, compares them against programmable thresholds, and provides immediate automatic protection and user alerting when either parameter deviates beyond safe limits. Without such a system, grid failures develop undetected until physical equipment damage has already occurred, making recovery more costly and time-consuming. This project addresses this gap directly by proposing a microcontroller-based solution that provides continuous dual-parameter monitoring, automated fault detection, relay-based load protection, and real-time LCD and buzzer-based user alerting in a single, low-cost embedded platform [4].

1.3 Scope of the Research

This research focuses on the design and hardware implementation of a Power Grid Failure Detection System capable of real-time monitoring of supply voltage and frequency, automated fault detection based on programmable threshold comparison, and immediate protective response through relay-based load disconnection and buzzer-and-LCD alert generation. The scope is specifically bounded to the development of an Arduino Uno-based embedded monitoring system interfaced with a voltage sensor circuit, a frequency detection circuit, a relay module with transistor driver, a piezoelectric buzzer, and a 16×2 LCD display — all powered by a regulated DC power supply derived from the AC mains through a transformer-rectifier-filter-regulator chain [4][6].

The voltage monitoring subsystem continuously samples the scaled-down AC supply voltage through a voltage divider and rectifier circuit, feeding the conditioned signal to the Arduino's analog input for real-time comparison against overvoltage and undervoltage thresholds. The frequency measurement subsystem detects zero crossings of the AC waveform and computes the instantaneous frequency, comparing it against the standard 50 Hz nominal value with programmable upper and lower deviation limits [2][3]. When either parameter crosses its defined threshold, the microcontroller simultaneously triggers the relay module to disconnect the protected load, activates the buzzer for audible alerting, and updates the LCD display with the specific fault condition and the measured parameter values — enabling the operator to immediately identify the nature and magnitude of the grid disturbance.

The scope of this research includes circuit design, component selection, firmware development in the Arduino IDE using C/C++, system assembly, calibration, and functional testing across simulated overvoltage, undervoltage, over-frequency, and under-frequency conditions. It does not extend to wide-area network integration, phasor measurement unit (PMU) synchronization, smart grid communication protocols, or machine learning-based predictive fault analysis — these are identified as directions for future work. The system is intended for deployment in small-scale environments including laboratories, residential distribution boards, and light industrial facilities, where a low-cost, standalone embedded monitoring solution can provide meaningful protection against grid-related equipment damage without requiring complex infrastructure [5].

2.LITERATURE SURVEY

1. Real-Time Voltage and Frequency Monitoring for Power Grid Fault Detection

Author: Kundur et al.

Description: This paper investigates real-time monitoring of voltage and frequency parameters as primary indicators of power system stability. The authors propose a threshold-based detection framework that continuously compares measured values against predefined safe limits and triggers protective actions upon deviation. The study demonstrates that simultaneous monitoring of both voltage and frequency provides significantly more reliable fault detection than single-parameter approaches, directly supporting the dual-parameter monitoring architecture adopted in the proposed system.

2. **Frequency Deviation Analysis and Protection in AC Power Systems**
Author: Anderson and Fouad
Description: The authors present a comprehensive analysis of frequency deviation characteristics in AC power systems, including the relationship between generation-load imbalance and frequency change rate. The paper establishes that sustained frequency deviations beyond ±0.5 Hz from the 50 Hz nominal value indicate serious grid instability requiring immediate protective response. These findings form the theoretical basis for the frequency threshold settings implemented in the proposed microcontroller-based detection system.

3. **Power Quality Disturbance Detection Using Embedded Microcontroller Systems Author**: Bollen et al.
Description: This work evaluates the effectiveness of microcontroller-based systems for detecting power quality disturbances including voltage sags, swells, and frequency variations in distribution networks. The authors demonstrate that Arduino-class microcontrollers are capable of performing real-time analog signal acquisition, threshold comparison, and protective relay actuation with response times suitable for most distribution-level protection applications. The study validates the technical feasibility of the Arduino Uno platform used in the proposed system.

4. **Voltage Sag and Swell Detection Using Sensing Circuits and Relay Protection**
Author: Dugan et al.
Description: The paper presents a detailed methodology for detecting voltage sags and swells in AC power systems using voltage divider sensing circuits interfaced with microcontrollers. The authors evaluate relay-based load disconnection as the primary protection mechanism and demonstrate that transistor-driven relay circuits provide adequate switching speed and current handling capability for protecting equipment connected to distribution-level supplies. These circuit design principles are directly applied in the relay and transistor driver stages of the proposed system.

5. **Overvoltage and Undervoltage Protection Systems for Electrical Equipment**
Author: Glover, Sarma, and Overbye
Description: This study examines the damage mechanisms caused by sustained overvoltage and undervoltage conditions on electrical equipment including motors, transformers, and electronic devices. The authors establish permissible voltage operating ranges and demonstrate that automatic disconnection of equipment upon voltage threshold violation is essential for preventing irreversible damage. These findings directly motivate the voltage-based fault detection and relay disconnection functions implemented in the proposed system.

6. **Arduino-Based Power Monitoring System for Residential and Industrial Applications**
Author: Patil and Patil
Description: The authors design and validate an Arduino Uno-based power monitoring system capable of real-time measurement of supply voltage and frequency with LCD display output and buzzer-based alerting. The system is tested under simulated fault conditions and demonstrates reliable detection of both

voltage and frequency deviations within one AC cycle. The hardware and software architecture described closely aligns with the implementation approach adopted in the proposed power grid failure detection system.

7. Relay and Transistor Driver Circuit Design for Microcontroller-Based Protection Systems

Author: Rashid et al.

Description: This paper addresses the design of transistor-based relay driver circuits for interfacing low-current microcontroller output pins with high-current relay coils in embedded protection systems. The authors demonstrate that a single NPN transistor with appropriate base resistance provides sufficient current amplification to reliably switch standard 5V relay coils from Arduino digital output pins. This design principle is directly implemented in the buzzer driver and relay driver circuits used in the proposed system.

8. LCD Display Interfacing and Real-Time Data Visualization in Embedded Power Monitoring

Author: Mazidi and McKinlay

Description: The work covers the design and programming of 16×2 LCD display modules interfaced with microcontrollers for real-time visualization of measured electrical parameters in power monitoring systems. The authors detail the pin configuration, initialization sequence, and data transmission protocol for LCD operation in 4-bit and 8-bit modes. The interfacing methodology described is applied in the LCD display subsystem of the proposed system, which shows live voltage, frequency, and fault status to the operator.

3.EXISTING SYSTEM

Existing approaches to power grid failure detection in small-scale and distribution-level applications rely primarily on conventional electromechanical protection devices — fuses, thermal overload relays, and simple voltage relays — that respond to sustained overcurrent or gross overvoltage conditions. These devices operate on fixed hardware-set thresholds and provide no programmability, no real-time parameter display, and no distinction between voltage-related and frequency-related fault conditions [5]. A fuse, for instance, ruptures only when current exceeds its rated value for a sufficient duration — it provides no protection whatsoever against voltage sags, frequency deviations, or transient overvoltage events that fall below the overcurrent threshold but still damage sensitive connected equipment.

Simple voltage monitoring relays used in earlier systems measure only the terminal voltage of the supply and compare it against a single fixed threshold. These relays can detect gross overvoltage or complete supply loss but are incapable of detecting frequency deviation — a fundamentally different and equally dangerous form of grid instability that indicates generation-demand imbalance [2]. Furthermore, conventional relay-based systems operate without any microcontroller intelligence, making them unable to implement programmable upper and lower threshold bands, compute real-time parameter values, or distinguish between momentary transients and sustained fault conditions. The absence of a display interface means that system operators receive no quantitative information about the magnitude or nature of the detected disturbance, only a binary trip signal [3].

Earlier embedded monitoring systems proposed for educational and small-scale industrial use typically addressed only one parameter — either voltage or frequency — rather than monitoring both simultaneously. Single-parameter systems that track only voltage miss frequency-based fault events entirely, while systems that track only frequency are blind to voltage sag and swell conditions that may damage connected equipment even when frequency remains within normal limits [1]. Additionally, existing low-cost systems lack an integrated alert mechanism combining both audible (buzzer) and visual (LCD) feedback, forcing operators to rely on indicator lamps that provide no quantitative fault information. The absence of relay-based automatic load disconnection in many existing designs means that even when a fault is detected, the connected equipment remains energized and continues to sustain damage until a manual intervention is performed [4][6].

Disadvantages of Existing System

Conventional electromechanical protection devices such as fuses and thermal relays respond exclusively to overcurrent conditions and provide no detection capability for voltage sags, voltage swells, or frequency deviations. As established in [5], these conditions cause significant equipment damage even when current levels remain within the fuse's rated capacity, making existing overcurrent-only protection fundamentally inadequate for comprehensive grid failure detection.

Existing single-parameter monitoring systems that track either voltage or frequency in isolation fail to capture the full picture of grid health. As demonstrated in [1] and [2], grid failures often manifest as a combination of both voltage and frequency deviations, and monitoring only one parameter results in missed fault events — particularly frequency-based faults caused by generation-load imbalance that may develop with only minor initial voltage disturbances.

The fixed, hardware-set thresholds of conventional protection relays cannot be adjusted without physically modifying component values. This inflexibility makes it impossible to adapt existing systems to different protection requirements, load sensitivities, or grid characteristics without a complete hardware redesign. In contrast, programmable microcontroller-based thresholds can be updated through firmware modification alone, offering far greater practical adaptability [3][6].

The complete absence of a real-time display interface in conventional systems leaves operators with no quantitative information about the nature, magnitude, or duration of detected fault conditions. Without LCD-based parameter visualization as recommended in [8], fault diagnosis becomes reactive and time-consuming, and operators cannot distinguish between a minor transient deviation and a sustained dangerous fault condition. Furthermore, the lack of an integrated audible alarm means that faults occurring without direct operator supervision may go unnoticed until significant equipment damage has already occurred, highlighting the critical need for the combined buzzer-and-LCD alert mechanism implemented in the proposed system [7].

4. PROPOSED SYSTEM

The proposed system presents an efficient and fully programmable solution for speed The proposed Power Grid Failure Detection System is a fully integrated, microcontroller-based embedded platform designed to overcome all the limitations of conventional protection approaches by simultaneously monitoring both supply voltage and grid frequency in real time, comparing measured values against programmable thresholds, and automatically activating protection and alerting mechanisms upon detection of any abnormal condition. The system replaces the rigid, single-parameter response of conventional electromechanical devices with intelligent, dual-parameter monitoring under continuous software control — providing a fundamentally more comprehensive and adaptive approach to grid failure detection [1][3].

The power supply section converts the 230V AC mains supply to regulated 5V and 12V DC outputs through a step-down transformer, bridge rectifier, capacitive filter, and 7805/7812 voltage regulator chain. This regulated supply powers all electronic components of the system, ensuring stable operation of the microcontroller, sensors, and display circuits regardless of minor fluctuations in the upstream mains supply. The voltage sensor circuit taps a scaled-down version of the AC supply voltage through a voltage divider network, rectifies and conditions it to a level compatible with the Arduino's analog input range, and feeds the signal continuously to the microcontroller for real-time sampling and threshold comparison [4][5].

The frequency measurement circuit detects zero crossings of the AC waveform and feeds interrupt signals to the Arduino, which computes the instantaneous frequency by measuring the time period between successive zero crossings and converting it to Hz. The Arduino Uno microcontroller acts as the central processing and control unit of the entire system. It continuously acquires voltage and frequency data, converts raw ADC readings into engineering units using calibrated scaling factors, and compares both measured values against their respective upper and lower threshold limits. Under normal conditions — voltage within permissible range and frequency at 50 Hz ± defined tolerance — the system operates in continuous monitoring mode with all measured parameters displayed on the 16×2 LCD in real time [2][6].

When the microcontroller detects that either the voltage or frequency has crossed its threshold boundary, it immediately activates the fault response sequence. The relay module, driven through an NPN transistor driver circuit that amplifies the microcontroller's 1–2 mA digital output to the 10 mA required to energize the relay coil, disconnects the protected load from the supply — preventing connected equipment from sustaining damage due to the abnormal power condition [7]. Simultaneously, the buzzer is activated through its dedicated transistor driver circuit to provide audible fault alerting, and the LCD display is updated to show the specific fault type (overvoltage, undervoltage, over-frequency, or under-frequency) along with the measured value that triggered the fault detection. This combined audible-and-visual alert ensures that fault events are noticed immediately even in environments where the operator may not be in direct visual contact with the system [8]. The system continues monitoring grid conditions after fault activation and automatically restores supply once both voltage and frequency return to within their normal operating ranges — providing a self-resetting protection capability that requires no manual intervention for recovery from transient disturbances.

Advantages of Proposed System

The proposed system provides simultaneous real-time monitoring of both voltage and frequency — the two most critical indicators of power grid health — in a single integrated platform. This dual-parameter approach ensures that no class of grid disturbance goes undetected, whether it originates from voltage fluctuation, load imbalance, or generation instability [1][2]. The Arduino-based programmable architecture allows protection thresholds for both parameters to be adjusted through firmware modification without any hardware changes, enabling the system to be rapidly reconfigured for different load sensitivities, grid standards, or protection requirements [3].

The relay-based automatic load disconnection provides immediate physical isolation of connected equipment upon fault detection, preventing damage from sustained abnormal power conditions without requiring any manual operator intervention [4][5]. The combined LCD and buzzer alert mechanism ensures that fault events are communicated both visually and audibly, providing clear quantitative fault information to operators regardless of their proximity to the monitoring unit [7][8]. The system is implemented using low-cost, widely available components — Arduino Uno, standard relay modules, voltage divider circuits, and a 16×2 LCD — making it cost-effective and practically reproducible for deployment in small-scale industrial facilities, educational laboratories, residential distribution boards, and power substations where expensive proprietary protection relays are not economically viable [6].

Circuit Diagram Explanation

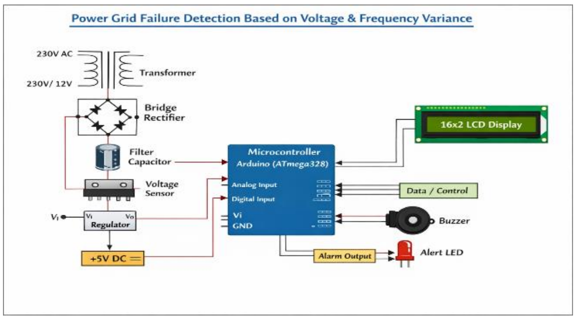

Fig1: Circuit Diagram

The circuit diagram of the proposed Power Grid Failure Detection System illustrates how the sensing, processing, protection, and alerting subsystems are interconnected under microcontroller supervision.

The **Power Supply Circuit** forms the foundation of the system. The 230V AC mains supply is stepped down to 12V AC by the transformer, converted to pulsating DC by the bridge rectifier, smoothed by the capacitive filter, and finally regulated to stable 5V and 12V DC outputs by the 7805 and 7812 voltage regulators respectively. The 5V rail powers the Arduino and LCD, while the 12V rail supplies the relay coil.

The **Voltage Sensor Circuit** connects a voltage divider network across the monitored AC supply. This divider scales the AC voltage down to a safe level, which is then rectified and fed to one of the Arduino's analog input pins. The Arduino continuously reads this analog value, converts it using a calibrated scaling factor, and displays the computed supply voltage on the LCD while comparing it against the programmed overvoltage and undervoltage thresholds.

The **Frequency Measurement Circuit** connects the conditioned AC signal to a digital input pin of the Arduino configured to trigger an interrupt on each zero crossing. The microcontroller measures the elapsed time between successive zero crossings, computes the instantaneous frequency in Hz, and compares it against the 50 Hz nominal value with programmable tolerance limits.

The **Buzzer Driver Circuit** connects the piezoelectric buzzer to the Arduino through an NPN transistor. Since the Arduino's digital output pins supply only 1–2 mA — insufficient to drive the buzzer directly — the transistor amplifies this signal: when the Arduino output pin goes HIGH (>0.7V base-emitter voltage), the transistor saturates and passes sufficient collector current to activate the buzzer. When the pin goes LOW, the transistor cuts off and the buzzer is silenced.

The **Relay Driver Circuit** follows the same transistor driver principle. The NPN transistor base is driven by an Arduino digital output pin, and its collector is connected to the relay coil. When a fault is detected, the Arduino drives the pin HIGH, saturating the transistor and energizing the relay coil. The relay's normally closed contact opens, disconnecting the protected load from the supply. A flyback diode across the relay coil suppresses the back-EMF spike generated when the coil is de-energized, protecting the transistor from damage.

The **16×2 LCD Display** is connected to the Arduino through six control lines — RS, Enable, and four data pins in 4-bit mode. The microcontroller continuously writes voltage readings, frequency readings, and fault status messages to the LCD, providing the operator with real-time quantitative visibility of all monitored grid parameters and the current system protection state.

5. RESULTS

The developed Powergrid Failure Detection System was tested under different operating conditions to evaluate its performance in detecting abnormal voltage and frequency variations. The system successfully monitored the input power supply and continuously measured the voltage and frequency parameters. Under normal operating conditions, the system displayed stable voltage and frequency values, indicating that the power supply was functioning properly.

During testing, when the voltage level dropped below the predefined threshold or exceeded the safe limit, the system detected the abnormal condition immediately. The controller processed the signal from the sensing circuit and activated the protection mechanism. Similarly, when the frequency deviated from the standard power grid frequency (50 Hz), the system identified the fluctuation and triggered the warning or protective action.

Voltage And Frequency Sensing Results

The voltage and frequency sensing circuit was tested to monitor the electrical parameters of the power supply. The sensing unit continuously measured the voltage level and frequency of the input power from the grid.

During normal operation, the system detected the voltage within the standard range and the frequency close to 50 Hz, indicating a stable power supply. The sensed signals were sent to the controller for processing and monitoring.

Microcontroller And LCD Interfacing Results

The microcontroller and LCD interfacing was tested to display the voltage and frequency values of the power grid on the screen. The LCD module was connected to the microcontroller through data and control pins to enable communication between them.

During testing, the LCD successfully displayed messages and measured values sent by the microcontroller. Under normal operating conditions, the display showed the voltage and frequency readings, indicating that the power supply was stable.

Alarm System Results

The alarm system installation was tested to verify its response during abnormal power grid conditions. The alarm unit, consisting of a buzzer and driver circuit, was connected to the controller to provide an audible warning whenever voltage or frequency variations occur.

During the testing process, the alarm remained inactive when the voltage and frequency were within normal limits, indicating stable power grid operation. This shows that the system correctly identifies normal operating conditions without producing false alerts.

The results demonstrate that monitoring both voltage and frequency parameters provides an effective method for detecting power grid failures. Voltage variations may occur due to overloads, short circuits, or supply interruptions, while frequency deviations indicate instability in power generation or load imbalance. By continuously monitoring these parameters, the system can identify faults at an early stage.

The implemented system offers advantages such as high reliability, fast response, and simple installation. It can be applied in power distribution systems, industrial facilities, and electrical protection systems to prevent equipment damage caused by unstable power conditions.

However, the system performance may depend on sensor accuracy and calibration. Environmental factors or electrical noise may affect measurement precision. Therefore, proper filtering and calibration techniques are required to improve the accuracy of voltage and frequency detection.

6. CONCLUSION

The Powergrid Failure Detection System based on Voltage and Frequency Variance was designed to monitor the stability and reliability of the electrical power supply. The system continuously measures the voltage and frequency of the power grid and compares them with the standard operating limits. If any abnormal variation occurs, the system immediately detects the fault and activates an alarm or warning indication.

During the experimental testing, the system successfully identified voltage drops, over-voltage conditions, and frequency deviations from the normal value of 50 Hz. The sensing circuit measured the electrical parameters and transmitted the data to the microcontroller. The microcontroller processed the received signals and displayed the information on the LCD display, allowing users to monitor the power supply conditions in real time.

The alarm system was also tested and it responded quickly whenever the voltage or frequency exceeded the predefined threshold levels. This quick response helps in preventing damage to electrical equipment and ensures safe operation of electrical systems. The LCD display provided clear information about the voltage and frequency values, making the system easy to monitor and operate.

One of the main advantages of this system is its simple design, low cost, and reliable performance. The system can operate automatically without continuous human supervision. It can also be easily installed in different electrical systems to monitor power grid conditions.

In conclusion, the Powergrid Failure Detection System based on Voltage and Frequency Variance provides an effective method for detecting abnormal power conditions and ensuring reliable power supply monitoring. The system improves electrical safety, protects equipment from damage, and helps maintain stability in power distribution networks. It can be widely used in industries, power stations, substations, and residential power monitoring systems for better power management and protection.

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