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Original Article

Innovative Approaches in Power Electronics For Cyber-Physical Systems Using Smart Grids

Mrs. Thilagavathy J[1], Ramalakshmi A[2]
[1,2]Department of Electrical and Electronics Engineering, Grace College Of Engineering, Mullakkadu, Thoothukudi.

Abstract: *This project, titled "Innovative Approaches in Power Electronics for Cyber-Physical Systems Using Smart Grids," explores advanced methodologies to enhance the quality and reliability of power systems. By integrating smart grid technologies and infrastructures, this initiative addresses the key challenges and vulnerabilities of traditional power grids. The proposed system employs wireless communication for real-time data transmission, ensuring seamless and efficient operations. A significant aspect of the project is the reconfirmation of the importance of timely applied load-shedding actions to prevent voltage collapse. The method for calculating critical load-shedding times is highlighted to maintain voltage stability when systems lose their regulation capability. Moreover, the incorporation of solid-state switches enhances system responsiveness and efficiency by enabling faster switching times, reducing power losses, and improving overall reliability. Furthermore, the project leverages IoT-based techniques to facilitate more manageable and effective load shedding control. Emphasizing load shedding on more critical buses yields more desirable results, demonstrating the project's potential to significantly improve power grid performance. This abstract encapsulates the innovative approaches in power electronics applied to cyber-physical systems using smart grids, aiming for a more resilient and reliable power infrastructure.*

Keywords: *Power Electronics, Cyber-Physical Systems, Smart Grids, Advanced Control Systems, Energy Management, Distributed Energy Resources (DERs), Grid Integration.*

INTRODUCTION

Aquaculture has been utilized as the substitute source of fish for human consumption to aid the declining global wild fish capture counts since the 1990s. It has been supplying the increasing demand for fish in the world market, which avoids increasing its price. Due to the nutritional contents of fish and its affordability the complementary relationship of fisheries' wild capture and aquaculture production significantly contributes to reducing poverty, livelihood, and sustaining food security, especially in developing countries and those countries heavily affected by the climate change Subsequently, aquaculture will be the primary source of fish for human consumption by In aquaculture, feed meal accounts for 65% to 70% of the overall expenses for fish production. The advantage of online and real-time monitoring, such as the use of the Internet of Things and Cloud, includes tracking capability, anomaly detection & prediction, and ease of access Globally, the Nile tilapia (Oreochromis niloticus) is ranked as one of the most cultured freshwater fish because it is affordable, mild in taste, and has high nutritional value Generally, the cultured Nile tilapia can be fed with farm made and commercial feeds. Between the sinking and the floating commercial feed pellets, the floating feed pellets reported favorable growth rates compared to the sinking pellets.

SYSTEM IMPLEMENTATION

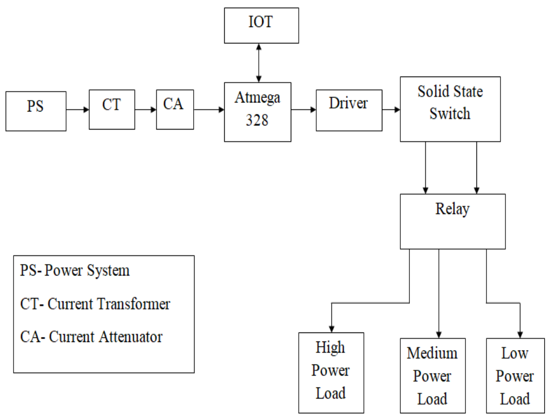
2.1 Existing System:

The existing power grid system relies on traditional methodologies and infrastructure, presenting several limitations and challenges. Load shedding is a manual process prone to delays and human errors, especially during peak load conditions or emergencies, which can result in voltage instability and power outages. Voltage regulation is inadequate, often causing voltage collapses and other power quality issues. Additionally, the integration of Internet of Things (IoT) technologies is minimal, resulting in a lack of automated, intelligent control over load shedding and other critical operations. These limitations underscore the need for a transition to a more advanced smart grid system, incorporating innovative approaches power electronics for enhanced reliability, efficiency, and resilience.

2.2 Proposed System:

The proposed system, titled "Innovative Approaches in Power Electronics for Cyber-Physical Systems Using Smart Grids," aims to revolutionize the current power grid infrastructure by integrating advanced technologies and methodologies. This system employs wireless communication for real-time data transmission, ensuring prompt decision-making and efficient operation. The system leverages IoT technologies for intelligent and automated control, making load-shedding management more effective. Additionally, it ensures better voltage stability and seamless integration with cyber-physical systems (CPS), addressing vulnerabilities such as increasing demand, renewable energy integration, and cyber threats. By enhancing the grid's reliability, efficiency, responsiveness, and security, the proposed system provides a robust and advanced solution for modern power infrastructure.

2.3 Block Diagram:



2.3.1 Block Diagram Description:

Power System

- This block represents the main power source, which could be from a conventional power plant or renewable energy sources integrated into the smart grid.

Current Transformer

- The current transformer is used to measure the current flowing through the power system. It steps down high current to a lower, manageable level suitable for measurement and monitoring.

Current Attenuator

- The current attenuator further processes the output from the current transformer, reducing the current signal to a level that can be safely and accurately read by the microcontroller (ATmega 328).

ATmega 328 Microcontroller

- This microcontroller is the brain of the system. It receives signals from the current attenuator, processes the data, and makes decisions based on pre-programmed algorithms. It can control various outputs based on the current readings and system requirements.

Driver

- The driver interfaces between the microcontroller and the solid-state switch or relay. It amplifies the control signals from the microcontroller to a level sufficient to operate the switching devices.

Solid State Switch

- A solid-state switch is used for high-speed switching and control of electrical loads. It provides a reliable and fast response without mechanical wear and tear.

Relay

- The relay is an electromechanical switch used to control the connection and disconnection of electrical loads. It can handle higher current loads but operates slower compared to solid-state switches.

High Power Load

- Represents high-power-consuming devices or systems, such as industrial machinery or large HVAC units, connected to the smart grid.

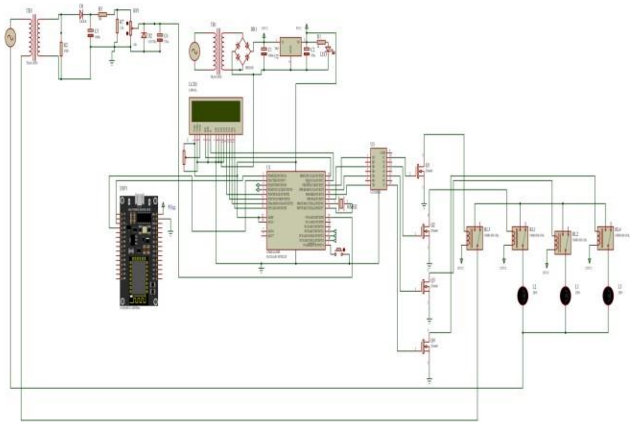
Medium Power Load

- Represents medium power-consuming devices or systems, such as smaller commercial equipment or moderate household appliances.

Low Power Load

- Represents low-power-consuming devices, such as lighting systems, small household appliances, or electronics.

2.4 Circuit Diagram:



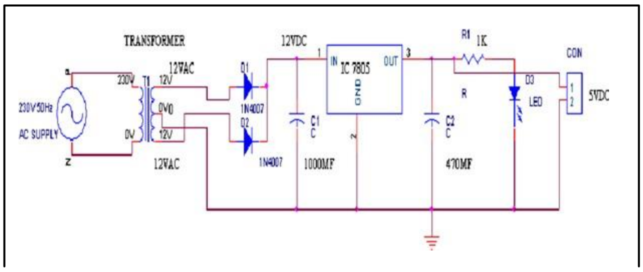
2.4.1 Circuit Diagram Description:

The main power source providing the electrical energy to the grid. This could be AC power from a utility or DC power from a renewable source like solar panels. Current Transformer (CT) Measures the current flowing through the power system. Connected in series with the power line to measure the current. Provides a scaled-down AC current proportional to the main line current. Current Attenuator Converts the current transformer's output to a lower voltage signal suitable for the microcontroller. Typically includes resistors and possibly operational amplifiers to attenuate and condition the signal. Provides a low-voltage AC signal proportional to the main line current. ATmega 328 Microcontroller Processes the signal from the current attenuator, performs computations, and generates control signals. Analog Input receives the attenuated current signal for processing. Driver Circuit Amplifies the control signals from the microcontroller to a level sufficient to drive the solid-state switches and relays. Transistors, MOSFETs, or dedicated driver ICs. Connected to the digital outputs of the microcontroller. Connected to the control terminals of the solid-state switch and relays. Solid State Switch (SSS) Provides fast and reliable switching of electrical loads without mechanical wear. Relay Electromechanical switch used to control medium and low load devices. Receives the amplified control signal from the driver. Connected to medium and low load devices. Often requires a separate power source for the coil, which can be managed by the driver circuit. High Load Connected through the solid-state switch, typically high power-consuming device Medium Load Connected through the relay, typically medium power-consuming devices. Low Load Connected through the relay, typically low power-consuming devices.

HARDWARE DETAILS

3.1 Single Power Supply:

Power supply gives supply to all components. It is used to convert AC voltage into DC voltage. Transformer used to convert 230V into 12V AC.12V AC is given to diode. Diode range is 1N4007, which is used to convert AC voltage into DC voltage. AC capacitor used to charge AC components and discharge on ground. LM 7805 regulator is used to maintain voltage as constant. Then signal will be given to next capacitor, which is used to filter unwanted AC component. Load will be LED and resister.LED voltage is 1.75V.if voltage is above level beyond the limit, and then it will be dropped on resister.



3.2 Atmega 328:

ATMEGA 328 microcontroller, which acts as a processor for the Arduino board. Nearly it consists of 28 pins. From these 28 pins, the inputs can be controlled by transmitting and receiving the inputs to the external device. It also consists of pulse width modulation (PWM). These PWM are used to transmit the entire signal in a pulse modulation. Input power supply such as Vcc and Gnd are used. These IC mainly consists of analog and digital inputs. These analog and digital inputs are used for the process of certain applications.

3.2.1 Description Of Input:

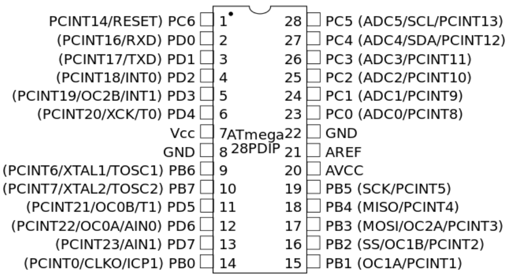
Analog Input:

Arduino atmega-328 microcontroller board consist of 6 analog inputs pins. These analog inputs can be named from A0 to A5. From these 6 analog inputs pins, we can do the process by using analog inputs. Analog inputs can be used in the operating range of 0 to 5V. Analog signal is considered as the continuous time signal, from which these analog signal can be used for certain applications. These are also called as non-discrete time signal. Inputs such as voltage, current etc.., are considered to be either analog signal or digital signal only by analyzing the time signal properties. Various applications of Arduino microcontroller can use only an analog input instead of digital inputs. For these applications, analog input ports or pins can be used.

Digital Input:

Digital inputs can be defined as the non-continuous time signal with discrete input pulses. It can be represented as 0's and 1's. These digital inputs can be either on state or in off state. Arduino atmega328 microcontroller also consists of 12 digital input pins. It can be stated as D0 to D11. Nearly 12 inputs can be used for digital input/output applications. The working of the digital input ports is where the discrete input pulses can be triggered and supplied to the ports. These ports receive the input and therefore the port can be used for both input and output process. These digital pins can access only the digital inputs.

3.2.2 Atmega-328 Ic:

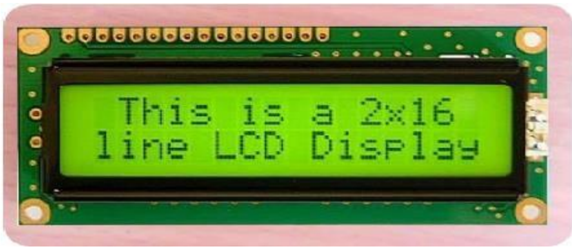


This ATMEGA-328 integrated chip consists of 28 pins. It consists of 6 analog inputs that are shown in the pin diagram. Analog inputs can be represented as PC0 to PC5. These analog input pins possess the continuous time signal which acts as an analog input for the system. These PWM, which transmits the signal in the form of discredited form. Both analog and digital input ports can be used for various applications for the input power supply, VCC and GND pins are used. Pins PB6 and PB7, which acts as a crystal to generate a clock signal. By using these crystal, we can generate the clock signals and by these clock signals, we can use this clock signals for input sources. PC6 pin are the one where it can be used for the reset option. Resetting the program can be done by using this PC6 pin.

3.3 Wi-Fi Module (Esp8266):

The ESP8266 WiFi Module is a self-contained SOC with integrated TCP/IP protocol stack that can give any microcontroller access to your WiFi network. The ESP8266 is capable of either hosting an application or offloading all Wi-Fi networking functions from another application processor. Each ESP8266 module comes pre-programmed with an AT command set firmware, meaning, you can simply hook this up to your Arduino device and get about as much WiFi-ability as a WiFi Shield offers (and that's just out of the box)! The ESP8266 module is an extremely cost effective board with a huge, and ever growing, community.

3.4 LCD – Liquid Crystal Display:

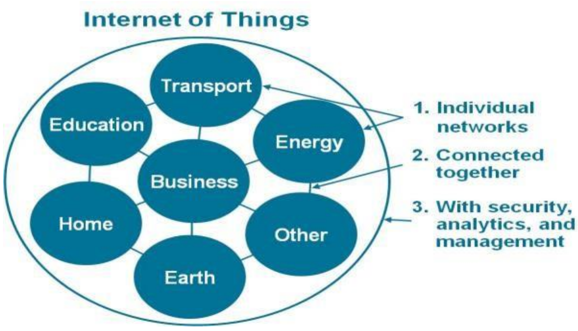


Liquid Crystal Displays (LCDs) have materials, which combine the properties of both liquid and crystals. Rather than having a melting point, they have a temperature range within which the molecules are almost as mobile as they would be in a liquid, but are grouped together in an ordered form similar to a crystal. An LCD consists of two glass panels, with the liquid crystal material sand witched in between them. The inner surface of the glass plates are coated with transparent electrodes which define the character, symbols or patterns to be displayed polymeric layers are present in between the electrodes and the liquid crystal, which makes the liquid crystal molecules to maintain a defined orientation angle. One each polarizer are pasted outside the two glass panels.

3.5 Internet of Things (IoT):

The Internet of Things (IoT) is the network of physical objects or "things" embedded with electronics, software, sensors, and network connectivity, which enables these objects to collect and exchange data. IoT allows objects to be sensed and controlled remotely across existing network infrastructure, creating opportunities for more direct integration between the physical world and computer-based systems, and resulting in improved efficiency, accuracy and economic benefit.

IoT as a Network of Networks:



These networks connected with added security, analytics, and management capabilities. This will allow IoT to become even more powerful in what it can help people achieve.

RESULT

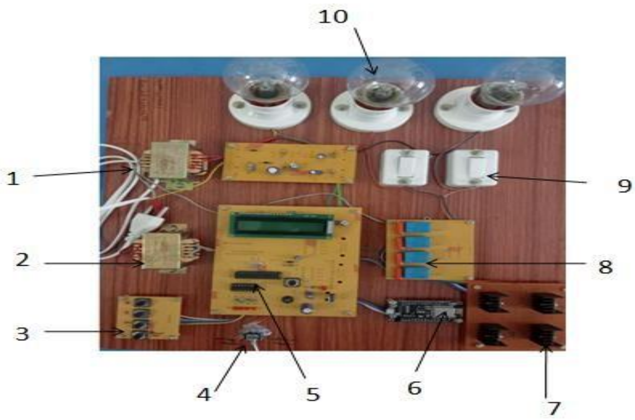


Figure 5.1: Hardware setup for "Innovative Approaches in Power Electronics for Cyber-Physical Systems Using Smart Grids"

The above figure 5.1 is hardware setup following components for

1. **Current Transformer**
2. **Power Transformer**
3. **Local control switch**
4. **Mode selection Online/offline**
5. **Driver IC ULN 2003**
6. **Wi-Fi Node MCU**
7. **Solid state switch**
8. **Relay 12V coil**
9. **Load On/Off Switch**
10. **Lamp Load**

Figure 5.2: IoT page

The above figure 5.2 known as login page of our website the user id „admin“ password „admin“

Figure 5.3: Hardware setup for local control mode

Figure 5.4: Hardware display

The figure 5.4 known as hardware display C load current value, M mode for offline or online, L for Local control and O is online control.

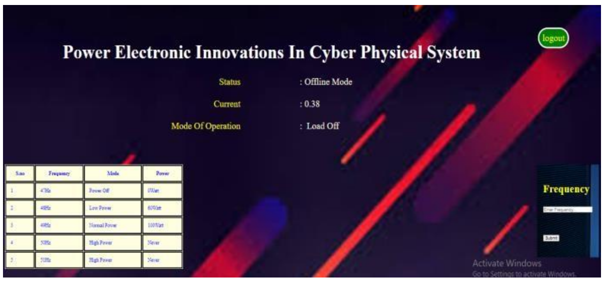


Figure 5.5: IoT page for Offline mode

The above fig: 5.5 is an IoT monitoring page for "status for offline line mode (or) online mode, Current is load side current value and mode of operation is a power mode for Low power, Normal power and High power mode" and the frequency chart and enter the frequency panel.

Figure 5.6: Low Power mode for local LCD display.

Figure 5.7: IoT page Low power mode monitor

The above figure 5.6 and 5.7 is hardware side display unit and IoT side monitoring page. Our project grid frequency 48Hz Low power mode minimum load power 60watts.

Figure 5.8: Normal Power mode for local LCD display.

Figure 5.9: IoT page Normal power mode monitor

The above figure 5.8 and 5.9 is hardware side display unit and IoT side monitoring page. Our project grid frequency 49Hz Normal power mode minimum load power 100watts.

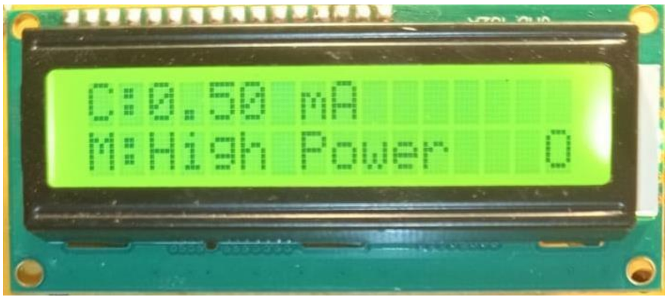


Figure 5.10: High Power mode for local LCD display.

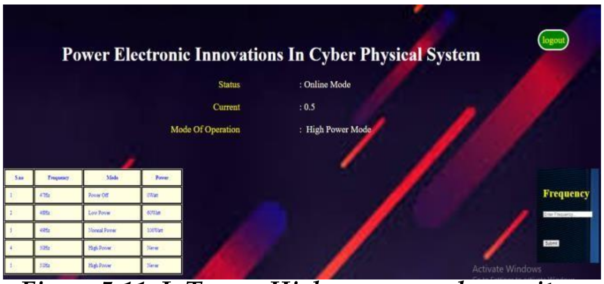


Figure 5.11: IoT page High power mode monitor

The above figure 5.10 and 5.11 is hardware side display unit and IoT side monitoring page. Our project grid frequency 50Hz High power mode load power Never.

Figure 5.12: Power Off mode for local LCD display.

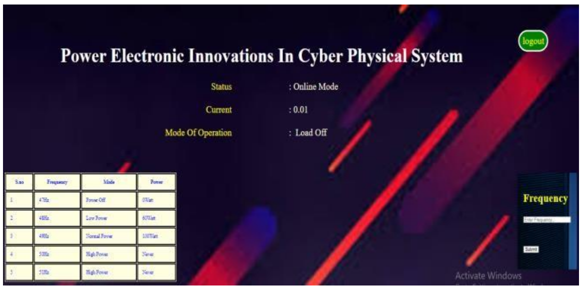


Figure 5.13: IoT page Power off mode monitor

The above figure 5.12 and 5.13 is hardware side display unit and IoT side monitoring page. Our project grid frequency below 48Hz Power off mode.

CONCLUSION

This project, ―Innovative Approaches in Power Electronics for Cyber-Physical Systems Using Smart Grids,‖ significantly enhances the quality and reliability of the power system. The technologies and infrastructure of this smart grid system are designed to address all the challenges and vulnerabilities it faces. The system's technical feasibility ensures that there should be no obstacles preventing the transition to a smart grid. The proposed system utilizes wireless communication for real-time data transmission. This project has reconfirmed the importance of timely applied load-shedding actions. If these actions are not performed promptly, more severe load-shedding measures must be taken to prevent voltage collapse. Voltage instability occurs when systems lose their voltage regulation capability, and a method for calculating the critical load-shedding time has been presented. Furthermore, incorporating solid-state switches into the system enhances its responsiveness and efficiency. Solid-state switches enable faster switching times, reduced power losses, and improved reliability, which are crucial for maintaining stability and performance in smart grids. Finally, by using IoT-based techniques, the control of load shedding becomes more manageable. It has been demonstrated that emphasizing load shedding on a more critical bus yields better results, as anticipated.

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