An intelligent power management system for developing a smart grid system

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Abstract— **The main aim of this work is to develop an intelligent power management system that can identify synchronization failures of any external supply source to the power grid by sensing frequency and voltage irregularities. Furthermore, in a three-phase system, an automated phase changeover of the load from the missing phase to the next available phase is included to provide continuous AC mains supply. In addition, a solar module with suitable storage capacity is attached to the proposed system to reduce grid energy use and play main energy sources to maximize green energy usage. The electrical loads can be protected by automatically shutting down the system utilizing microcontroller programming. The LCD shows the current supply voltage as well as the overall system's operating frequency. The complete unit will be shut down by the intended controlling unit if any of these parameters increases or lowers over the limit of every separate incoming source, and the system will automatically reconnect following stabilization. The results include the successful operation of the intelligent power management system. This system is fully automatic and we can control and maintain the amount of bill per month for ourselves.**

Keywords— Communication, Distribution loss, Energy storage, Power system, Smart grid, Sensor, Smart Meter, Security System.

I. INTRODUCTION

A self-healing network with dynamic optimization algorithms that employ real-time measurements to minimize network losses, maintain voltage levels, boost reliability, and enhance asset management is referred to as a "smart grid." The operational data acquired by the smart grid and its subsystems will allow system operators to quickly determine the optimal plan for securing against different situations like assaults, vulnerabilities, and so on. Except in an emergency, when a portion of the loads can be lowered as needed to balance the power grid generation with its loads, the traditional power system operator has no control over the loads. As a result, most grid elements are only employed for a brief time during peak power demand and are idle during normal operation. To preserve dependability, stability, and efficiency, today's electric grid was constructed as a vertical system that included generation, transmission, and distribution, as well as controls and devices. However, system operators are now confronted with additional issues, such as renewable energy resources (RER) penetration in legacy systems, fast technical development, and a variety of market actors and end-users [1]. The smart grid, the next version, will have communication support schemes and real-time measuring techniques to improve resiliency and forecasting, as well as safeguard against internal and external threats [2]. Significant infrastructure investment in the form of a communication system, cyber network, sensors, and smart meters must be implemented to limit system peak demands when the cost of electric energy is highest for an effective smart power grid system design and operation. The smart power grid incorporates a sensing, monitoring, and control system that offers end-users real-time pricing on energy costs at any given time. Furthermore, smart metering's powerful control systems provide energy consumers the flexibility to react to real-time pricing. The smart power grid also provides a framework for the utilization of renewable and green energy sources, as well as sufficient emergency power for large urban load centers. It protects the linked electrical systems against a full blackout caused by man-made or natural disasters. It also permits the linked electrical grid to be broken up into smaller, regional clusters. Furthermore, the smart power grid allows every energy user to become an energy producer by giving them the option of using solar or wind energy, fuel cells, or combined heat and power (CHP) energy sources, as well as participate in the energy market by buying or selling energy via the smart meter connection.

Automated and smart management is a vital component for determining the efficacy and efficiency of these power systems in future generation electrical systems that combine diverse renewable energy supplies [3]. In terms of digitalization, flexibility, intelligence, resilience, sustainability, and customs, the Smart Grid moniker is designed for management automation and intelligence in terms of a number of benefits over the existing systems [4]. The intelligent control centers are expected to remotely monitor and interact with electrical devices in real-time, the intelligent transmission infrastructures will use new technology in order to improve the quality of power, and the intelligent substations should coordinate their local devices consciously [5]. The concept of the Energy internet [6] has been presented to provide exciting potential for the future energy usage paradigm through all the power generation, storage, transmission, and distribution stages, thanks to substantial developments in system automation and intelligence.

With the introduction of cutting-edge technology such as cellular communications [7] [8]-[12], internet of things [13], [14], antenna design [15]-[17], sensor design [18]-[23], advanced optics [24]-[27], health sector [28], [29], and a reliable power system [30]-[32], the world is ushering in a new era, which is recognized by technology enthusiasts. Energy harvesting from locally accessible renewable energy sources (RES) is a popular technique that is portrayed as an established technology for numerous reasons [33]-[36]. First and foremost, it lowers dependency on fossil fuels. Second, renewable energy sources are widely available around the world. Third, a substantial amount of green energy may be created from renewable sources of energy by lowering the cost of generating power and lowering the carbon content. Numerous research [37]-[42] have been conducted in an attempt to build a long-term, reliable, and energy-efficient supply network based on locally available renewable energy sources. Some researchers advocate combining separate renewable energy sources or non-renewable energy sources with renewable energy sources, while others advocate integrating a renewable energy source with electricity grid infrastructure or a single renewable energy source with appropriate energy storage systems [43]-[49]. A photovoltaic system, often known as a PV system or solar power system, is a power system that uses photovoltaic [50], [51] to provide useable solar electricity. It is made up of several components, including solar panels that collect and convert sunlight into power, a solar inverter that converts DC to AC power, as well as mounting, wiring, and other electrical accessories to put together a functional system. It may also feature an integrated battery solution and employ a solar tracking system to improve the system's overall performance since storage device prices are predicted to fall.

The primary goal of this study is to design and construct an intelligent power management system and to educate people about the benefits of a smart mini-grid. The research's major goals are to learn about the smart grid system's potential advantages and the integration mechanism with legacy power systems, and (ii) construct an intelligent smart grid framework utilizing a microcontroller platform.

II. Smart Grid Concept

The basic concept of a smart grid system is shown in Figure 1. Smart grid with automation, communication, and IT systems that can monitor power flows from sites of generation to points of consumption (even down to the level of individual appliances) and manage or constrain the load in real-time or near real-time to match generation. Smart grids are self-healing and allow power users to have an active role in the system. By minimizing usage, a smart grid saves energy. It has the potential to provide better customer service and more precise billing. It lowers carbon dioxide emissions. Smart grids are currently being employed in electrical networks, from power plants to residential and commercial customers. The "grid" refers to the networks that transport electricity from power plants to homes and businesses. Wires, substations, transformers, switches, and other components make up the grid. The main advantages are a large increase in energy efficiency on the power grid as well as in the homes and workplaces of energy consumers.

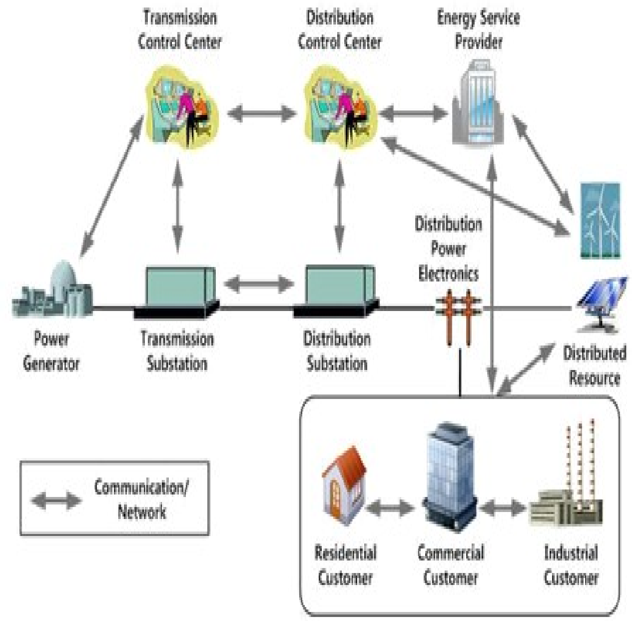

Figure 1: Concept of smart grid.

III. System Description

A. Block Diagram

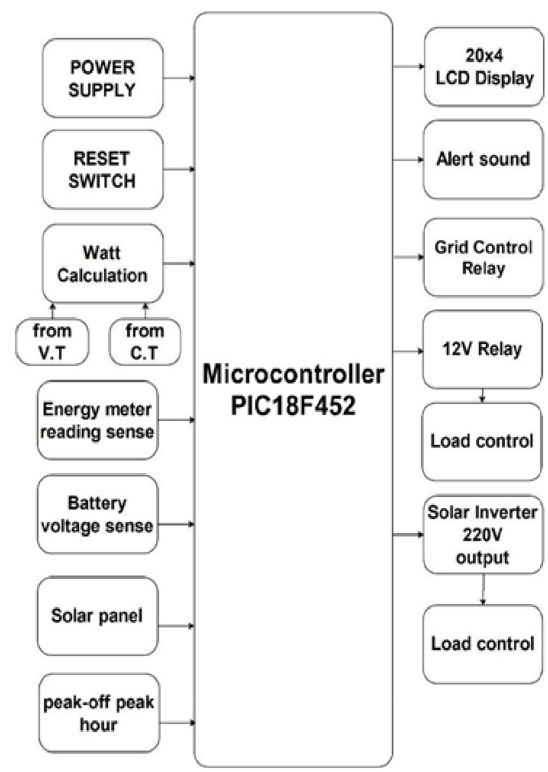

Figure 2: Block diagram of the system.

The block diagram representation of the system is shown in Figure 2. The PIC18F452 IC, a 40DIP microcontroller with 35 I/Os, is the core component. This system detects a few circumstances and then acts intelligently. Our major priority setting is a peak and an off-peak hour. With pin 30 of the microcontroller, we install a button to toggle between peak and off-peak hours. We will be able to determine how much power is utilized as well as the current operational load using this system. We attached a single-phase energy meter to pin 15 of the microcontroller and got a pulse. This system was intended to handle a maximum load of 200 watts. We constructed an inverter with P55 MOSFET switching oscillated from microcontroller pins 27 and 28 to convert solar PV dc power to 220 V 50Hz AC. One 12V battery is used to store solar PV generation, and its charging and discharging rates are controlled by the microcontroller pin number 3. Other auxiliary components, such as the LCD, are linked to pins 33 to 38.

B. Microcontroller

Transmitter with the asynchronous receiver (AUSART). It's perfect for manufacturing equipment, instrumentation and monitoring, data collecting, power conditioning, environmental monitoring, telecommunications, and consumer audio/video applications because of all of these qualities. This high-performance 10 MIPS (100-millisecond instruction execution) processor is also simple to develop (only 77 single word instructions) Upwards compatible with the PIC16C5X, PIC12CXXX, PIC16CXX, and PIC17CXX devices, this CMOS FLASH-based 8-bit microcontroller packs Microchip's powerful PIC® architecture into a 40- or 44-pin package and provides a fluid migration path of software code to higher levels of hardware integration. The PIC18F452 has a C compiler-friendly development environment, 256 bytes of EEPROM, Self-programming, an ICD, 2 capture/compare/PWM functions, 8 channels of 10-bit Analog-to-Digital (A/D) converter, the synchronous serial port that can be configured as either 3-wire Serial Peripheral Interface (SPI) or 2-wire Inter-Integrated Circuit (I2CTM) bus, and Addressable Universal. Figure 3 and 4 shows the pin arrangement and top view of the specified microcontroller.

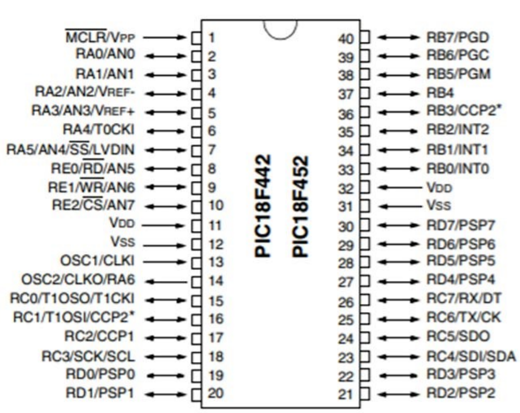

Figure 3: Pin configuration of the microcontroller.

Figure 4: Tow view of the microcontroller.

C. Energy Meter

A device that monitors the quantity of electric energy utilized by a household, a company, or an electrically powered item is known as an electricity meter, electric meter, electrical meter, or energy meter.

D. Solar PV Module

The direct conversion of light into electricity at the atomic level is known as photovoltaic. The photoelectric effect is a feature of some materials that causes them to absorb photons of light and release electrons. When these free electrons are collected, they produce an electric current that may be utilized to generate power.

E. Solar inverter

A solar inverter, also known as a PV inverter, is an electrical converter that converts a photovoltaic (PV) solar panel's variable direct current (DC) output into a utility frequency alternating current (AC) that can be fed into a commercial electrical grid or used by a local, off-grid electrical network. In a photovoltaic system, it is a vital balance of system (BOS) component that allows the use of standard AC-powered equipment. Maximum power points, tracking, and anti-islanding protection are all features that solar power converters have developed for use with photovoltaic arrays.

F. Display

A liquid-crystal display is a flat-panel display or similar electronically manipulated optical device that takes advantage of liquid crystals' light-modulating characteristics. To generate color or monochrome pictures, liquid crystals need a backlight or reflector rather than emitting light directly. LCDs can show random graphics (as in a general-purpose computer display) or fixed graphics with minimal information content that may be displayed or concealed (as in a digital clock), such as preset text, numbers, and 7-segment displays. They share the same underlying technology, with the exception that random pictures are made up of a vast number of little pixels, whereas other displays contain bigger parts.

The total capital cost of the system is BDT 4,330 which means that the system is cost-effective and can be widely used for residential and commercial purposes.

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IV. RESULTS AND DISCUSSIONS

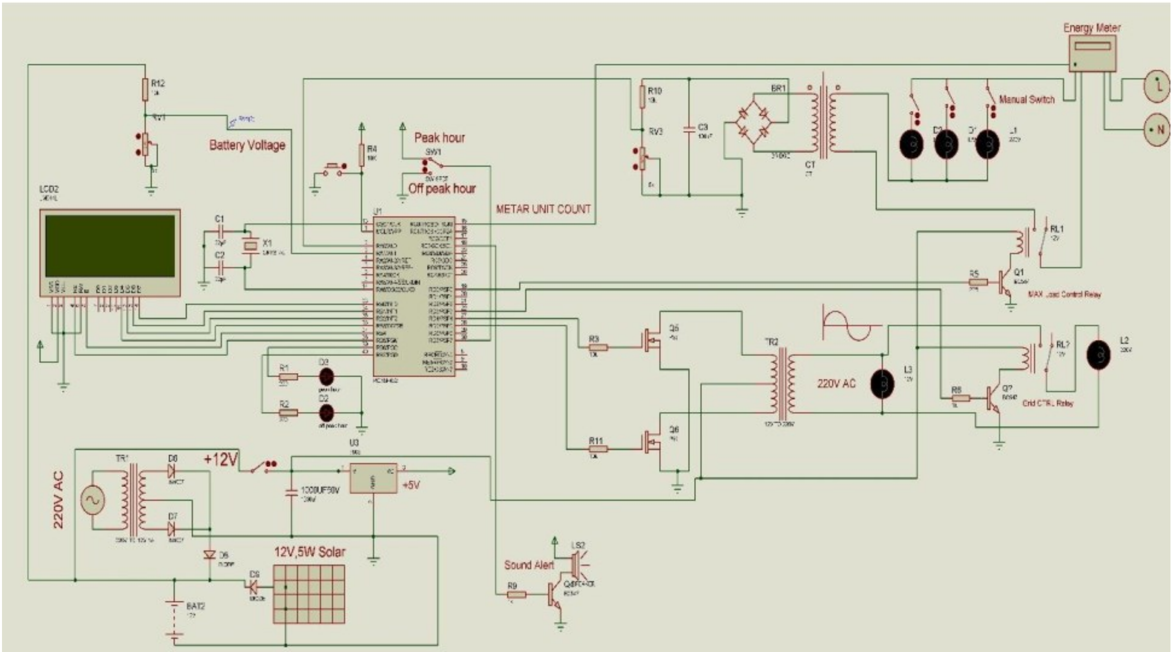

Figure 5: Circuit diagram of the system.

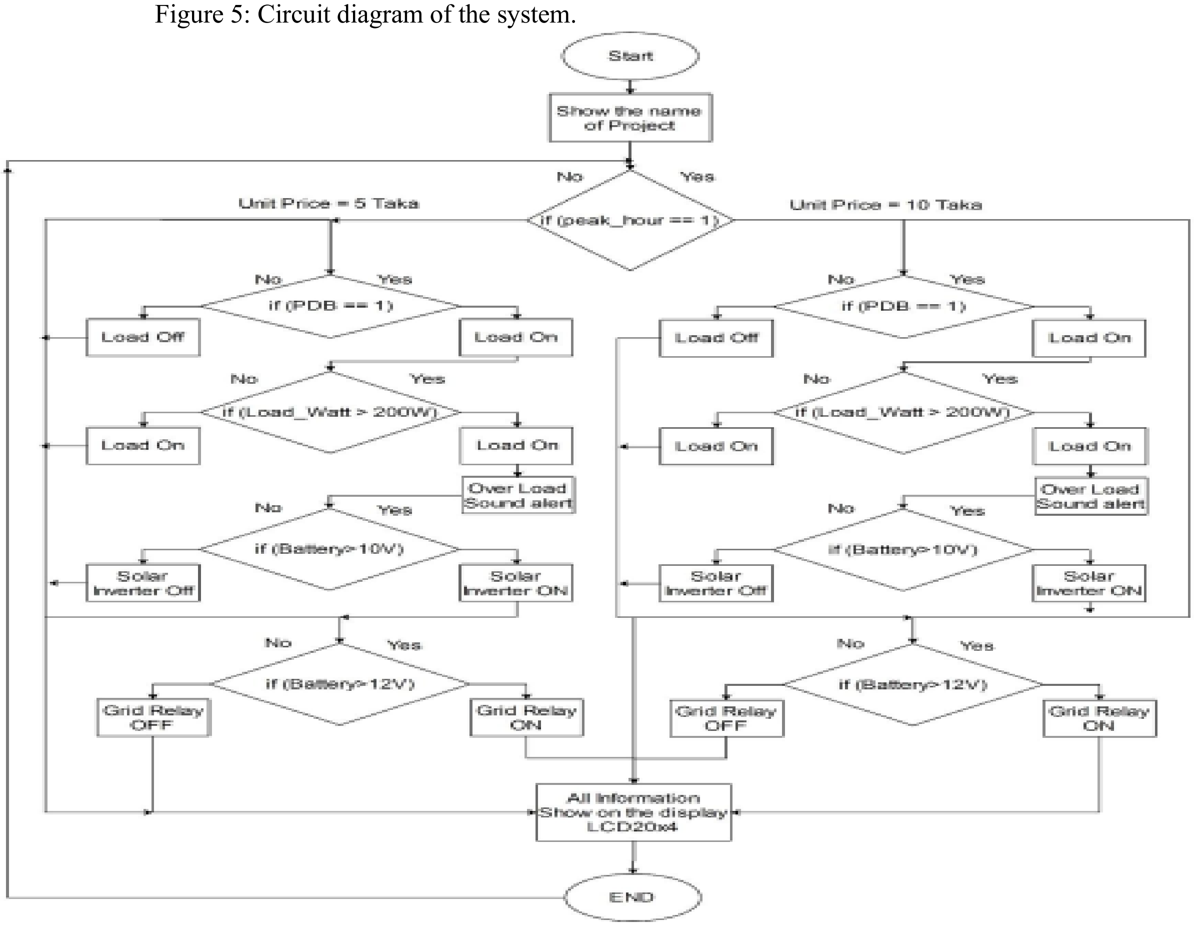

Figure 6: Flow chart of the proposed system.

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This entire system functions according to a set of criteria or requirements that we established. There are two major functions to it. One is the load side, while the other is the power supply. Because this is a dual-source power control system, the utility grid will take precedence, with a maximum operational load of 200 Watts. We installed a battery storage system to store dc power and discharge it as needed. When the user's consumptions reach 200 W during peak hours, the system will emit a beep to lessen the load for a few seconds before disconnecting from the utility. When the consumer consumes more than 200 W during off-peak hours, our system will alert the user that the load has exceeded its maximum capacity and, at the same time, it will coordinate the solar PV power (after inverting dc to 220V AC) with the utility to power up the entire system. This smart technology also determines the monthly bill amount and the unit of energy consumption (kW).

We've also included safeguards in the battery charging and discharging mechanism so that if the battery voltage falls below 12V, the solar PV generation will never be able to provide the load. This is how it works in our system. The circuit diagram of the system is shown in Figure 5 where the microcontroller is the main component. The flow chart of the system is shown in Figure 6. The flow chart of the system describes the operational mode of the system.

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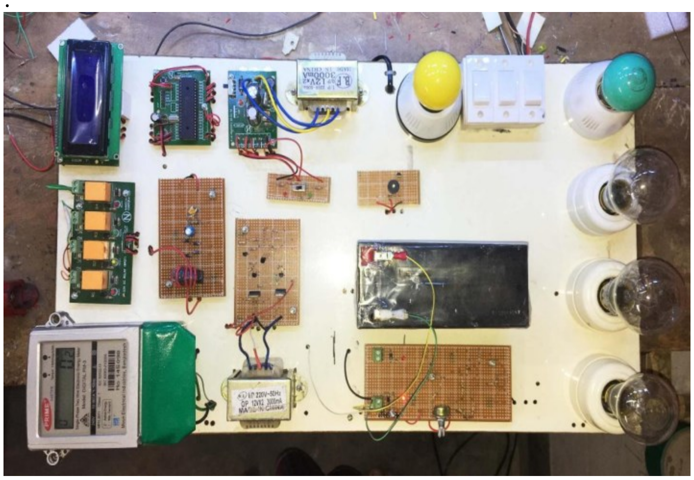

Figure 7: Real image of the system.

The real image of the system is shown in Figure 7. We aimed to develop an intelligent and smart energy management system that can be functional in different conditions in different ways. Here are two load conditions, peak hour, and off-peak hour, thus the unit price is different though. The charging system from the solar panel and discharging while operating load also controlled from the microcontroller when the battery voltage remains under 12V it will not invert to AC, thus does not connect to the grid as well. When battery voltage remains over 12 volts it will then connect with the grid in off-peak load condition only. Besides this system controls the maximum operating load as expected. So the challenge was to comply with all the conditions works under one controlling unit. The output wave shape of the electrical grid system is shown in Figure 8.

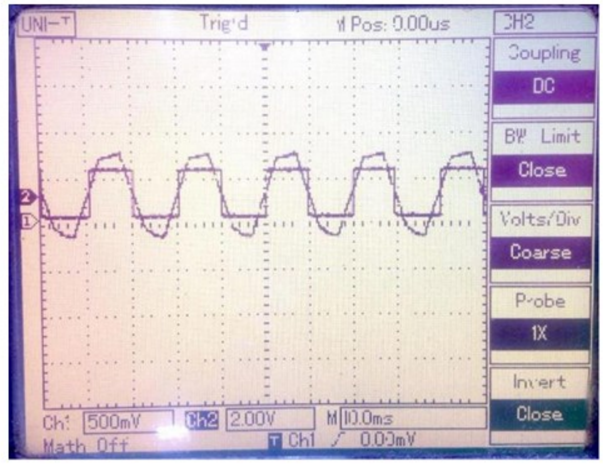

Figure 8: Output waveform of the utility grid and generated ac signal.

The developed system can also be implemented for the following purpose; (i) a smart load management system, (ii) a solar PV smart mini-grid system, and (iii) a grid-solar PV hybrid system.

V. CONCLUSIONS

The key concern of this work is to develop an intelligent and smart energy management system that can be functional in different conditions in different ways. Recent environmental awareness sparked by conventional power plants has prompted research into modern smart grid technology and its integration with climate-friendly green renewable energy. Through more flexible system management, smart grid operations enable wider penetration of variable energy sources. Experiments on the effects of renewable energy sources in a smart power network, particularly large-scale solar PV penetration into the grid were conducted. Voltage fluctuations and harmonic injection grow with increasing PV penetration, according to experimental and simulation findings. It is also very problematic for peak hour and power-off conditions since it has both an on-grid and a battery backup system. The use of zero-crossing detection for synchronization ensures a safe and smooth start. We can regulate and manage the quantity of charge every month for ourselves because this is an intelligent method. It can also be used in off-grid settings. This system may be utilized as a smart load management system, a solar PV smart mini-grid system, or a hybrid grid-solar PV system. We successfully created the fundamental concept of the synchronization method as well as making this inverter usable to charge the battery using this system, which sought to produce an intelligent energy management system with the capability of synchronizing utility grid to solar PV power. This one has undergone several adjustments and try-and-error processes to become functioning. Finally, this smart management system can be implemented for developing a smart grid system.

This is only a prototype of the smart grid system. Some major development should have to do for commercial use. That is: (i) Prepaid energy metering concept should be incorporated, (ii) Maximum power point tracking (MPPT) facility should be incorporated for better generation, and (ii) Remote monitoring and data logging system can also be incorporated.

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