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IoT-Based Monitoring System Framework

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Introduction

The Internet of Things (IoT) must be able to manage and analyze data in real time while experiencing extremely low latency if it is to stand out from other technologies. This is one of the characteristics that distinguishes IoT from other technologies. One of the differentiating characteristics that sets IoT apart from previous technologies is the presence of this functionality. Real-time monitoring systems are able to provide information to system operators about the general status of the monitoring objects they are keeping an eye on when they are placed in power substations. These systems are keeping an eye on. As a consequence of this, there is a chance that not only the dependability of the system, but also the efficiency with which it is operated, will be enhanced. During the course of this inquiry, we will make use of a Field-Programmable Gate Array (FPGA) integrated controller that is built in accordance with a particular industry standard.

Literature Review

A standardized strategy for building and implementing a new fog-based framework for innovative city platforms is presented by **Cheng et al. (2018).** This method can be found in the article. The name "FogFlow" has been given to this framework. With the assistance of this framework, we will be able to gather and evaluate the data that is produced by fog devices. Developers of Internet of Things services now have the possibility, thanks to the FogFlow editing mechanism, to design readily extensible Internet of Things resources that can be accessible through the cloud as well as on the edges. In addition to this, it makes it feasible to exchange and reuse content data across services by utilizing standardized methods that may be used by these services. This was accomplished by employing standardized ways that may be utilized by these services. Hu and Ni (2018) provide an innovative approach to the problem of locating urban monitoring systems. This is the final part of their contributions, but it is certainly not the least important. This cutting-edge method is used to detect and pick the image waves with the greatest frequencies that may be discovered in digital camera sensors. These image waves are then used to choose license plates for automobiles. These picture waves are analyzed in order to establish the license plate information.

Kantamneni and colleagues (2015) investigated the uses of multi-agent systems in the monitoring and management of microgrids as part of their research. The authors have conducted research on the fundamentals of multi-agent systems, including their structural designs, build platforms and methods, example application recommendations, and limitations. In addition, they have looked at the limits that these systems are subject to.

Castellani et al. (2010) gives a practical understanding of this framework. Castellani and colleagues are the ones that authored this study. The authors state that the intended network will cover all of the floors within the buildings that are home to the information engineering departments throughout its whole as part of its overall scope. In addition, the authors note that the network was established in order to provide faster access to basic services like environmental monitoring and the localisation of university customers. This was accomplished through the development of the network. Because the network is constructed on an architecture that is not only malleable but also durable, it is feasible to manage nodes in a manner that is extremely basic. This is made possible by the network being built on an architecture that is both malleable and durable.

Monitoring System Functioning

It is possible to think of the operation of this monitoring system as consisting of three distinct stages that occur in sequential order. These stages include data collection, data processing, and data logging. These phases are presented in the order that they occurred in time. On the hybrid controller, which is made up of a CPU and an FPGA, different tasks are handled by employing the targets that are associated with them.

Controlling of Monitoring

The controller has been pre-programmed to use Linux as its operating system (OS), and it has been given the instruction to collect data in real time using a range of sampling rates concerning the voltage, actual power, and reactive power as well as the state of the circuit breaker and the temperature of the transformer. Additionally, the controller has been instructed to monitor the temperature of the transformer. In addition to that, the controller now has the capability to keep an eye on the temperature of the transformer. Field programmable gate arrays (FPGAs) are produced using reprogrammable silicon chips, which gives them a bigger processing capacity in addition to a faster reaction time than digital signal processors (DSPs), which are made using non-reprogrammable silicon chips. DSPs are referred to by its acronym in full, which stands for digital signal processors. Digital signal processors are composed of silicon. At current moment, a wide range of research projects have shown a variety of uses for the FPGA technology, which may be employed in a variety of contexts. These applications can be utilized to improve the efficiency of various processes.

Characteristics of IoT

A waveform character searching system that was based on an FPGA was constructed by the authors of the study throughout the course of the test. During the course of their inquiry, they make use of a Xilinx Kintex-7 device that is equipped with 34 megabytes of RAM on the chip's inside and comes preloaded with the operating system already installed. Because of this, they are able to digest information a great deal more swiftly. The authors of the study discussed the field of technology known as field-programmable gate arrays (FPGA), as well as the prospective applications of this branch of technology for high-performance computer systems. This research effort focuses on analyzing and describing several technologies that are referred to as field-programmable gate arrays (FPGA). In addition to being intended for computation, these FPGAs also include communication capabilities. For the goals of this study, the creation of three-dimensional fast Fourier transforms (3D FFTs) and their implications for molecular dynamics were carried out on FPGA clouds with the intention of attaining an improvement in performance. As an extra component of this study, the development of a high-performance hardware generator that is capable of being implemented on FPGA is now taking place. A high sample frequency is required in order to successfully carry out a wide variety of examinations and research that are connected to the power system. Two examples of these kinds of investigations are the analysis of transient studies and the analysis of the signal in its frequency domain. Both of these types of analyses are quite useful. When it comes to high-speed multiple-input-and-output (MIMO) applications, the use of field-programmable gate arrays, which are more often referred to as FPGAs, offers a number of major benefits that are hard to ignore. This is because the processing operations that occur on FPGAs are carried out in a fashion that is entirely parallel, and they do not compete with one another for the same resources. As a result, this allows for a far higher level of efficiency.

Vision of IoT Monitoring System

An industrial-grade controller is what's used for this particular setup of the system. This controller is equipped with a Kintex-7 325T FPGA, an RJ-45 Gigabit Ethernet connection, a Quad-Core CPU operating at 1.91 GHz, 2 GB of DRAM, 16 GB of Storage, and an RJ-45 connector for Gigabit Ethernet. In addition to that, this specific configuration is equipped with a Gigabit RJ-45 Ethernet connection. You may investigate the particulars of this controller by looking at the graphical depiction that is provided for you in Figure 3.1. As can be seen in Figure 3.1, the controller is outfitted with not one, not two, but all three of its own unique input modules. This is because the controller is a three-in-one device. This is not an error in the text. These many constituents are depicted in the picture. Utilizing the analog input 1, which is a DC + 10V 16-bit analog input module, it is possible to reach an absolute accuracy of 6230 V while doing measurements at full scale.

This is made possible by the utilization of the analog input 1. The analog input 2 is an AC 300Vrms, 24-bit simultaneous analog input module that employs an internal master time-based system. Its data rate range has the potential to go as high as 50kS/s and it has a simultaneous analog input module. The analog input module contains a total of 24 bits, and the input noise is 2 millivolts root mean square. In addition, the analog input 2 is a module that has a data rate range that is capable of reaching up to 50 kS/s at its highest setting. This maximum value may be achieved by setting the module to its highest possible value. A module that can accept 24 V in the opposite direction that the current is flowing may be found at the digital input.

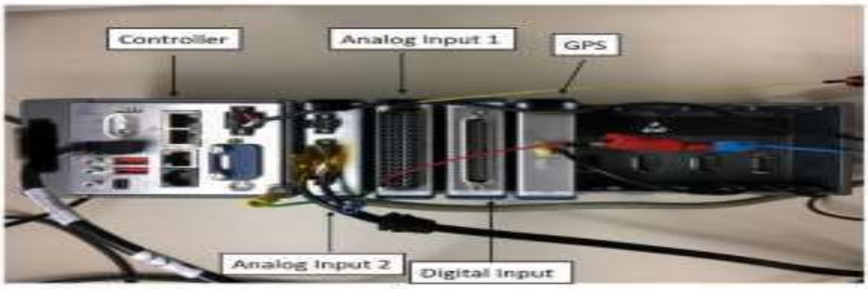

Fig.: Controller with Embedded Software for FPGA

After it has been written to storage, the data that has been collected by an Internet of Things-based monitoring system is held in a repository that is known as a Network-Attached Storage (NAS) device. Users of this gadget have the added benefit of being able to view the data even when they are at a remote location. Unlike direct-attached storage (DAS) and storage area networks (SAN), network-attached storage (NAS) is a type of file storage that can be accessed by a large number of authorized users and heterogeneous client devices to retrieve data in a variety of categories from a centralized location within the network.

DAS and SAN

This is in contrast to DAS and SAN, both of which are types of storage that are used for storing large amounts of data. In contrast to this, DAS and SAN are both devoted to storing massive volumes of data in a single area. This is a key distinction between the two. In contrast to this, there is the distributed automated storage (DAS) and the storage area network (SAN), both of which were developed expressly for the goal of storing enormous amounts of data in a single location. NAS is an abbreviation that stands for network-attached storage, which is another word for NAS. NAS is often referred to simply as NAS. The administrator of the system has the ability to collect the necessary data at the right time depending on the needs that are imposed by the scenario, provided that they access the network with a login and a password. This allows them to access the network. This capability requires the administrator to have access to the network in order to function properly. An embedded controller that contains an FPGA, a host computer, and a NAS are all connected to a hardware firewall that is contained within the substation, as shown in Figure 3.2. Ethernet cables are utilized in order to effectuate these connections amongst devices. This link contains a question about the firewall that stands on its own as a distinct component from the rest of the link. A computer that is installed in the command center is in charge of receiving the data as they are being provided in real time, and this task rests on the computer itself. In this section of the guide, the structure of the system will be outlined according to the sequence in which the data will methodically and sequentially make its way through the system. This will be done in accordance with the previous section.

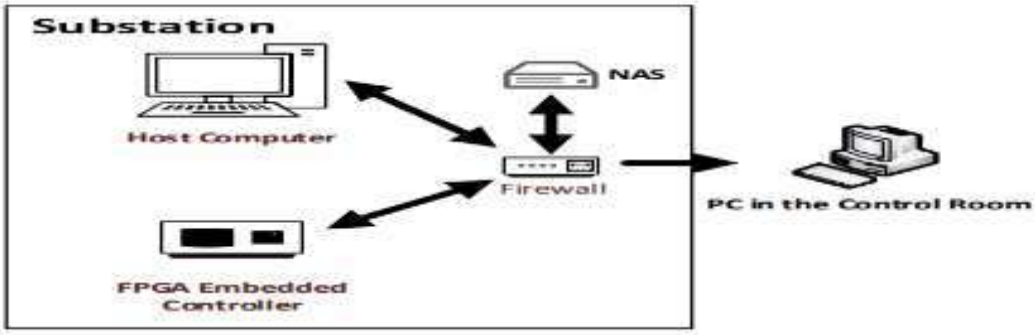

Fig.: Framework for an IoT-Based Real-Time Monitoring System

Data Gathering

This specific system makes use of three separate sorts of input modules, as can be seen in Table 3-1, in order to gather a variety of different forms of input data at a range of different sampling rates. This enables the system to fulfill its intended purpose. The FPGA will be in charge of gathering and processing any and all data that is available. In order to acquire high-resolution data of AC analog voltage signals and frequency signals for the purpose of conducting in-depth analysis, AC analog voltage signals are sampled at a rate of two thousand samples per second. Signals for actual power, reactive power, and transformer temperatures are all converted by transducers. Transducers are responsible for this conversion. A sampling speed of 10 samples per second is used to collect signals relating to the power, temperature, and condition of the circuit breakers.

TABLE: Modules for Data Acquisition and Sampling Rates

Module Type	Measurement Objects	Sampling Rate
AC Analog Voltage InputModule (- 300 to 300Vrms)	Voltage and Frequency	2000 S/s
Analog Voltage Input Module (-10 to 10V)	Real Power, Reactive Power and Transformer Temperatures (Transducers)	10 S/s
Digital Input Module	Circuit Breaker Status	10 S/s

Using the zero-crossing method, one may calculate the period T(s) of the input voltage, and then use that information in equation (1) to compute the frequency of the system. This can be done by using the information obtained from the previous step. This makes it possible to calculate the frequency of the system in hertz (Hz).

$$f\,(Hz) = \frac{1}{T}$$

The controller is going to gather the sampled data and then transfer it to a NAS whenever the required events have been triggered. These occurrences include overheating of the transformer, abnormally high voltage, abnormally low voltage, abnormally high frequency, and abnormally low frequency. The local area network (LAN) grants the system operator unrestricted access to the network attached storage (NAS) at any time.

Synchronization and Timestamps

You will want time sources that have a high resolution and an accurate reading in addition to having a high sample rate if you want your system to perform as a real-time monitoring system with a high rate of sampling. When creating a monitoring system for power substations that is based on the Internet of Things, it is imperative that cybersecurity be taken into consideration as a crucial component. One of the most used protocols that is utilized in the process of synchronized clocks across various networking systems. The Network Time Protocol, often known as NTP, was not deployed because there were worries about the level of security provided by the system. In its place, an industry-standard GPS synchronization module that can achieve an accuracy of +100 ns has been implemented. The data that is sampled is accompanied with timestamps that are provided by this module. A more digestible representation of the synchronization process may be found in the figure that can be found in Fig. 3.3. In order to synchronize and timestamp the data that is collected on the FPGA, the absolute time that is delivered by a 40MHz FPGA internal clock is synchronized to the time that is received from a GPS receiver. This is done in order to preserve the accuracy of the absolute time. Following the application of a timestamp to the data, it is then sent on to the device's central processing unit (CPU) so that the subsequent step may be executed.

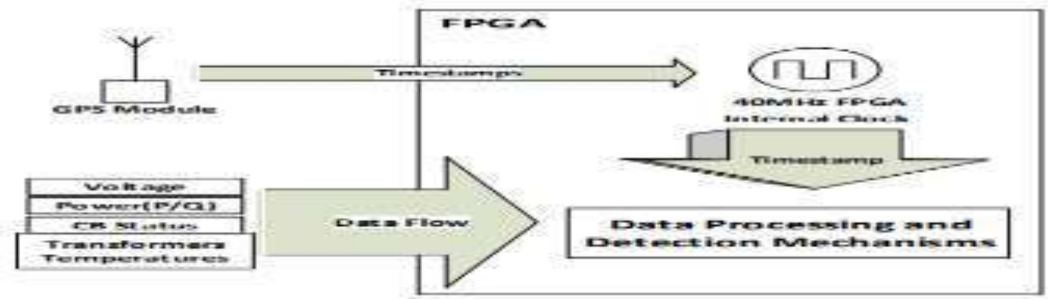

Fig.: Process of Synchronization and Timestamping

A timestamp is appended to each and every piece of data as it travels through the processing stages, whether it is destined to be displayed or logged. When the designated detection techniques are put into use, the network attached storage (NAS) is used to save all timestamps and data that has been sampled, as shown in Figure 3.4. When an alarm is activated, this event takes place. In this particular case, epoch time is used as the time reference for the GPS, and the beginning of the time reference is set to 00:00:00.000 Coordinated Universal Time (UTC) on January 1, 1904.

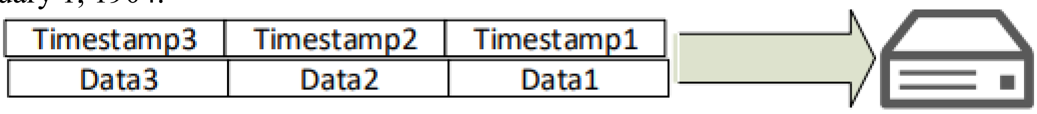

Fig.: Synchronization of Data and Recording of It

Data Display

As was covered in earlier sections, all of the data collection and defined detection techniques are encoded onto the FPGA target so that the computing capabilities and determinism may be utilized. This is done in order to maximize efficiency. It is necessary for the data to be continuously transmitted across the network in order for them to be shown in real time on the computers that are situated in the control room as well as at the substation. You may observe the Human-Machine Interface (HMI) that is present on both personal computers by looking at Figure 3.5. In this specific investigation, for reasons of both security and confidentiality, the power indicators as well as the time have been concealed. The necessity for the system to be scalable and the need to facilitate the access of other authorized computers to the HMI of the monitoring system led to the implementation of the tag communication technique inside the system. This technique will be examined in greater depth in the part that comes after the one in which it is mentioned, so stay tuned for that!

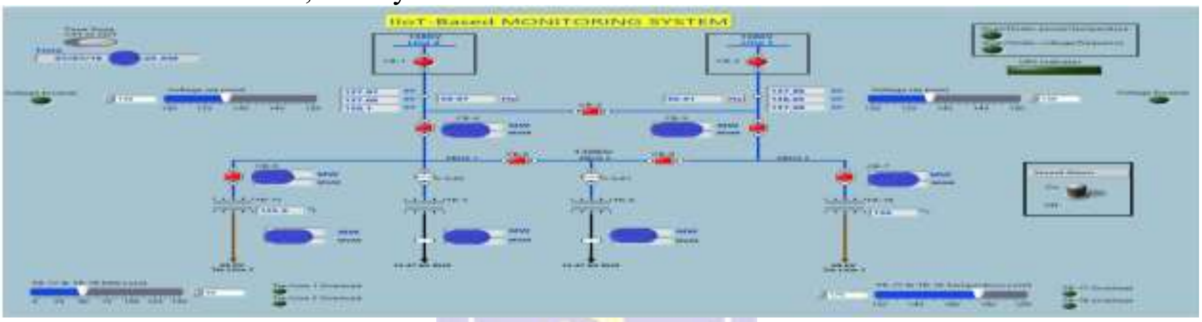

Fig.: Human Machine Interface of the Monitoring System

Data Logging

One of the most important components of this monitoring system is that the data recording is taken care of on a CPU-based target. This is one of the many reasons why this system is so important. After the specified event mechanisms have been brought into play, the data is moved from the memory of the CPU-based target target to the memory of the FPGA-based target. After that, the data is stored in the local storage in the form of files, and the files are written in a binary format. Transferring these files from the local storage to the NAS is accomplished through the use of the File Transfer Protocol, more often referred to as FTP. Table 3-2 provides an example of a portion of the data that was collected by displaying one phase of the voltage readings that were taken. This is done for illustrative purposes. For the purpose of determining this system's RMS and frequency statistics, the raw voltage information from just one cycle is utilized as the point of departure.

TABLE: A Voltage Data Logging File Containing One Phase

Timestamp (µs)	Raw (kV)
1533116616359500	-71.96577761
1533116616360000	-34.92403722
1533116616360500	3.456600666
1533116616361000	40.08871722
1533116616361500	76.97151464
1533116616362000	110.4259613
RMS (kV)	**Frequency (Hz)**
137.6861599	60.0234375

Conclusion

Internet of Things (IoT) applications are investigated in this article-based dissertation in the context of power system monitoring, power system demand-side management, and power system protection. This dissertation is made up of a total of six pieces that have been published in various academic publications throughout the world. The Internet of Things (IoT), which offers a platform that enables the conveyance of data without being constrained by either time or place, is the most significant component in the development of smart grids. This is due to the fact that it provides a platform that enables the conveyance of data.

In the first part of this research, it is shown that the use of a monitoring system that is based on the Internet of Things may be expanded to embrace a number of monitoring and control systems that have a variety of intended objectives. This finding was made possible by the fact that the researchers were able to demonstrate that this expansion is possible. It may be possible to capture more relevant data, such as weather, sun radiation, and electricity use, using this cutting-edge invention, and then combine them in further study in order to enhance overall monitoring. As a direct result of this, there is potential for improvements to be made to the effectiveness, dependability, and robustness of the electrical networks.

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