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A Novel System for Substation Health Monitoring

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***Abstract*— Fault diagnosis is vital for power system operation. This paper presents a hardware implementation for substation fault diagnosis. The hardware implemented fault diagnosis system (HIFDS) can achieve high-speed inference and has some advantages over traditional approaches. The performance of the proposed HIFDS is evaluated. The experimental results show that the hardware prototype is feasible for practical applications.**

Keywords— ***Field-programmable gate array (FPGA), power supervisory control and data-acquisition (SCADA) systems, substation fault diagnosis.***

I. INTRODUCTION

THE objective of power system operation is to supply reliable and stable power to customers. However, faults resulting from disturbances or equipment failures are inevitable in practical operation. When a fault occurs, it is imperative to restrict the impact of outages to a minimum by restoring power to the fault area as soon as possible. This requires that the fault section first be identified, which is the main issue of fault diagnosis in power systems. A SCADA system is a centralized control and monitoring system that typically consists of a master station, communication networks, and remote terminal units (RTUs).

Most current power systems are equipped with supervisory control and data–acquisition (SCADA) systems. A SCADA system is a centralized control and monitoring system that typically consists of a master station, communication networks, and remote terminal units (RTUs). Fig. 1 shows the basic architecture of a typical power SCADA system with centralized fault diagnosis functions. In power SCADA systems, all of the field data are collected by RTUs, and then the RTU transmits the collected data to the control center through communication networks. A fault can cause a large number of alarm messages in a short period of time in a power SCADA system. This will impose heavy stress on dispatchers and hamper their decision-making during the restoration process. However, an FPGA-based fault diagnosis approach has not yet been applied to power substations due to the complexity of existing fault diagnosis algorithms.

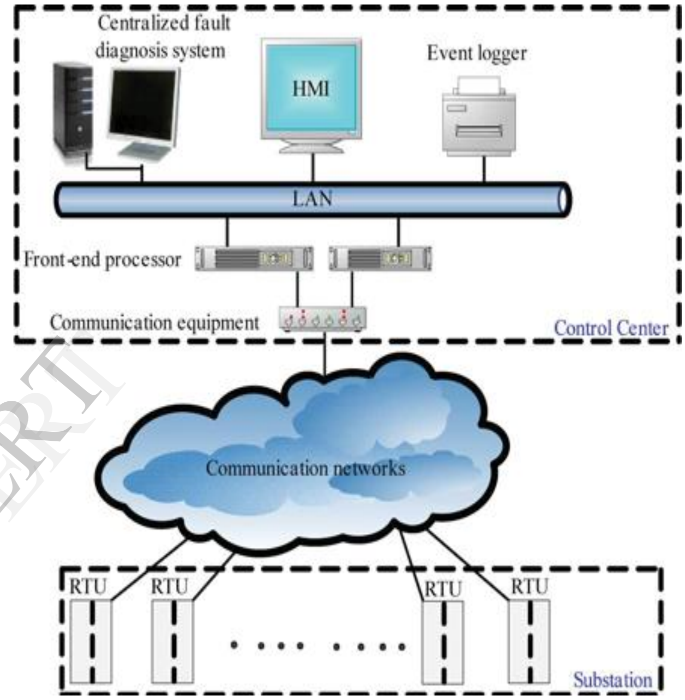

Fig. 1 Architecture of a typical power SCADA system

The paper proposes a decentralized fault diagnosis approach for power substations, and shows how the proposed framework can be integrated in existing SCADA systems to make them capable of withstanding the failure of communication links between the host computer and RTUs. The main contributions of this paper include: 1) providing a procedure to realize hardware based fault diagnosis system for power substations; 2) proposing a decentralized fault diagnosis framework for power SCADA systems; and 3) allowing the fault diagnosis function to be integrated in existing SCADA systems.

II. A NOVEL SYSTEM FOR SUBSTATION HEALTH MONITORING

In this system, all of the field data are collected by RTUs, and then the RTU transmits the collected data to the control center through communication networks. There are two main parts for this system. These are the substation part and the monitoring part. Substation part is shown in fig.2. In this project, the substation part is considered as the remote terminal unit (RTU). There can be so many remote terminal units (RTUs) in this system. In the substation part, several measurements are monitored such as the voltage, temperature, frequency, transformer oil levels. These measurements are displayed in a

LCD display placed in the substation part. Zig-bee module is used for the communication between these two parts. i.e, the substation part and the monitoring part. A pair of zig-bee module is used for this purpose. When multiple remote terminal units are sending the data at the same time, multiple zig-bee modules are used.

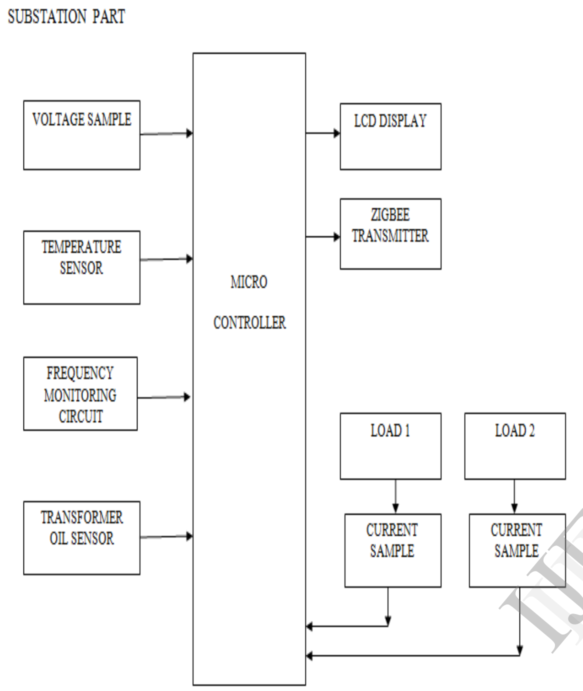

Fig:-2 substation part

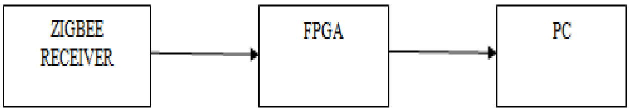

Fig3: Monitoring Part

The output side is the monitoring part. It is shown in fig.3. The transmitted data is received in the receiver side by the zig-bee receiver. In the receiver side FPGA is used. Major benefits gained from using FPGAs include easy implementation of design alteration and rapid product development for industrial applications. Since FPGAs are reprogrammable silicon chips, they can be employed to implement the fault diagnosis function, which is more flexible and can handle the changes of network configuration or protective schemes of a power substation. The final output is observed in the PC.

In the proposed approach, the fault information used for analysis is obtained directly from RTUs, which is more reliable and can avoid the influence of communication problems. To make the proposed method suitable for being implemented on a hardware platform, a fault diagnosis algorithm that contains only addition and multiplication operations was developed

III. HARDWARE SECTION

Hardware section consists of temperature sensor, transformer oil sensor, frequency monitoring circuit, voltage sample, current samples with loads.

A. *Temperature measurement*

LM 35 temperature sensor is used for temperature measurement. It gives linear 10 mV/°C scale factor. ADC will show the temperature.

B. *Frequency measurement*

Measurement of frequency is done through opto-coupler and comparator. The bridge rectifier produces positive half cycles. The output of the bridge rectifier is passed through the MCT 2E opto-coupler. An opto-isolator contains a source (emitter) of light, almost always a near infrared light-emitting diode (LED), that converts electrical input signal into light, a closed optical channel (also called dielectrically channel), and a photo sensor, which detects incoming light and either generates electric energy directly, or modulates electric current flowing from an external power supply. The sensor can be a photo resistor, a photodiode, a phototransistor, a silicon-controlled rectifier (SCR) or a trial. Because LEDs can sense light in addition to emitting it, construction of symmetrical, bidirectional opto-isolators is possible. An optocoupled solid state relay contains a photodiode opto-isolator which drives a power switch, usually a complementary pair of MOSFETs. A slotted optical switch contains a source of light and a sensor, but its optical channel is open, allowing modulation of light by external objects obstructing the path of light or reflecting light into the sensor.

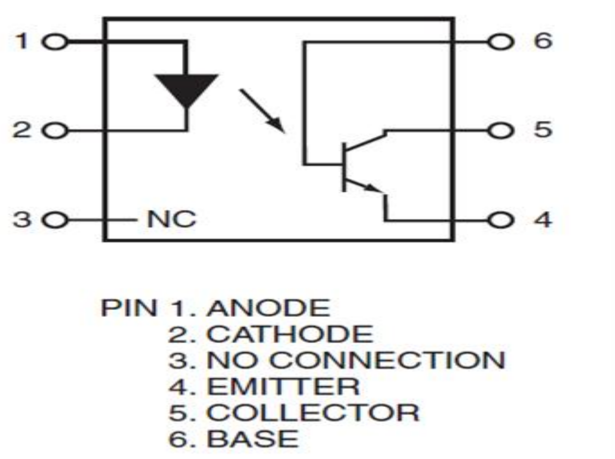

Fig4: Mct2e Optocoupler

LM 358 comparator IC is used followed by the opto-coupler. It is used to obtain the accurate pulses. The count is calculated and it is the frequency. The package consists of a gallium-arsenide infrared-emitting diode and an npn silicon phototransistor mounted on a 6-lead frame encapsulated within an electrically nonconductive plastic compound. The case can withstand soldering temperature with no deformation and device performance characteristics remain stable when operated in high-humidity conditions. Unit weight is approximately 0.52 grams. It has a Low Cost Dual-In-Line Package. Surface Mount Option Available. All electrical parameters are 100% tested by manufacturing. Specifications are guaranteed to a cumulative 0.65% AQL

C. Voltage measurement

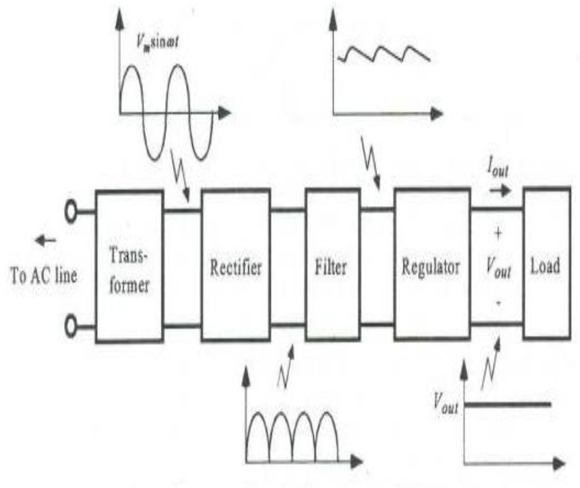

Fig6: Voltage Measurement

The supply voltage is stepped down by a step-down transformer and is fed to a rectifier. The output obtained from the rectifier is a pulsating d.c voltage. So in order to get a pure d.c voltage, the output voltage from the rectifier is fed to a filter to remove any a.c components present even after rectification. Now, this voltage is given to a voltage regulator to obtain a pure constant dc voltage.

D. Current measurement

For calculating the line current, CT 1270 current transformer is used. Its range is 0.5-5 v.

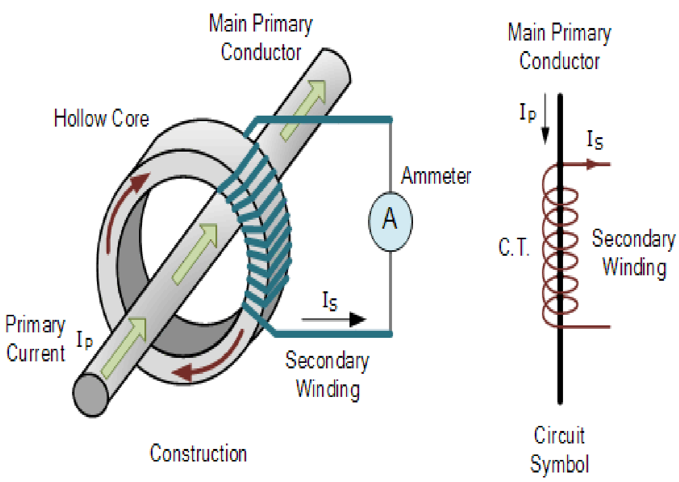

Fig5: Ct 1270 Current Transformer

The Current Transformer (C.T.), is a type of "instrument transformer" that is designed to produce an alternating current in its secondary winding which is proportional to the current being measured in its primary. Current transformers reduce high voltage currents to a much lower value and provide a convenient way of safely monitoring the actual electrical current flowing in an AC transmission line using a standard ammeter. The principal of operation of a current transformer is no different from that of an ordinary transformer.

E.Oil level problem detection

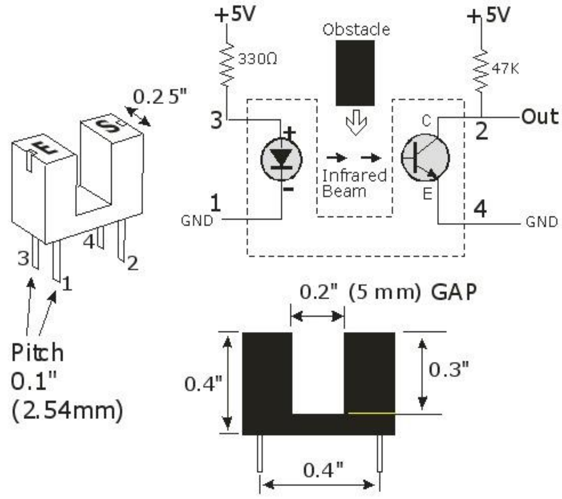

Fig7: Slot Sensor

MOC7811 is a slotted Opto isolator module, with an IR transmitter & a photodiode mounted on it. Performs Non-Contact Object Sensing. This is normally used as positional sensor switch (limit switch) or as Position Encoder sensors used to find position of the wheel. It consists of IR LED and Photodiode mounted facing each other enclosed in plastic body. When light emited by the IR LED is blocked because of alternating slots of the encoder disc logic level of the photo diode changes. This change in the logic level can be sensed by the microcontroller or by discrete hardware.

IV. DESIGN AND IMPLEMENTATION

An FPGA is a matrix of configurable logic blocks (CLBs), linked to each other by an interconnection network which is completely reprogrammable. The use of FPGA in modern digital systems has become a common practice. Major benefits gained from using FPGAs include easy implementation of design alteration and rapid product development for industrial applications. In addition, modern electronic design automation (EDA) packages provide designers with an efficient method using hardware description languages (HDLs) to simulate and verify their circuit designs before the designs are implemented in a target device. Since FPGAs are reprogrammable silicon chips, they can be employed to implement the fault diagnosis function, which is more flexible and can handle the changes of network configuration or protective schemes of a power substation.

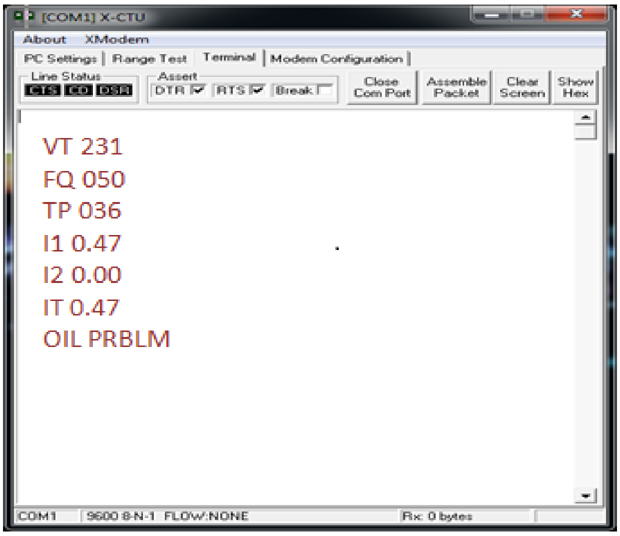

Fig8: output observed in pc

With FPGA technology, the computing tasks of fault diagnosis algorithms in software can then be transformed down to a configuration file that contains information on how the logic blocks should be wired together. In addition, FPGAs are truly parallel in nature, and are particularly suitable for parallel algorithm implementation, so different processing operations can be assigned to a dedicated section of the chip, and can function autonomously without any influence from other logic blocks. The parallel and reconfigurable features are well suited for implementing the proposed matrix-based fault diagnosis algorithm

V. CONCLUSIONS

This study proposes a novel system for substation health monitoring, which has its merits of fast inference speed and low cost. In addition, it is easily integrated into existing systems, and is adaptive to network reconfiguration.

1) Fast Inference Speed: Since the proposed fault diagnosis approach has fast inference speed, it is suitable for real-time applications.

2) Decentralized Fault Diagnosis Framework: Traditional fault diagnosis has problems when the host computer in the control center fails to obtain accurate data from remote sites due to communication problems. The proposed decentralized system performs fault analysis in the field site, which has less of an influence on communication failure since the data for analysis is obtained directly from RTUs.

3) Feasibility for Power Utilities: The proposed system can be easily integrated with the existing systems, which makes it feasible for power utilities.

4) Adaptive to Network Reconfiguration: Since FPGAs are reprogrammable silicon chips, the proposed approach can deal with the changes of network configuration, which is effective in power system operation.

VI. ACKNOWLEDGMENT

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