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Design and Analysis of a Substation Digital Control System

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Abstract: *This article sufficiently explains a substation digital control system whose purpose was to build a prototype of a digitized substation control system operated by a remote controller and using Arduino. The project was designed to remotely switch on the loads one at a time until an excess load is detected after which it is commanded to go off by itself in order to protect the distribution transformer from overload. Transformer overload is the most frequent cause of transformer failure and can sometimes lead to explosions as it causes the transformer to overheat. After overheating, the insulation of the transformer windings is damaged creating a short circuit, which eventually makes the transformer to fail or eventually explode. The aim was to automatically limit the number of loads connected to the transformer depending on the transformer rating and at the same time avoiding direct contact with any of the substation equipment by using a remote controller to avoid electric shock. Consequently, this report details the development of the system's decision-making mechanism and also mentions the project management. The project's decision making aspect is the main aspect of the system as it is automatic and does not require any physical operation.*

Keywords: Arduino, Load switching, Transformer protection, current sensing, Remote control.

INTRODUCTION

A substation is part of an electrical system with a set of equipment that transforms voltage or current from one level to another and may perform other several important functions like measurement, monitoring, control and switching of power before it reaches its desired destination. A typical substation facility consists of a small building with a fenced-in yard that contains transformers, switches, voltage regulators, and metering equipment that are used to adjust voltages and monitor circuits.

One of the key elements of a substation is a power transformer. It is a static device totally enclosed and generally immersed in oil which primarily steps up or down voltage or current for either transmission or distribution. Therefore, the chances of a fault occurring on it are very rare. However, the consequences of even a rare fault may be very serious unless the transformer is quickly disconnected from the system. This necessitates providing adequate automatic protection for a transformer against possible faults.

Due to load imbalance and overload on power lines caused by improper connections, distribution substation equipment for example transformers breakdown. This lead to high repair and maintenance costs. Furthermore, electrical power variations from substations also affect the quality of the delivered power.

To improve the quality of power delivered, it is pertinent to get acquainted with the possible challenges and problems associated with the operation of a substation. Additionally, if there is any insufficiency in the protection, monitoring and control of a power system, the system might become unstable. Therefore, a monitoring system that is capable of automatically detecting, monitoring, and controlling the existing constraints on electrical lines is necessary.

This is advantageous to both end-users and utility companies in that it guarantees the stability and reliability of the power delivered to the end-users and minimizes the chances of transformer breakdown which reduces on the maintenance and repair costs on the side of the utility companies. For decades, fuses, circuit breakers and electromechanical relays were used for the protection of the power system. The traditional protective devices such as fuses and electromechanical relays present several drawbacks. The advanced method used in this project for the protection purpose in the power system was an Arduino. An Arduino is an open-source electronics platform based on easy-to-use hardware and software. An Arduino is able to read inputs from the input devices and turn them into outputs through the output devices - activating relay switches and turning on electrical loads. It is better, highly accurate, and cheaper and its programming is also simple as compared to other microcontrollers.

SYSTEM DESCRIPTION

The design system comprises an IR sensor. The sensor is employed for the purpose of triggering the loads connected to the transformer through wireless switching by a remote. The current sensor is incorporated in the circuit to detect any slight increase in the current being supplied to the loads. The relays operate and isolate the circuit if the loads exceed the desired or required loads. The system has three bulbs to represent three loads. When the first load is activated, it is considered ass the desired load and a notification is read through the LCD module stating the condition as 'the first

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load connected, system stable'. When the second load is also connected, another notification is sent to the LCD stating 'second load connected, system stable'. When the last load is connected, the current sensor detects excess current and the LCD displays 'excess load detected'. The third load is automatically disconnected by the help of the relay and it is shut down after a few microseconds. Once the last load is has been put off, the system stabilizes and the LCD displays 'system stable'. Hence the design system protects, monitors and controls the transformer from excess loads or overload automatically without shutting down the entire system.

THE FLOW CHART

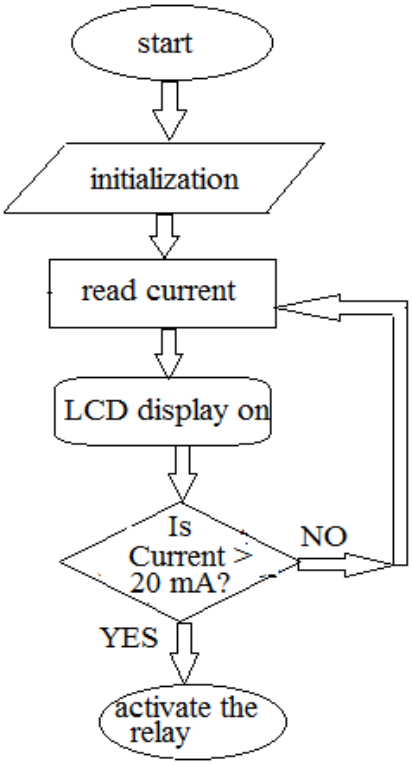

Figure 1. Flow chart of the system

THE BLOCK DIAGRAM

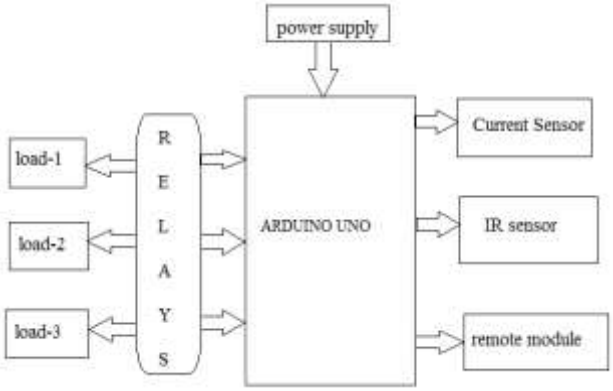

Figure 2. Block diagram of the system

CIRCUIT DIAGRAM

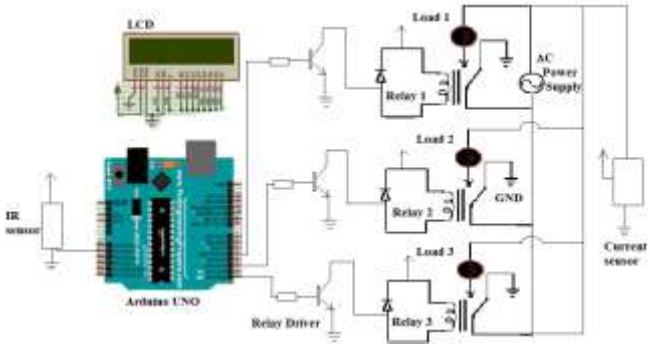

Figure 3. Circuit diagram of the system

APPLICATIONS

The substation digital control system has quite a number of applications due to its versatility and flexibility in the following areas which include;

Load supervision.

The system can perform supervisory control on the number of loads connected to a particular distribution transformer basing on its current rating in order to protect it from overload which is the biggest cause of transformer failure. Therefore areas that need this kind of intervention can find this system a handy tool so as to minimize the costs of purchasing a completely new machine as a result of a breakdown.

Remote controls of switches circuit breakers and other protection devices.

Most of the substations are located far away from load centres thus switching of these loads can become a very hard task to do. With that being said, remote switching can serve a very useful tool in as far as minimizing transport costs of having to reach the load centres is concerned. The system can do that with the help of a remote.

Measurements

Measurement of current is another function of this system and it can be applied in areas where the current rating of certain devices is key for the proper function of the system. Other applications of the substation digital control system include monitoring and presenting the information on the state of the switches (breakers, disconnectors), alarm processing, display and dispatching to control centre earth fault and short circuit indications (indications must work both in the isolated and compensated network and also in intermittent fault conditions)

RESULT

Figure 4. Implemented system design

The main objective of this project was achieved as the system works effectively. As the current circulating in the transformer coil varies, the LCD displays the readings. The relay is able to operate and isolate the transformer from excess load in case of an overcurrent fault. The relay is the main switching element in the system. When energized, it opens its contacts and de-energizes the contactor thus isolating the transformer to safety in case of adverse current conditions.

CONCLUSION

Generally, transformers are very important components of the electrical power system and their safety should be paramount. Overcurrent situations can cause damage to transformers causing interrupts to electrical supply. Blackouts cause economic derailment and disorient consumers' work schedule. This explains why this system is needed to help mitigate the effects of fault that may happen on the transformer. The system if properly put to use in power transformer protection can serve the purpose with greater advantages than the analogue overcurrent relay.

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