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PLC Based Smart Relay Coordination System for Smart Electricity Distribution

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Abstract - The increasing complexity of power systems and the critical role of transformers in distribution networks necessitate robust protective measures. This paper proposes a PLC-based relay coordination system for smart electricity distribution, focusing on monitoring and diagnosing distribution transformers. By integrating PLCs, relays, and sensors, the system aims to detect various faults such as overloading, overvoltage, under-voltage, phase faults, and over temperature conditions. The design emphasizes automation for efficient operation, labor, and energy savings, while ensuring the reliability of distribution transformers. Additionally, the paper discusses the challenges in protective relay design methods, emphasizing the transition from electromechanical to microprocessor-based systems. Testing principles and objectives are outlined, including fault identification and remediation techniques such as continuity tests and power-on tests. Overall, the proposed system offers a comprehensive approach to transformer protection and monitoring in modern power distribution networks.

Key Words*: *Relay coordination, Distribution transformers, Programmable Logic Controllers (PLCs), Fault detection, Overloading, Overvoltage, Under-voltage, Phase faults, Over-temperature, Automation, Protective relay design

1.INTRODUCTION

In last few years so many techniques are developed in field of relay coordination. The importance of coordination of different protective device is increasing now days. A power system consists of many number of equipment. So more number of circuit breakers and relays are required to protect the system. A relay must get sufficient chance to protect the zone under its primary protection. Only if the primary protection does not clear the fault the back-up protection should initiate tripping and therefore over current relay coordination in power distribution network is a major concern of protection engineer.

From many decades transformer are playing vital role in industries, substations, generation, distribution etc Main aim of studying this project is to design and implementation of PLC (Programmable Logic Controllers) automation to monitor as well as to diagnose condition such as load, currents, transformer temperatures and voltages of the Distribution transformers of substation which is one of the most important equipment in the power system network. The Data acquisition condition monitoring automatic controlling are important issues as there are large no of transformers and various components over a wide area in power system

In proposed system with PLC, relays and sensors are used to detect the faults of transformer such as overloading, overvoltage, under-voltage, phase to phase fault and over temperature faults. Probability of faults on distribution transformers is undoubtedly more and hence protection of transformer is highly essential.

Automation control is used for various systems for operation of equipments. Some processes are completely automated. Benefit of automation is it saves labor and saves energy and material improve quality accuracy and precision. Reduces dependency on human presence and decision making for any process A distribution transformer is a transformer that provides the final voltage transformation in the electrical power distribution system stepping down the voltage used in the distribution lines to the level used by the customer. Distribution transformers normally have ratings less than 200 KVA although some national standards can allow for unit up to 5000 KVA to be described as distribution transformer. Since these transformers are energized for 24 hours a day its proper working is very important and so a strong protection is required.

The main concern of this project is to rescue the distribution transformer in power system network against the internal and external faults. Overloading of transformer beyond the rating can cause a rise in temperature of both transformer oil and winding overloading is nothing but it is an over current fault occurring on secondary side of distribution transformer or rise in the load. Increase in the winding temperature will increase the stress on the insulation and then insulation deteriorates and may fail. Power system faults external to transformer can increase or decrease the voltage of the transformer which leads to overvoltage or under voltage fault. When fault occurs current increases and hence a comprehensive transformer protection scheme needs to include protection against overvoltage, under-voltage, overload, phase to phase fault and over temperature. Following system is a proposed system which consist all these protections.

2. SCOPE OF PROJECT

With the ongoing state of energy crisis worldwide and especially in Indian industries are often at the mercy of the local utility supplies or power distribution authorities. This is due to the fact that there exists a short fall between the demand and supply of electric power. Therefore most industries prefer to operate on generators along with the local utility supply.

In case of tripping loads at the plant need to be shed in order to meet with the supply and often this results in a “not up to the standard” batch of the good. This happens because of care not being taken in shedding the loads by switching off essential loads or miss timing the shedding.

Shedding is vital because if the loads are not shed then all will shut down eventually due to lack of supply. To overcome this problem non-essential loads are often shed following a certain scheme developed after thorough understanding of the product in production. To expand the scope of protective relay

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functions across traditional boundaries additional hardware is generally required. For example, to integrate another zone of protection into a digital relay requires only the alteration of software but to add panel meters or transducers requires dedicated additions and modifications to the hardware as well. Also considerable time is involved in developing the embedded firmware for new applications.

3. Blocks Description Of PLC Based Relay co-ordination System for Smart electricity distribution:

The purpose of this work is to the tool is developed using concept of adaptive protection scheme. Relay setting parameters are set automatically in response to changing systems. Furthermore, this proposed tool is suitable for the complex future radial distribution system. The block diagram of PLC Based Relay co-ordination System for Smart electricity distribution is as shown in below figure 1

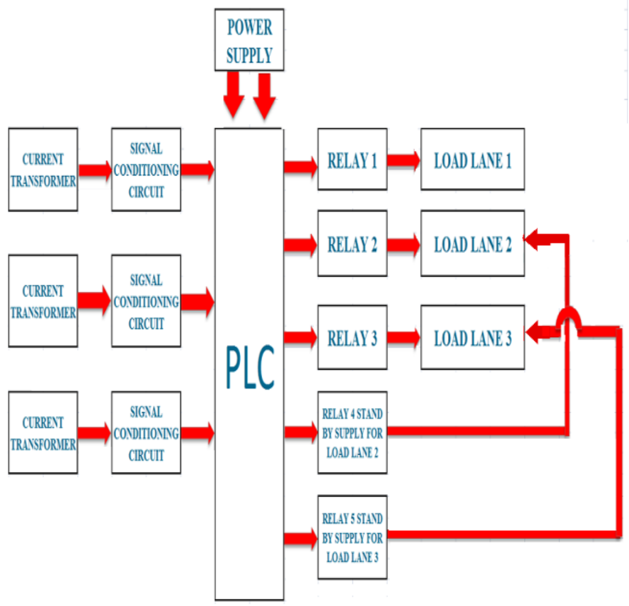

Fig -1: PLC Based Relay co-ordination System for Smart electricity distribution.

3.1 PLC:-

A programmable logic controller (PLC) or programmable controller is an industrial digital computer which has been ruggedized and adapted for the control of manufacturing processes, such as assembly lines, or robotic devices, or any activity that requires high reliability control and ease of programming and process fault diagnosis.

PLCs were first developed in the automobile manufacturing industry to provide flexible, ruggedized and easily programmable controllers to replace hard-wired relays, timers and sequencers. Since then, they have been widely adopted as high-reliability automation controllers suitable for harsh environments. A PLC is an example of a "hard" real-time system since output results must be produced in response to input conditions within a limited time, otherwise unintended operation will result.

3.2 Power supply:-

A device is the conversion of available power of one set of characteristics to meet specified requirements. Typical application of power supplies includes converting raw input power to a controlled or stabilized voltage and current for the operation of electronic equipment.

Power supplies belong to the field of power electronics the use of electronics for the control and conversion of electrical power. A power supply is sometimes called a power converter and the process is called power conversion. It is also sometimes called a power conditioner and the process is called power conditioning.

3.3 Relay:

Relay is an electromagnetic device which is used to isolate two circuits electrically and connect them magnetically. They are very useful devices and allow one circuit to switch another one while they are completely separate. They are often used to interface an electronic circuit (working at a low voltage) to an electrical circuit which works at very high voltage. For example, a relay can make a 5V DC battery circuit to switch a 230V AC mains circuit. Thus a small sensor circuit can drive, say, a fan or an electric bulb.

3.4 Current transformer:

Current Transformer Theory can be explained this way: Central to all of the AC power transducers is the measurement of current. This is accomplished using a current transformer (CT), a "donut" shaped device through which is threaded the wire whose current is to be measured.

A current transformer is a type of "Instrument Transformer" that is designed to provide a current in its secondary which is accurately proportional to the current flowing in its primary.

Current transformers are designed to produce either an alternating current or alternating voltage proportional to the current being measured. The current transformers used with the Watt node transducers produce a 333 mV alternating voltage when the rated current is measured (either 30A, or 50A). The OSI power transducers employ CT's that produce 5V output at rated value.

3.5 Signal conditioning circuit:

Most analog signals require some form of preparation before they can be digitized. Signal conditioning is the manipulation of a signal in a way that prepares it for the next stage of processing. Many applications involve environmental or structural measurement, such as temperature and vibration, from sensors. These sensors, in turn, require signal conditioning before a data acquisition device can effectively and accurately measure the signal.

For example, thermocouple signals have very small voltage levels that must be amplified before they can be digitized. Other sensors, such as resistance temperature detectors (RTDs), thermistors, strain gages, and accelerometers, require excitation to operate. All of these preparation technologies are forms of signal conditioning.

3.6 Load Lane:-

Thus the utilities that purchase electricity instead of its own generation they could also benefit from the installation of load management system. The penalties for peak usage be paid to the supplier will be significantly reduced. It is reported a load management system reimburse for itself in a season. The wholesale price of energy in a free market differs considerably all over the day. As the system reaches its maximum capacity and power plants use the most expensive peak periods the cost will increase during the day free market economy should increase the price.
As the system reaches its maximum capacity and power plants use the most expensive peak periods the cost will increase during the day free market economy should increase the price. Corresponding decrease in the demand for the product must comply with the decline in prices. While this works as expected in short supply many of the scenes take place in a matter of seconds due to unforeseen disturbances system. To avoid the blackout it should be resolved in the similar timeframe. The biggest electrical load management system is implemented in Florida & is operated by Florida Power and Light. It utilizes 800 K load control transponders LCT and controls one thousand Mega Watt (in an urgent situation two thousand Mega Watt). FPL has now been able to avoid the development of several new power plants due to its load management programs.

4.PROTECTIVE RELAYING DESIGN METHODS:

Presents a traditional protective scheme employing electromechanical metering and protective devices. This scheme requires separate current transformers (CTs) for metering and protection. Metering CTs are designed to be accurate under normal operating conditions. Their V-I saturation level is low since metering accuracy is not important during faults, and the saturated CTs protect metering equipment against high current faults. The protection CTs are less accurate than the metering CTs, but their saturation level is high so that the CTs can accurately replicate high fault currents to enable correct protection operation. Electromechanical relay burden is high and one CT cannot drive the entire protective relays data site. Different protection functions require different CTs.
Microprocessor-based equipment with its inherently low burden has made the high power output of CT sun necessary and the use of other measurement transducers possible. One such measuring device that does not produce high power output but offers many advantages over CTs is the Rogowski coil. Rogowski coils have high measurement accuracy (they can be designed to be better than 0.1%, but are typically 1%-3%) and wide measurement range (the same coil can be used to measure currents from several amps to hundreds of kilo amps). Rogowski coils do not measure direct currents but, unlike CTs, they can accurately measure currents when a large DC component is present because they are not constructed with a satiable iron core. They also have a wide frequency range -typically 0.1 Hz to over 1 MHz (depending on design), can with stand unlimited short-circuit currents; can be very small to allow measurement of currents in restricted areas can be flexible or rigid depending on application requirements; can be used to measure current distributions in circuits having very small impedances without affecting the circuits; are galvanic ally isolated from the primary conductor; and have low production cost [2].
Another possible current sensor is the optical CT [3]. On-going developments in this area include Faraday Effect (magneto-optic) based devices, devices using silica optical fiber, and CT or shunt devices using fiber-optical cables. Conventional CTs or current sensors when used with microprocessor-based equipment can combine measurements and protection and significantly reduce the required number per design. Voltage transformers can also be replaced by low power voltage sensors (resistive or capacitive dividers) [4].Electromechanical protective devices have inflexible operational characteristics. Engineers need to study relay application criteria in detail before ordering an electromechanical relay because its operational characteristics cannot be changed. For example, an over current relay with normal time-current curves (TCCs) is not readily changed into a relay with extremely inverse TCCs, and is impossible to change into a frequency relay. Directional ground-fault protection operating angles depend on the power transformer's neutral connection. For ungrounded systems, fault current flows back to the source through the stray capacitances of the healthy phases and the phase difference between voltage and ground-fault current is 90 degrees. For solidly and resistively grounded
Systems ground-fault current returns back to the source through the transformer neutral. The phase difference between voltage and ground-fault current is 0 degrees in resistively grounded systems and 30 degrees to 60 degrees in solidly grounded systems. Electromechanical relays are designed with one fixed operating angle and require different relays for different neutral treatment and system characteristics. Earlier microprocessor relays introduced a high degree of flexibility because they provided a number of different
Operational characteristics in the same chassis. One relay could and does satisfy many applications. But different protective functions still require different relays. Metering and control functions also require different hardware.

4.1 SOFTWARE DEVELOPMENT

In many respects, the architecture of the programmable logic controller (PLC) resembles a general-purpose computer with specialized input/output (I/O) modules. However, some important characteristics distinguish a PLC from a general-purpose computer. Most important, a PLC is much more reliable, designed for a mean time between failures measured in years. Second, a PLC can be placed in an industrial environment with its substantial amount of electrical noise, vibration, extreme temperatures, and humidity. Third, PLCs are easily maintained by plant technicians.

5.PERFORMANCE AND ANALYSIS:

System Testing:-

System is critical element of measure of assurance and represents the review of specification ultimate review of specification and design. The system is tested during above methods as a theoretical and practical verification of the results. An effort is made to compare the system with traditional one.

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5.1 Testing Principles: -

Before applying method to the design test, must understand the basic principle that guide testing. The testing principle include

- The entire test should be traceable to the operator requirement. The most serve defect is those that the program fails to meet its requirement.
- Test definition be planed long testing begins, test planning can be begin as soon as requirement model is complete.
- Detailed definition of the test has been solidified. Exhaustive testing is not possible. The path permutation for even or moderately sized programs exceptionally large. For this reason it is possible, however to adequately cover. The program logic and to ensure that all condition to complete level has been exercised.

5.2 Testing Objectives:

There are various testing objective. Testing is process of executing hardware with intend of finding an error. We can find out an undiscovered error with minimum amount of time and effort. If testing is conducted successfully it will uncover error in hardware. As a secondary benefit, testing demonstrate that hardware function appear to the working specification that behaved and performance requirement appears to have been met. In addition data collected as testing cannot show absence of error and defect. It can show accuracy and deviation in the measured value. A good is one that of the has probability of finding an un discovered error. The objective is to design the test is that of systematically uncover different types of error and to do with minimum time and effort.

5.3 Faults and their Possible Remedies:

- Checking all the connections.
- Checking all the Power Supply Sections.

5.4 Checking all the connections:

By using the DMM check all the connection made by the wire. Also check the connections that the any wire is break or disconnected. If found so then connect it using the soldering Gun.

5.5 Checking the Power Supply Output:

By using the DMM test all the Power Supply output voltage available at the series voltage regulator and Transformer bridge rectifier output.

5.6 Continuity Test:

In electronics, a continuity test is the checking of an electric circuit to see if current flows (that it is in fact a complete circuit). A continuity test is performed by placing a small voltage (wired in series with an LED or noise-producing component such as a piezoelectric speaker) across the chosen path. If electron flow is inhibited by broken conductors, damaged components, or excessive resistance, the circuit is "open".
Devices that can be used to perform continuity tests include multi meters which measure current and specialized continuity testers which are cheaper, more basic devices, generally with a simple light bulb that lights up when current flows.An important application is the continuity test of a bundle of wires so as to find the two ends belonging to a particular one of these wires; there will be a negligible resistance between the "right" ends, and only between the "right" ends.
This test is the performed just after the hardware soldering and configuration has been completed. This test aims at finding any electrical open paths in the circuit after the soldering. Many a times, the electrical continuity in the circuit is lost due to improper soldering, wrong and rough handling of the PCB, improper usage of the soldering iron, component failures and presence of bugs in the circuit diagram. We use a multi meter to perform this test. We keep the multi meter in buzzer mode and connect the ground terminal of the multi meter to the ground. We connect both the terminals across the path that needs to be checked. If there is continuation then you will hear the beep sound.

5.7 Power on Test:

This test is performed to check whether the voltage at different terminals is according to the requirement or not. We take a multi meter and put it in voltage mode. Remember that this test is performed without microcontroller. Firstly, we check the output of the transformer, whether we get the required 12 v AC voltage. Then we apply this voltage to the power supply circuit. Note that we do this test without microcontroller because if there is any excessive voltage, this may lead to damaging the controller. We check for the input to the voltage regulator i.e., are we getting an input of 12v and an output of 5v. This 5v output is given to the microcontrollers' 40th pin.
Hence we check for the voltage level at 40th pin. Similarly, we check for the other terminals for the required voltage. In this way we can assure that the voltage at all the terminals is as per the requirement.
In this power on test we also check for the sensors i.e., as we know from the circuit explanation that when there is no vehicle on the highway, then the input to the microcontroller is logic ZERO. This can be tested by checking the voltage level at pot1 pins. Consider the second case when the vehicle obstructs the IR path, then we should get a high at port1 pin. This can be checked using the multi meter.

6. CONCLUSIONS

The implementation of a PLC-based relay coordination system offers a promising solution for enhancing the protection and monitoring of distribution transformers in modern power distribution networks. By integrating PLCs, relays, and sensors, the system enables efficient fault detection and diagnosis, including overloading, overvoltage, under-voltage, phase faults, and over-temperature conditions. Automation plays a crucial role in improving operational efficiency, reducing labor requirements, and ensuring energy savings. The transition from electromechanical to microprocessor-based relays presents challenges but also

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opportunities for increased flexibility and reliability in protective relay design. Testing principles such as continuity tests and power-on tests are essential for verifying system integrity and identifying potential faults. Overall, the proposed system offers a comprehensive approach to transformer protection, addressing the evolving needs of modern power distribution infrastructure.

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