A Review Of Numerical Protection Relays

Sanketa.S.Keshkamat[1], Jagdish.A.Patel[1]

[1]*Sandip Institute of Technology and Research Center, Nashik, India*

Abstract— Upgrading old numerical relays with the modernized second generation relays increases its reliability. Second generation relays have more reliability, and also it is used to improve dependability and security. It also provides self checking facility. It also has more flexibility because of programmable capability. The new-technology second-generation numeric relays are equipped with more powerful microprocessors, have a more reliable surface-mount construction, and have improved algorithms and elements. Modern second-generation numeric relays offer a variety of secure communications capabilities for interfacing.

Keywords—*Failure, Power System, Protective Relays, Monitoring.*

I. INTRODUCTION

Electrical energy generated by various electrical power stations is gathered by a central electrical grid and then redistributed to various users based on real-time supply and demand characteristics. Have you ever wondered what would happen when one or more of these power stations stopped producing electrical energy, or when some of the loads suddenly demanded excessive power from the grid? As a result of the high energy levels involved (powers measuring in MW), this imbalance generated by such sudden events could lead to catastrophic failures.

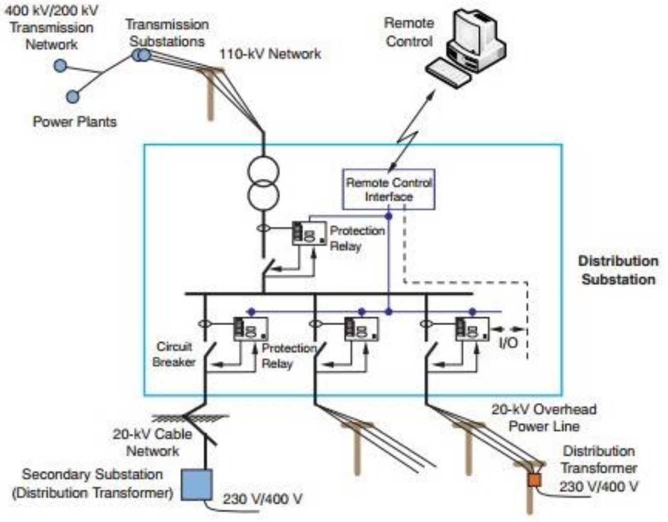

Fig. 1. Typical Substation in Electrical Energy Distribution Network

Some of these situations are unavoidable and beyond human control. Consequently, the central electrical grid must run a real-time algorithm to detect such fault conditions and react quickly in order to minimize adverse impact. This monitoring function is typically managed by make-or-break contacts called switch-gears or relays. These relays are, in turn, controlled by a smart controlling unit that continually monitors the grid parameters (such as voltages, currents, temperature, and so forth) and switches the appropriate relays in case fault conditions occur. Most of the data processing happens in the digital domain; thus, these relays are often called Numerical protection Relays, or NPRs.

A. Motivation

Modern power systems require high degree of reliability. It could be assumed that properly planned, dimensioned, installed, operated and maintained drives should not break down. However, in real life, these conditions are hardly ever ideal. A system during its operation may develop some trouble or may produce some abnormal condition of operation, which may cause damage to the equipment. Some of the situations are unavoidable and beyond human control. Therefore, it is necessary to provide measures to detect these faults & protect the system from getting damaged.

B. Protection relays

A Protection relay is an intelligent electronic device that receives input; compare them with the set points, and provides output. Inputs can be current or voltage. Outputs can be visual feedback in the form of indicator lights and/or alphanumeric display, communication, control warning, alarms, and turning off and on.

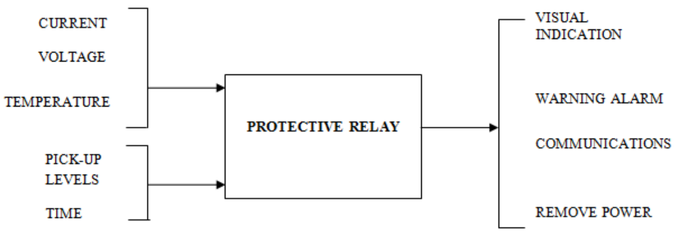

Fig. 2. Black box of Protective Relay

1) Need of Protective Relaying

Protective relaying is necessary in almost every electrical plant and no part of the power system is left unprotected. The choice of protection depends on several aspects such as type & rating of protected equipment, its importance, location, probable abnormal conditions, cost, etc.

A fault in the equipment in supply system leads to disconnection of supply to a large portion of system. If the faulty part is quickly disconnected, damage caused by the fault is minimum, faulty part can be repaired quickly & service can be restored without further delay. Thus protective relays helps in improving service continuity and its importance is self evident.

2) Functions of Protective Relaying

The relays are compact, self contained devices which respond to abnormal condition. The relays distinguish between normal & abnormal condition. Whenever an abnormal condition develops, relay closes its contacts. Thereby the trip circuit of circuit breaker (CB) is closed. Current from battery supply flows in trip coil of CB and CB opens the faulty part is disconnected from supply. This entire process is automatic & fast. The functions of protective relaying include the following:

- To close the trip circuit of CB or to alarm so as to disconnect a component during abnormal condition, which includes overload, under voltage, load unbalance, reverse power, short circuit, etc.
- To disconnect the abnormally operating part quickly so as to prevent subsequent faults & minimize the damage to the faulty part.
- Along with the basic protection functions, relay measures various parameters like current, voltage, frequency, power, energy and harmonics.
- Does the job of CT & VT supervision.

C. Objectives of Research

The proposal is to fully design the protection device by using digital / numerical technology, i.e. All the processing phases like signal filtering, protection and control functions will be implemented through digital processing. The technique used here will be fundamentally based on Fast Fourier Transformation (FFT), which will require a 32 bit Digital Signal Controller:

- To sound an alarm or activate the trip circuit in case of the fault according to the preset threshold of the parameter in order to minimize the damage to the motor.
- To maintain a fault disturbance record, which can be helpful for further fault analysis.
- To indicate the faults using LEDs and display various measured parameters and curves on graphical display.

II. LITERATURE SURVEY

Protective relaying in industrial and utility power systems has tremendously evolved since the beginning of system protection over a hundred years ago. Electromechanical relays were the defacto protection devices when no microcontrollers were available.

Investigations and research on protection and protective relaying continues. Relay models have been used for a long time by manufacturers, consultants and academics for designing new prototypes and algorithms, to check and optimize the performance of relays already installed in power systems and to train new protection personnel. A comparative study of all the available numerical protection relays by leading manufacturers was done. I referred the technical manuals for Schneider Electric MiCOM P 21, Siemens SIPROTEC 7SK80, & ABB REM 610.

The major difference found was that, none of the relays provide a graphical display. Also, there is less number of fault records. This relay will be featuring a graphical LCD with160*160 dots to display the measured values and the corresponding vector diagrams. This seminar provides guidance for our next replacement or upgrade project, including ways to reduce costs, save time, and minimize unexpected or unplanned complications.

A. Evolution of Relays

Protective relaying in industrial and utility power systems has changed greatly since the beginning of system protection over a hundred years ago. The theory and application of these protective devices is an important part of education of an engineer. During primitive age when no micro controller or other electronics was available, electromechanical protection relay were used. But as technology evolved, more and more electronics was used for development of protection relay. The journey of protection relay is shown as follows:

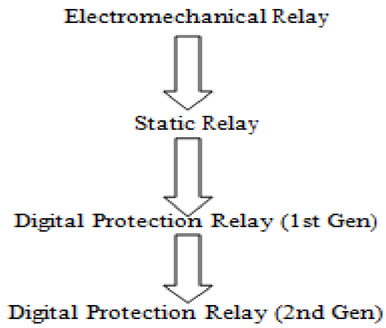

Fig. 3. Evolution of Relays

1) Electromechanical Relay

An electromechanical relay uses the magnetic field produced by an electrical current flowing through a coil to close one or more mechanical switches.

2) Static Relay

The term ‘static’ suggest that the device has no moving parts. The design consists of analog circuits for detection of current/voltage value, instead of coils and magnets. After the detection of input signal, a comparator circuit is used to determine the overload condition.

3) Digital Protection Relay (1st Gen)

Widespread growth of computer technology resulted in the introduction of microprocessor-based numeric (or digital) relays to analyze the power system current and voltages. This first generation of numeric relays brought innovations in developing new algorithms and the beginning of combining several protection functions in one multifunction relay package. In this type of devices again current and voltage signals are detected by use of analog circuits. Major difference in analog circuits here is that, this circuit involves analog to digital converter. The voltage and current signals are stepped down to acceptable value of ADC. Then ADC converts this signal to digital form. This digital signal is read by a microprocessor/microcontroller for further processing.

4) Digital Protection Relay (2nd Gen)

The new-technology second-generation numeric relays are equipped with more powerful microprocessors, have a more reliable surface-mount construction, and have improved algorithms and elements. These developments have provided relay protection engineers with new protection schemes and advanced the quest for more reliable, more secure, and more dependable operation. These relays have built-in test routines (a "watchdog") that signal an alarm output, & the operators know when the numeric relay fails. EM designs and most solid-state designs did not have a watchdog alarm output.

TABLE I. COMPARISONS OF PROTECTION RELAY TYPES

Characteristics of relays	Electro-mechanical	Static	Digital	Numerical
Technology Standard	1st generation relays.	2nd generation relays.	Present generation relays.	Present generation relays.
Relay Size	Bulky	Small	Small	Compact
Speed of Response	Slow	Fast	Fast	Very fast
Reliability	High	Low	High	High
Vibration Proof	No	Yes	Yes	Yes
CT Burden	High(8 to 10 VA)	Low(1 VA)	Low(< 0.5 VA)	Low(< 0.5 VA)

Limitations in Available Relays

5) Phase angle error while detection.
6) Limitation of analog input range
7) Noise and malfunctioning problems on field.
8) Less communication capabilities.
9) Low precision in calculation of analog inputs.
10) Slow response time in decision making.
11) Non volatile data storage.

III. DESIGN METHODOLOGY

A. Product specification

1) Measuring Circuit

a) For Current Section:

Rated phase Current (In): 1A/5A (Configurable)

Thermal withstand: 2 X In (Continuously)

20 X In (for 3 seconds)

b) For Voltage Section:

Rated Voltage (Un): 63.5 Vac (L-N)

Voltage measuring range: 5% to 200% of VT Secondary

2) Auxiliary Voltage

Rated Voltage: 18-52VDC / 75-250VDC

B. Features of Relay

1) Independently settable Directional and Non directional setting stages are available for the flexibility of customer operation.
2) For easy adoptions to varying system operating conditions four independent setting groups are provided.
3) Suitable for both 1A & 5A CT configuration on same terminals.
4) Graphical LCD with 160*160 dots display to view the Relay features, System Voltages, Currents phase angles.

IV. DETAILED DESIGNING

A. Hardware Designing

This part includes designing of the entire analog section, i.e. Transducers, Signal Conditioner and the ADC.

1) Signal Conditioning Section for Input Current

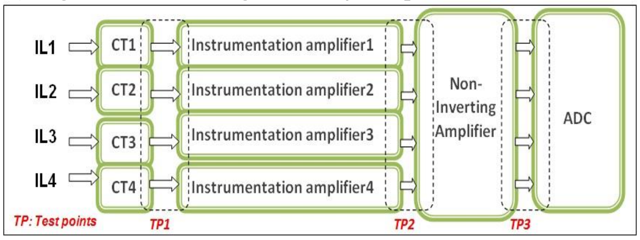

Fig. 4. Signal Conditioning Section for Input Current.

TABLE II. INPUT RANGE OF CT

	Range	CT RATING	
		1A	***5A***
IDMT Protection	5%	50mA (min)	250Ma
	400%	4A	20A
High set Protection	50%	0.5A	2.5A
	4000%	40A	200A (max)

2)Signal Conditioning Section for Input Voltage

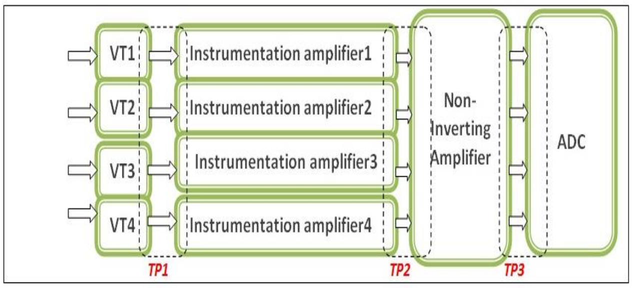

Fig. 5. Signal Conditioning Section for Input Voltage

TABLE III. INPUT RANGE OF VT

Range	VT RATING
	63.5 V
5%	3.175 V
200%	127

3) Analog to Digital Conversion

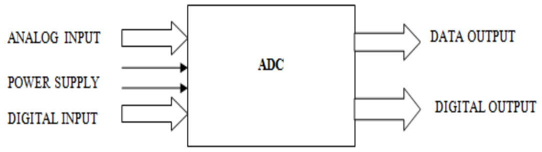

Fig. 6. ADC

Analog input signals are given to ADC to get digital signals. Here, we have used 16-bit ADC. The LSB size is given by FSR/65,536.

B. Software Tool Used

1)PCB Package: Altium Designer

There are many PCB design packages available in the market, a few of which are freeware, shareware, or limited component full versions. We have used software package Altium Designer, Version 14.3 to design our schematics and PCBs.

Altium Designer combines Schematic, ECAD Libraries, Rules & Constraints, BoM, Supply Chain Management, ECO Processes and World-Class PCB Design tools in one easy to use, Native 3D enhanced, Unified Environment, increasing your entire team's productivity, efficiency and reducing your overall costs and time to market.

a) History

In 1985, Altium launched the DOS based PCB design tool known as Protel, and later named Autotrax. Originally sold only in Australia, it has been exported to the United States and Europe since 1986. In 1987, Altium launched the circuit diagram editor Protel Schematic. The launch of Protel 98 in 1998 saw the consolidation of all components, including Protel Advanced PCB and Protel Advanced Schematic, into a single environment. Protel 99 introduced the first integrated 3D visualization of the PCB assembly, and from 2007 Altium Designer version 6.8 was the first to offer 3D visualization and clearance checking of PCBs directly within the PCB editor. It has separate modules for PCB Designing & Schematic Designing.

b) Schematic Capture

Schematic capture module provides electronic circuit editing functionality, including:

- Component library management
- Schematic document editing (component placement, connectivity editing and design rules definition)
- Integration with several component distributors allows search for components and access to manufacturer's data

c) PCB Design

Printed circuit board design module of Altium designer supports:

- for Flex and Rigid-Flex Design
- Enhanced Layer Stack Management
- Support for Embedded Components
- Component footprint library management
- Component placement

d) Steps for Creating Schematic

- Locating the Component and Loading the Libraries
- Placing the Components on Your Schematic
- Wiring up the Circuit
- Compiling the Project to Check for Errors

V. APPLICATIONS

The multifunction relay platform provides cost effective, integrated Numerical Protection, Control, Monitoring &Measuring functions with Communication functionality. The platform has state of-the-art technology which ensures superior performance. The multifunction capability of Aegis finds application as main or backup protection in almost every area of power system protection. It can be used for the protection of High and Medium voltage networks. This Platform provides the ability to define an application solution and through extensive communication capabilities to integrate with your system control.

- Incomer, Outgoing feeders protection
- Main or backup protection on MV&HV systems.
- High Impedance circulating earth fault protection and cable differential protection
- neutral current and Residual voltage detection principle
- Auto reclosing function (4shots)

VI. CONCLUSION

Digital Protection Relays are critical elements in any power distribution subsystem. In order to avoid catastrophic failures, these relays should employ high-speed and high-accuracy electronics. Applications like motor protection require different techniques and input/output capabilities. Depending on this application we have undergone systematic study for designing such type of electronics protection system. This embedded system should be capable of applying advanced logic. It should be capable of analyzing whether the relay should trip or restrain from tripping based on current or voltage magnitude and phase angles, parameters set by the user, relay contact inputs, and in some functions, the timing and order of event sequences. Thus, the logic is user-configurable at a level well beyond simply changing front panel switches or moving of jumpers on a circuit board.

VII. REFERENCES

[1] Pero Ostojic, Arijit Banerjee, Dhaval C. Patel, Wrichik Basu, Shahid Ali," Advanced Motor Monitoring and Diagnostics",

IEEE Transactions On Industry Applications, Vol. 50, No. 5, September/October 2014

[2] Sham M V and Dr. K P Vittal, "Development of DSP Based High Speed Numerical Distance Relay and its Evaluation Using Hardware in Loop Power System Simulator", *IEEE PES Innovative Smart Grid Technologies – India*, 2011.

[3] S.P. Patel, Kyle Weeks, "Protection of Motors", *IEEE Industry Applications Magazine*, Nov-Dec 2014

[4] Daniel Ransom, "Upgrading Relay Protection", *IEEE Industry Applications Magazine*, Sept-Oct 2014

[5] S.P. Patel, R. Hunt, "Protecting Remotely Located Motors", *IEEE Industry Applications Magazine*, Nov-Dec 2012

[6] C37.92 : IEEE Standard for Analog Input to Protection Relays from Electronic Voltage and Current Transducers

[7] VAMP 50/51, & Rho 3 Overcurrent, Earthfault, and Motor Protection Relay Technical Manual

[8] B. Ram, D. Vishwakarma, "Power System Protection & Switchgear", *TMH Publication*, 2014

[9] S.S. Rao, "Switchgear Protection & Power System", *Khanna Publishers*, 2013

[10] Altium manuals

[11] Texas Industry manual

Sanketa.S.keshkamat pursued his Bachelor of Engineering in Electronics and Telecommunication from Karmaveer Kakasaheb Wagh Institute of Engineering Education and Research, Nashik, which is affiliated to Savitribai Phule Pune University, former UoP in 2014. She is currently pursuing Masters of Engineering in Electronics and Telecommunication, with specialization as VLSI and Embedded Systems from Sandip Institute of Technology and Research center, Nashik. This research work is sponsored by Crompton Greaves Limited, Nashik, and this paper is published as a part of the research work done for the fulfillment of degree of Masters

Jagdish Patel received his Bachelor of Engineering in Electronics and Telecommunication in 2007 from North Maharashtra University, Jalgoan. He got his Master in Technology in 2012 from RGPV, Bhopal. He then join North Maharashtra University as Assistant Professor in 2008. He is now working as a Assistant Professor in Savitribai Phule Pune University from 2012. His current research interest includes digital communication, Networking, Electromagnetic and Digital Electronics