Development of DSP Based Numerical Protection Device for Switchgear

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***Abstract*—** Electronic devices are present in distribution of medium voltage switchgears since many decades. These numerical relays play a significant role in the automation, protection and control of switchgear in medium voltage substation. DSP based numerical protection device is low cost and compact in size and capable of handling the protection requirements of the switchgear of medium voltage substation, consisting of current and earth based protections for both retrofit and new installations with event and fault recording capabilities. Faulty condition is detected and suitable action can be taken at a premature stage. This paper discusses the functional and design consideration of protection system.

***Keywords*—** *Medium voltage; Numerical protection device; switchgear*

I. INTRODUCTION

Electric medium voltage protection relays constitutes a safety-critical class of devices. Numerical device offer increased functionality at lower cost, high reliability and long service life. The digital signal Processor (DSP) and the data converters used in the protection device have a major influence on the performance of the protective device. In order to achieve high reliability and to reduce the size of the relay, it is desirable to use minimum hardware components. The monitoring function is typically managed by make-or-break contacts called switch-gears. These switch gears 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 devices in case fault conditions occur. Most of the data processing happens in the digital domain. These devices are often called Numerical Protection device, or NPDs. These are currently considered the backbone devices for efficient power system protection and substation automation. It can be used for the protection of High and Medium voltage networks. Numerical device design is extended to cover control, metering, monitoring, and disturbance/event recording along with its basic protection function. This platform provides the ability to define an application solution and through extensive communication capabilities to integrate with your system control [1] [2] [3].

It is observed that current and earth related protections are basic need in power system protection scheme. To fulfill the basic needs, many customer demands for basic protection device to along with cost effective product. The proposal presents design and developments of Numerical Protection Device, which provides all the basic protection functions i.e. current and earth related protection function for switchgear which operates in medium voltage which range from 3kV to 33kV. The protection device hardware is based on DSP along with analog to digital converter (ADC) from Texas Instruments. The advancements in digital technology have given birth to numerical protection device and has gained wide acceptance in power utilities. These device being programmable use both hardware and software components. The hardware mainly consists of signal conditioning circuits, DSC and ADC modules. The accuracy and operating speed of the device depends greatly upon these modules. Further, the protection algorithms demand considerable computation power. Therefore, a floating point processor will be preferred over a fixed point processor for achieving higher accuracy and faster computations. In a numerical protection device, the dynamic range of the input signal is often very high. It is also expected that the device maintain its measurement accuracy across the entire input range. For protection device application, the phase relationship between the signals sampled from different channels is as important as the value of the signal to measure the impedance accurately. Therefore, a simultaneous sampling bipolar ADC is required in these applications [9].

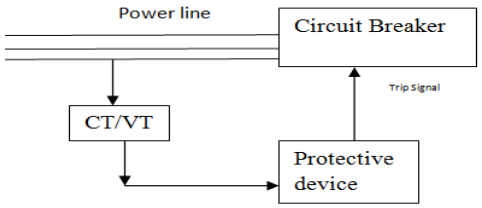

Fig. 1. General concept of Protection system

Fig.1 shows the general concept of protection system. In the domain of electrical network protection, a relay is a device that detects and isolates faults in the network. It performs advanced signal processing algorithms, and takes decisions according to the configuration settings. The protective device is a part of a complete solution composed of three essential components: a measurement sensor (either current and/or voltage transformer); the protection device to analyze signals; and the breaking device (circuit breakers or contactors) to isolate the faulty part when required [1].

The paper is organized as follows. Section II presents Functional overview. Design consideration of proposed device is presented in section III. Features and application of Numerical switchgear protection device is discussed in Section IV. Finally, the section V presents conclusions drawn.

II. FUNCTIONAL OVERVIEW

The scheme design is being taken in consideration based on functional requirement. Fig. 2 shows Graphical functional overview.

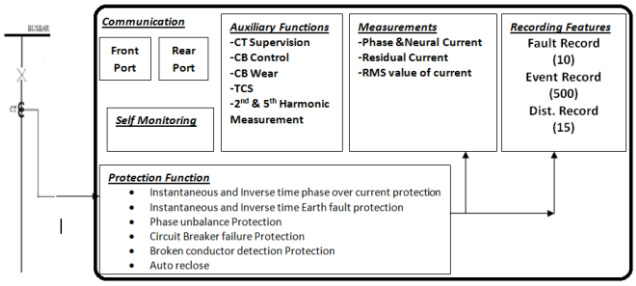

Fig. 2. Graphical functional overview

A. Protection functions

To design the relay following major Protection functions are provided:

- Over current Protection
- Earth Fault Protection
- Negative Phase Sequence over Current Protection
- Sensitive Earth Fault
- Restricted Earth Fault
- Auto-Reclose Function
- Cold Load Pickup & Inrush
- Broken Conductor Protection
- Circuit Breaker Failure Protection
- Current Transformer Supervision
- Trip Circuit Supervision

B. Recording function

The Protection device provides the following recording functions:

- Fault recording: Storage of latest 10 fault records.
- Event recording: Storage of latest 500 event records
- Disturbance recording: Storage of latest 15 disturbance records

These records are displayed on the LCD on the front panel of the relay or on a local/remote PC for future access.

C. Communication

One of the important features offered by a numerical relay, Which is not available with electro-mechanical and solid-state relays, is the ability to communicate with external devices through communication ports. Data transmitted through these ports provide valuable information to the relay engineers, either locally or to a remote location. Communication ports at the front and rear of the relay allow USB connection with computers for local access to relay records and settings. Two communication protocols e.g. Modbus and IEC 60870-5-103 on RS485 remote panel has can be provided to allow integration into a wide range of substation control systems for remote monitoring and control.

In order to provide a centralized remote control operation on the substation level, it is necessary to use supervisory system known as Supervisory Control and Data Acquisition (SCADA) system using MODBUS communication. Modbus protocols are often used in power plants and in industrial applications. Particular focus is given to MODBUS protocol standard prevalent in electric power SCADA and the related field of substation automation. It relies on communication systems that transfer data periodically and also intermittently [8].

D. Additional Function

Analog input scanning, digital filtering, protection algorithms and monitoring functions are some of the additional features available with the system. It provides the fundamental frequency component present in the (composite signal) instantaneous samples of the analog input signals. At the same time, it resolves them into sine and cosine phasors, from which the RMS value of the input signal is computed. Also different parameter such as residual current value, phase and neutral current values, require for protection algorithm are evaluated. Along with that, harmonics measurement function is also provided.

III. DESIGN CONSIDERATION OF PROPOSED DEVICE

First, in analog input module, the strong current signal of current transformer is converted to weak electric signal which is used in numerical protection and monitor device in the power system. The range of input current for desired protection range is 5% to 4000% of the rated value, which is 50mA to 200A. This output is applied to Signal Conditioner or analog input subsystem. This signal conditioning block includes a high precision two amplifier, first used to condition small signals, followed second as a non inverting amplifier to enhance adjustable increase the gain. Output of first amplifier is considered as analog value without gain and output of second amplifier is considered as analog value with gain. For each current value, there is two analog output values. So, such total eight analog output values are connected to analog channel of DSP chip [6] then can be calculated and judged. And which analog value to be select is decided by software.

On boot up all the interrupts are disabled, multiplexed I/O pins are programmed as general purpose I/O pins, watchdog timer is disabled and the CPU clock is set to 80MHz. CpuTimer0 is used to generate the start of conversion signal of 1600Hz with 50% duty cycle. Therefore, SOC is applied to all eight channels at every 0.625 milliseconds. The input signals are simultaneously sampled and held by the respective sample and hold circuits. Then all eight channels will be converted simultaneously. During the conversion period busy signal (EOC) will remain high and becomes low after conversion is finished. So, the busy signal is used as an interrupt signal to the DSP. After receiving the interrupt DSP will jump to the ADC interrupt service routine. Fig. 3 shows Principle block diagram of software of protection device [7].

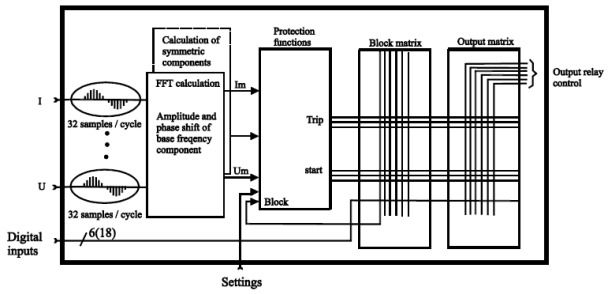

Fig. 3. Principle block diagram of software

In ADC interrupt service routine, after sampling signal, all the channels magnitude and phase of the three phases current is calculated using the Fast Fourier Transform for saving computation time. Along with that calculation of parameter require for protection algorithm is done. Accordingly Protection algorithm is executed, considering setting enter by user. Output signals are given to output relay which in the form of trip and alarm signal after processing through block and output matrix.

The software for the numerical distance relay is developed in embedded C language. For this purpose Code composer studio (CCS5.4) is used as a development tool. The CCS provides easy debugging and real time refreshing capabilities [10].

A. Over current Protection algorithm

The protective scheme which responds to a rise in current flowing through the protected element over a pre determines value is called as "Over current Protection". The algorithm used to build it as follows:

1. The inverse time characteristics are defined as to what delay is required at what value of over current.
2. Analog to Digital Converter (ADC) is used for getting digital value of current value which is then send to digital chip.
3. This digital current value is compared with set current limit.
4. If the data is not within limits a delay value is selected, corresponding to value of over current. And alarm signal gets issued.
5. The delay is generated before sending the trip signal. Hence inverse time characteristic has been realized, which is provided by IEC 60255 standards [5].

IV. FEATURES AND APPLICATION

This Numerical protection device is suitable for most new medium voltage industrial power system projects, because of their multiple features and application.

A. Features

- Integration of many functions into one numerical relay, resulting in lower cost, less wiring and testing, and reduced panel space.
- Minimal maintenance/testing, due to integral self-monitoring.
- User interface for local keypad operation, with large LCD display to show settings, metering, event data.
- Front USB port for local communication and for relay configuration software interaction with PC.

B. Application

- Incomer, Outgoing feeders protection and switchgear.
- Main or backup protection on MV systems.
- High Impedance circulating earth fault protection and cable differential protection.
- In overhead lines and underground cables network for Sensitive Earth fault Protection.
- The relays provide circuit-breaker control functionality, additional primary switching devices (earthing switches and disconnect or switches) can also be controlled from the relay display or the automation system.

V. CONCLUSION

Numerical device offer increased functionality at lower cost, high reliability and long service life. The advancements in digital technology have given birth to numerical protection device and has gained wide acceptance in power utilities and ensures superior performance. The digital signal Processor (DSP) and the data converters used in the protection device have a major influence on the performance of the protective device. In order to achieve high reliability and to reduce the size of the relay, it is desirable to use minimum hardware components with Communication functionality. The multifunction capability of device finds application as main or backup protection in almost every area of power system protection for both retrofit and new installations with event and fault recording capabilities.

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