Advanced Numerical Relay Incorporating The Latest Features Which Can Compute The Interfacing With The Automation Using DSP

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ABSTRACT
Modern numerical relays have many new features that were not available in electromechanical and static relays. In numerical relays there is an additional entity, the software, which runs in the background and which actually runs the relay. With the advent of numerical relays, the emphasis has shifted from hard ware to soft ware. Hard ware is more or less the same between any two numerical relays, what distinguishes one numerical relay from the other is the software.

Keywords- relays, numerical relays, DSP, software, hard ware

1. INTRODUCTION
With the tremendous developments in VLSI and computer hardware technology, microprocessors that appeared in the seventies have evolved and made remarkable progress in recent years. Fast and sophisticated microprocessors, microcontrollers, and digital signal processors (DSPs) are available today at affordable prices. Their application to power system protection have resulted in the availability of compact, faster, more accurate, flexible and reliable protective relays, cost effective as compared to the conventional ones.

Numerical relays which are based on numerical (digital) devices e.g. microprocessors, microcontrollers. DSPs etc. are the latest development in the area of power system protection. In these relays, these relays, the analog current and voltage signals monitored through primary transducers (CTs and VTs) are conditioned, sampled at specified instants of time and converted to digital form for numerical manipulation, display and recording. Thus, numerical relays, having monitored the current and voltage signals through transducers, acquire the sequential samples of these ac quantities in numeric (digital) data form through the data acquisition system, and process the data numerically using an algorithm to calculate the fault discriminate and make trip decisions. With the continuous reduction in digital circuit costs and increases in their functionality, considerable cost-benefit improvement ensures. At present microprocessor/microcontroller-based numerical relays are widely used. There is a growing trend to develop and use numerical relays for the protection of various components of the modern complex power system. Numerical relaying has become a viable alternative to the traditional relaying systems employing electromechanical and static relays. Intelligent numerical relays using artificial intelligence techniques such as artificial neural networks (ANNs) and Fuzzy Logic Systems are presently under active research and development stage.

The main features of numerical relays are their economy, compactness, flexibility, reliability, self- monitoring and self-checking capability, adaptive capability, multiple functions, metering and communication facilities, low burden on transducers (instrument transformers) and improved performance over conventional relays.

2. DSP Based Block Diagram of a Numerical Relay:
The levels of voltage and current signals of the power system are reduced by voltage and current transformers (VT and CT). The outputs of the CT and VT (transducers are applied to the signal conditioner which brings real-world signals into digitizer. The signal conditioner electrically isolates the relay from the power system, reduces the level of the input voltage, converts current to equivalent voltage and removes high frequency components from the signals using analog filters. The output of the signal conditioner are applied to the analog interface, which includes sample and hold (S/H) circuits, analog multiplexer and analog-to-digital (A/D) converters. These components sample the reduced level signals and convert their analog levels to equivalent numbers that are stored in memory for processing.
The signal conditioner and the analog interface (i.e., S/H CKt, analog multiplexer and A/D converter) constitute the data acquisition system (DAS). The acquired signals in the form of discrete numbers are processed by a numerical relaying algorithm to calculate the fault discriminates and make trip decisions. If there is a fault within the defined protective zone, a trip signal is issued to the circuit breaker.

**Fig1 DSP Based Block Diagram of a Numerical Relay**

**A. Hardware Architecture**

The typical architecture of a numerical relay consists of a power supply, digital and analogue input/output (I/O), one or more DSP Microprocessors, few memory and other interfacing components here multiple processors are provided are among them is to be dedicated to execute the protection relay algorithms, while the other implements any associated logic and handles the interfaces like Human Machine Interface (HMI) to enhance the capability of printed circuit boards (PCB’s), the I/O can be organized properly so as to enhance the limits of hardware/software additional I/O can be easily added to support the functionality. The internal communications bus links the hardware and is considered as the critical component in the design. The work speed must be high. The interference from the noisy substation environment is to be encountered and to do so low voltage levels are used to avoid the interference proper shielding of the relevant areas is required. The digital inputs are optically isolated to prevent the transmission of transients to the internal circuitry. Similarly analog inputs are also isolated using precision transformers, this is required in order to maintain the accuracy in the measurement along with removing harmful transients. In addition to this the in put signals must be amplitude limited so as to avoid them exceeding the power supply voltages. If this condition is not considered the waveform will appear distorted. The analog signals A/D converter is employed to convert the analog signals to digital signals. The cost effective method is to use single ND converter preceded by a multiplexer to connect each of the input signals to the converter and all converters perform the measurement simultaneously. The frequency of sampling must be carefully considered, as the Nyquist criterion applies:

\[
fs > 2 \times fh
\]

where:

- \(fs\) = sampling frequency
- \(fh\) = highest frequency of interest

If too low a sampling frequency is chosen, aliasing of the input signal can, resulting in high frequencies appearing as part of signal in the frequency range of interest. Incorrect results will then be obtained. The solution is to apply an anti-aliasing filter, coupled with an appropriate choice of sampling frequency, to the analogue signal, so those frequency components that could cause aliasing are filtered out. Digital sine and cosine filters are used with a frequency response in order to extract the real and imaginary components of the signal. Frequency tracking of the input signals is applied to adjust the sampling frequency so that the desired number of samples/cycle is always obtained. A modern numerical relay may sample each analogue input quantity at between 16 and 24 samples per cycle. All subsequent signal processing is carried out digitally in software, final digital outputs use relays to provide isolation or are sent via an external communications bus to other devices.

**B. Relay Software**

The series of tasks, operating in real time is the backbone of software provided it is organized in to series of tasks. the most essential component is the Real Time Operating System (RTOS), this ensures that the other tasks are executed at the time of need, on a priority basis. Other task software provided will naturally vary according to the function of the specific relay, but can he generalized as follows:

a. system services software - this is akin to the
BIOS of an ordinary PC, and controls the low-level I/O for the relay (i.e. drivers for the relay hardware, boot-up sequence, etc.)

b. HMI interface software - the high level software for communicating with a user, via the front panel controls or through a data link to another computer running suitable software, storage of setting data, etc.

c. application software - this is the software that defines the protection function of the relay

d. auxiliary functions - software to implement other features offered in the relay - often structured as a series of modules to reflect the options offered to a user by the manufacturer

C. Application Software

The relevant software algorithm is then applied. Firstly, the values of the quantities of interest have to be determined from the available information contained in the data samples. This is conveniently done by the application of the Discrete Fourier Transform (DFT)

3. EXTRA FEATURES OF NUMERICAL RELAYS

The DSP chip in a numerical relay is normally of sufficient processing capacity that calculation of the relay protection function only occupies pan of the processing capacity. The excess capacity is therefore available to perform other functions. Of course, care must be taken never to load the processor beyond capacity, for if this happens, the protection algorithm will not complete its calculation in the required time and the protection function will be compromised. Typical functions that may be found in a numerical relay beside; protection functions are described in this section. Note that all functions may be found in a particular relay. In common with earlier generations of relays, manufacturers, in accordance with their perceived market segmentation, will offer different versions offering a different set of functions. Function parameters will generally be available for display on the front panel of the relay and also via an external communications port, but some by their nature may only be available at one output interface.

A. THE DISPLAY

This involves at least the simple function to implement, and is perhaps the least processor time. The values that the relay must measure to perform its protection function are acquired and processed. It will be displayed on the front panel and its simplest task to transmit as required to a remote computer/HMI static & it is less obvious in computing the extra quantities that may be able to be derived from the measured quantities which depends on the available input signals. These might include:

a. sequence quantities (positive, negative, zero)

b. power, reactive power and power factor

c. energy (kWh, kvarh)

d. max. demand in a period (KW, kvar, average and peak values)

e. harmonic quantities

f. frequency

g. temperatures/RTD status

h. motor start information (start time, total no. of starts/reacceleration, total running time)

The accuracy of the measured values could be made equivalent to the transducers that are used (VT’s CT’s, A/D converter, etc.). As CT’s and VT’s have a different accuracy specification to those for metering functions, such data may not be sufficiently accurate for tariff purposes. However, it will be sufficiently accurate for an operator to assess system conditions.

B. VT/CT SUPERVISION

If suitable VT’s are used, supervision of the VT/CT supplies can be made available. VT supervision is made complicated by the different conditions under which there might be no VT signal - sonic of which indicate VT failure and some occur because of a power system fault having occurred.

C. DISTURBANCE RECORDER

The relay memory requires a certain minimum number of cycles of measured data to be stored for correct signal processing and detection of events. The memory can easily be expanded to allow storage of a greater time period of input data, both analogue and digital plus the state of the relay outputs. It then has the capability to act as a disturbance recorder for the circuit being monitored, so that by freezing the memory at the instant of fault detection or trip, a record of the disturbance is available for later download and analysis. It may be inconvenient to download the record immediately, so facilities may be provided to capture and store a number of disturbances.

D. A TIME SYNCHRONISATION

Any data with a time tagging serves the purpose here the disturbance recorders and energy consumption data could be time tagged for a useful and efficient performance an internal clock is provided for the time information. Even though the clock performance is optimized. It may pose some problems if the disturbance record has to be correlated with similar records from other sources to get the complete picture of the event. The disturbance records from all the sources has to be time tagged many numerical relays have the facility for time synchronization from an external
clock.
The signal for the clock will be a standard one
derived from an external source, the latest one
being a GPS Satellite signals.

E. PROGRAMMABLE LOGIC
The invent of microprocessors brought many
advance functions in the operation of relays, the
implementation of logic for the function such as
tripping and re-closure requires updated logic
functions.

F. PROVISION OF SETTING GROUPS
Earlier the static and electromechanical relays
have been provided with a group of settings. Due
to the operational reasons over the decades. The
power system topology have changed on a regular
basis. The different configurations may require
different relay settings to maintain complete
network protection. The slot protection differs for
different fault levels in a network. The problem
Can be overcome by the provision within the
relay of a number of circuits with in a relay which
operates one group of setting in one time. This
may necessitate the changeover between the
groups of setting. Which can be achieved by a
remote command from the operator, it is possible
to give a logic command through programmable
logic system. The switching arrangement of the
inputs and outputs is employed by providing the
duplicating relays if needed. the operator will be
given option to remote programme the relay.

CONCLUSIONS
The all in one relay which covers the need of other
measurement/control devices to be fitted in
substation. These special features creates a trend
to adopt the latest, efficient and accommodative
numerical relays this relay no longer performs just
a basic function but also is becoming an integral
and a major part of substation automation scheme
Thus the function primly carried out by separate
devices such as bay controllers. Discrete metering
transducers and similar devices are now found in a
protection relay. It is now possible to implement a
substation automation scheme using numerical relays as the principal or indeed only hard ware
provided at bay level. As the power of

microprocessors continues to grow and pressure on
operators to reduce costs continues, this trend will
probably continue, with the provision being the
RTU facilities in designated relays that acts as
local pockets of information with in overall
network automation scheme. The developments in
the areas of RTU promises a further improvement
in providing more features in to numerical relays

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