Study and Analysis of Modern Numerical Relay Compared to Electromechanical Relay for Transmission of Power

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Abstract-*Protection is one of the most important aspect to be considered in power systems. In this concept relays play a major role. Relay is a device which senses an electrical quantity either to trip the source of fault or to alert the operating staff to take protective step in time to even further damage. The main functions of protective relays are to sound an alarm or to close the trip circuit, to isolate or disconnect faulted circuits or equipment to localize the effect of fault to improve system stability, service continuity and minimize hazards to personnel. This project deals with the study of different relays and how the modern numerical relays are used to overcome the disadvantages of electromechanical relays. Here, a case study relating to both electromechanical relay and numerical relay will be done and the results are analyzed.*

Keywords-*Electromechanical relay, numerical relay, Local breaker backup, Bus bar protection, Goose feature in Numerical relay.*

I. INTRODUCTION

Protection is the important aspect to be considered in power generation, transmission and distribution. Relays play a vital role in protection. Relays are electrically operated switches, it protects the power system from faults, short circuits, other abnormal conditions like under frequency, over voltages. Its main function is to sense the abnormal conditions and initiate the isolation of faulty section from healthy sections.

It is important that a relay should detect all fault conditions and also, it must not trip due to spurious signals generated during power system transients. Here, we are studying and analyzing different types of relays used in Karnataka Power Transmission Corporation Limited and improvements that should be implemented for the protection system for good working.

II. ELECTROMECHANICAL RELAY

Electromechanical relays were the earliest forms of relay used for the protection of power systems, and they date back nearly 100 years. They work on the principle of a mechanical force causing operation of a relay contact in response to a stimulus. The mechanical force is generated through current flow in one or more windings on a magnetic core or cores, hence the term electromechanical relay. The principle advantage of such relays is that they provide galvanic isolation between the inputs and outputs in a simple, cheap and reliable form – therefore for simple on/off switching functions where the output contacts have to carry substantial currents, they are still used.

A. Function

These relays are usually instantaneous in action, with no intentional time delay, closing as soon after pickup as the mechanical motion permits. By means of clockwork escapement mechanism the time delay can be added. They can operate with either AC or DC coils. Therefore, these relays can be affected by the DC component of fault.

B. Limitations

The main cons of electromechanical relay are

1) The operation speed is less.
2) Due to ageing effect, there is a change in characteristics over a period.
3) Relay failure is due to the component failure.
4) Due to the presence of internal mechanical components the relay is bulky.
5) High burden on CT.
6) Except phase indication no fault data is available.

C. Formula and Table to Calculate the Operating Time of Electromechanical Relay

Formula to calculate the operating time of electromechanical relay

$$T=0.14 / [(I_f / I_{set})^{0.02} - 1]$$

T - Operating time in seconds.
I_f – Fault current in amperes.
I_{set} – Setting current in amperes.
TSM –Time Setting Multiplier in seconds.

TABLE 1

Test datas of electromechanical relay

Panel	Relay Details		Phase	CT RATIO		Relay Settings Found			Curve	Pick up	Test current		Trip time in sec		Relay settings left/Tested			Target		Remarks
				Available	Connected	CL	TL	Ins			Times	Amps	Found	Left	CL	TL	Ins	Inv current	High set	
66KV IC Line 1	Make	GEC ALSTOM	OCR	400-200/1-1-1 A	400/1-1-1 A	100%	0.1	-	3Sec NI	1	2	2	0.96	0.96	100%	0.1	-	OK	-	-
	Type	CDD									5	5	0.46	0.46						
	SNo	140119 570205 018																		
	Make	GEC ALSTOM	OCR			100%	0.1	-	3Sec NI	1	2	2	1	1	100%	0.1	-	OK	-	-
	Type	CDD	B								5	5	0.49	0.49						
	SNo	140119 580205 006																		
	Make	GEC ALSTOM	EFR			100%	0.1	-	3Sec NI	0.2	2	0.4	0.95	0.95	20%	0.1	-	OK	-	-
	Type	CDD									5	1	0.45	0.45						
	SNo	140119 580205 009																		
66KV IC Line2	Make	ER	OCR	400-200/1-1-1A	400/1-1-1A	75%	0.15	-	3Sec NI	0.75	2	1.5	1.44	1.44	75%	0.15	-	OK	-	-
	Type	TJM12									5	3.75	0.65	0.65						
	SNo	HRC354 360																		
	Make	ER	OCR			75%	0.15	-	3Sec NI	0.75	2	1.5	1.42	1.42	75%	0.15	-	OK	-	-
	Type	ZTJM12	B								5	3.75	0.63	0.63						
	SNo	HRC354 361																		
	Make	ER	EFR			20%	0.15	-	3Sec NI	0.2	2	0.4	1.4	1.4	20%	0.15	-	OK	-	-
	Type	ZTJM12									5	1	0.64	0.64						
	SNo	HRC354 377																		

III. NUMERICAL RELAY

In 1985, the first protection devices based on microprocessors were employed. In 1990, the acceptance of numerical technology by the customer and the experiences of the user helped in developing the second generation numerical relays.

The electromechanical and static relays are hard wired relays. Their setting can be manually changed but their wiring is fixed. Numerical relays are also called as programmable relays. The characteristics and behavior of the numerical relays can be programmed.

The numerical relays of first generation were mainly designed to meet the protection characteristic of the static relay, whereas the modern numeric protection devices will provide complete protection with added functions like control and monitoring. The advantages of numerical protection devices are in terms of protection, reliability, and trouble shooting and fault information.

The distinction between digital and numerical relay rests on points of fine technical detail. It is rarely found in areas other than Protection. As a result of advances in technology, they can be viewed as natural developments of digital relays. They use a specialized digital signal processor (DSP) as the computational hardware, and both are associated software tools.

A. Function

The process of converting analogue signal into digital signal is done according to appropriate mathematical algorithm. Using a specialized microprocessor, processing is carried out that is optimized for signal processing applications, known as a digital signal processor or DSP for short. A very high power microprocessor is required for digital processing of signals in real time.

The measuring principles and techniques of numerical technique has many features compared to electromechanical and static relays, which can differ in many aspects like the usage of protection algorithm type, sampling, signal processing, hardware selection, software discipline etc. Numerical relays are microprocessor-based relays whereas the other relays are controlled electromechanically.

B. Advantages

- Due to the use of Indication on LCD for relay activation the numerical Relay is in Compact Size.
- Numerical relay is flexible, using software and the hardware with slight modifications in the hardware, a variety of protection functions can be accomplished with suitable modifications.
- Due to the use of fewer components results in less interconnections and reduced component failures this leads to high reliability.
- Range of operation of numerical relay is more than electromechanical relay.
- The microprocessor based relay furnishes easy interface with digital communication equipments.
- These relays have low burden on the instrument transformers.
- It has high pickup ratio and greater sensitivity.

C. Limitations

It has some limitations,

1) Unfortunately, the numerical relays have more functionality and greater precision are not necessarily translate into better protection.

2) Numerical Relay can make faster decisions. Circuit breakers are still required to interrupt at the direction of the protective equipment, and the ability to make circuit breakers interrupt faster is very limited. Therefore, in the real world, faster protection itself is of no value.

3) Numerical Relay protection often relies on non-proprietary software, exposing the system to potential risk of hacking.

D. Additional Features

1) Goose Feature

The abbrevation of GOOSE is Generic Object Oriented Substation Event. GOOSE is used to quickly transfer the transformer substation event such as the break state and trip isolator command. And it is also used for the communication between the equipments or between the equipment and intelligent first device. GOOSE command uses the distribution and subscription mechanism to send the non-response, the packet which can be equipment by priority.

For the protection equipment, GOOSE can be used for bay locking and program operation. It can transfer real time knife-break signal, later is very meaningful in the digital transformer substation.

2) Data History

Availability of fault data and disturbance record helps in the analysis of faults by recording details of:

- Nature of fault.
- Magnitude of fault level.
- Breaker problem.
- Duration of fault.

E. Test Datas of Numerical Relay

PCM6002.6 is the software used to record the operating time of the Numerical Relay. Since this software records the datas during disturbances, the obtained recordings is also called as Disturbance Record. There are three forms to record the datas of numerical relay.

They are:

- DR graphs
- Tabular form and
- DR waveforms

1) DR Graphs

Here, the recordings are in the form of graphs. It gives the information about fault time, trip details and other general recordings. In this form, recordings are represented in two diagrams namely Analog time diagram and Digital time diagram.

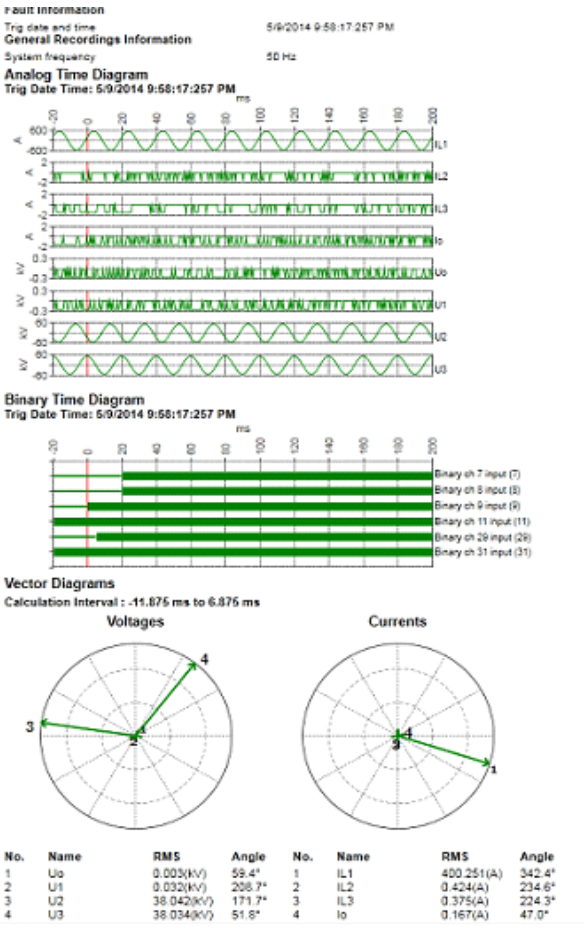

Fig 1: DR graphs

2) Tabular Form

Here, the current values of all the 3 lines, the voltages of all the 3 lines, operating time and voltage sequence values are mentioned in the form of table.

Name	Value	Unit
Protection	3I>->(1)	
Start duration	100	%
Operate time	0.614	s
Active group	1	
Shot pointer	0	
Max current IL1	0.001	xIn
Max current IL2	0.001	xIn
Max current IL3	5.008	xIn
Max current Io	0	xIn
Current IL1	0.001	xIn
Current IL2	0.001	xIn
Current IL3	5.007	xIn
Current Io	0	xIn
Current Io-Calc	5.006	xIn
Current Ps-Seq	1.669	xIn
Current Ng-Seq	1.669	xIn
Voltage UL1	0.578	xUn
Voltage UL2	0.577	xUn
Voltage UL3	0.577	xUn
Voltage U12	1	xUn
Voltage U23	1	xUn
Voltage U31	1.001	xUn
Voltage Uo	0	xUn
Voltage Zro-Seq	0.001	xUn
Voltage Ps-Seq	0.577	xUn
Voltage Ng-Seq	0.001	xUn
PTTR thermal level	0	
I2/I1> rat. I2/I1	0	%

Fig 2: Tabular form

*3) **DR Waveforms***

Here, the recordings are in the form of waves. The red line indicates the fault time and the fault current. In this form, the readings at every instant of time can be seen by moving the black line on the waveforms.

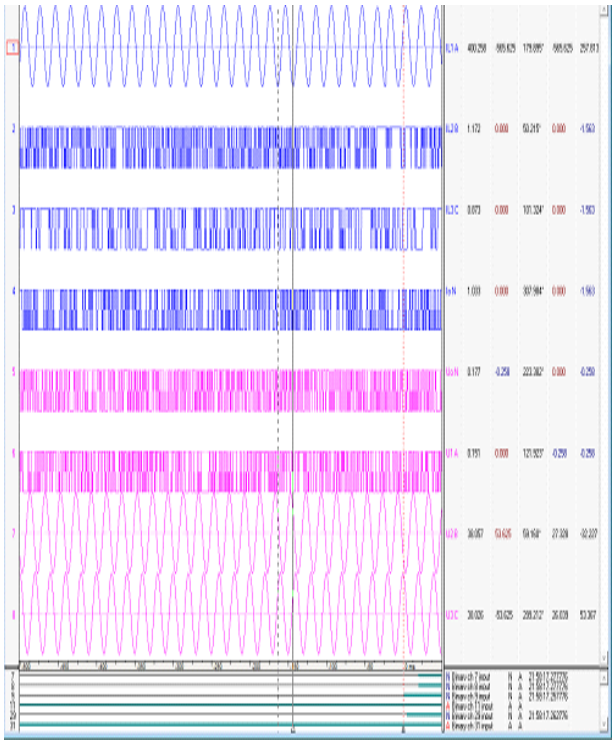

Fig 3: DR waveforms

IV. MATLAB SIMULATIONS

The relay settings or datas are collected from KPTCL, based on the same datas we can implement the Electromechanical and Numerical relays in the MATLAB.

A. Electromechanical Relay

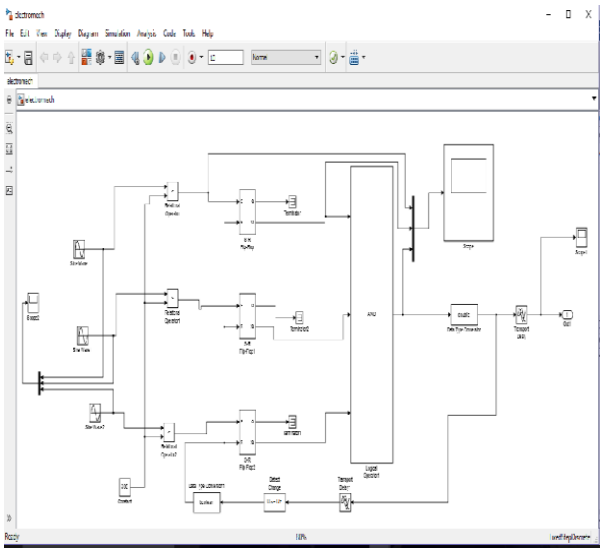

Fig 4: Block diagram of electromechanical relay

Here, we have given input as the sine wave with the amplitude of 400V for R-phase and 230V for Y and B-phase. Therefore the fault is created on R-phase. Then the comparater compares the input of R and Y-phases and give the output as 1(in the binary form). This output is given as input to the flip-flop. And its output becomes zero due to the negation of Q. This is given to the AND gate. Here, if any one of the input is zero then its output is zero. It indicates that fault has occurred in the system. The current flow and fault cleared can be seen in the scope.

B. Simulation Results

1) **Input waveforms**

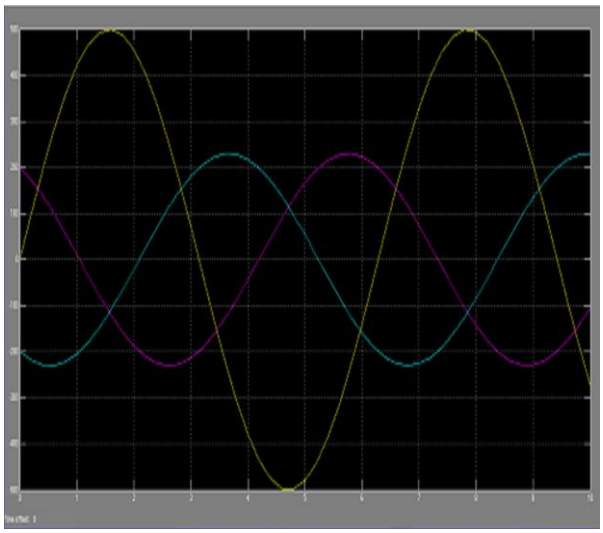

Fig 5: Input waveforms

These are the input sine waveforms for R, Y, B phases.

2) **Time delay**

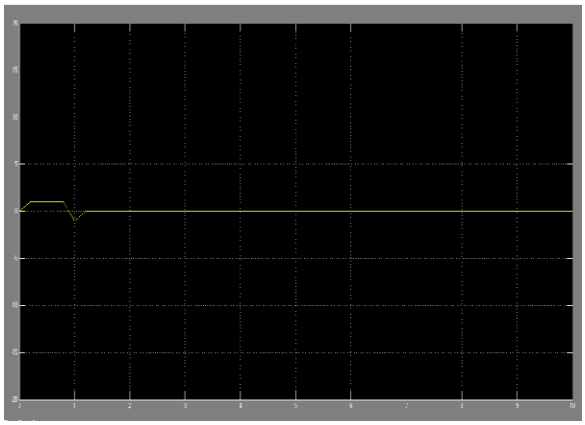

Fig 6: Time delay

This waveform gives the time delay to trip the circuit when fault is detected.

*3) **Output waveforms***

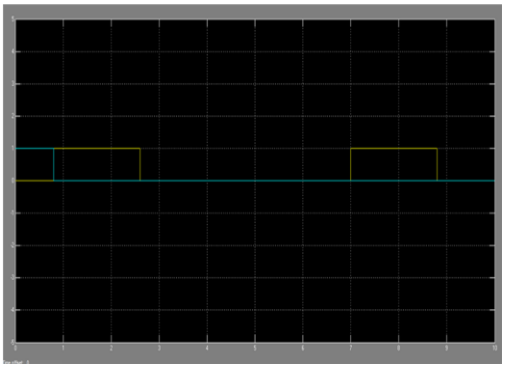

Fig 7: Output waveforms

This is the output of the electromechanical relay. Here the blue line indicates the current flow in the line and the yellow line indicates the operation of relay to clear the fault in the circuit. Even though the fault has been cleared the current does not flow on until the resetting of flag is done manually.

C. Numerical Relay

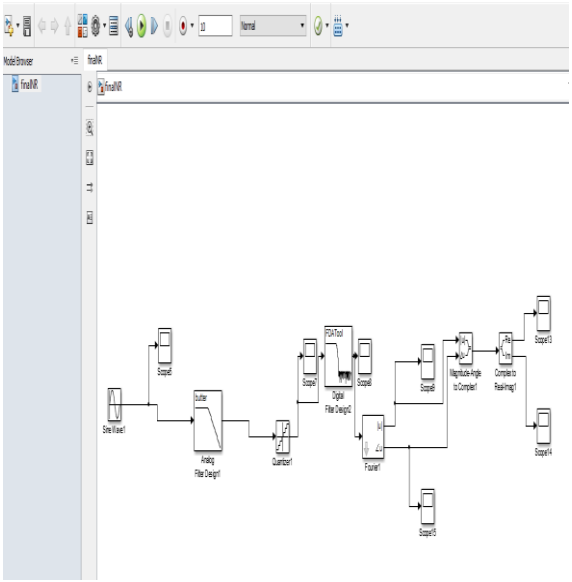

Fig 8: Block diagram of numerical relay

Here, also the input is given as sine wave with the amplitude of 400V. The analog input filter is used to filter the AC components of the waveforms. And the quantizer will sample the output in the form of discrete (step wise). The digital filter design will convert the output of quantizer into digital one. We can also see in the form of rectangular form and polar form.

D. Simulation Results

*1) **Input Waveform***

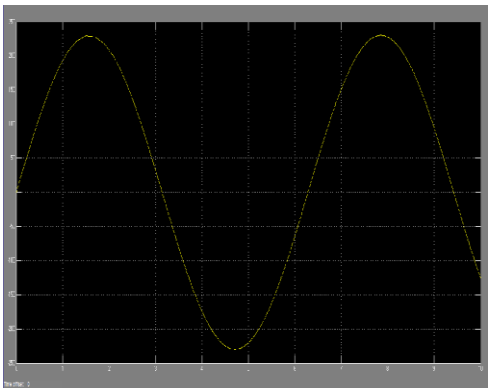

Fig 9: Input waveforms

Input sine wave with the amplitude of 400V.

*2) **Output Waveforms***

Here, we can see the output in the form of polar form. The first graph indicates the voltage magnitude and the second graph indicates the phase voltage. This will prove that, the Numerical relay is more efficient than Electromechanical relay.

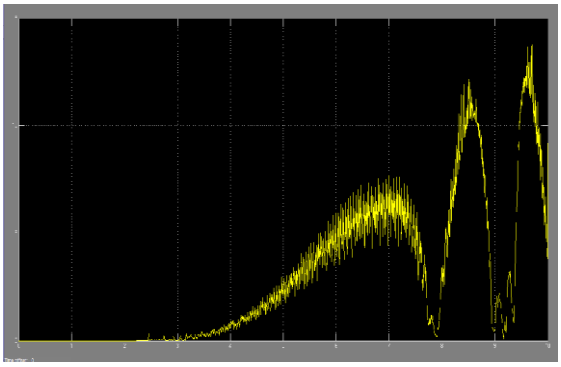

Fig 10: Output voltage in magnitude

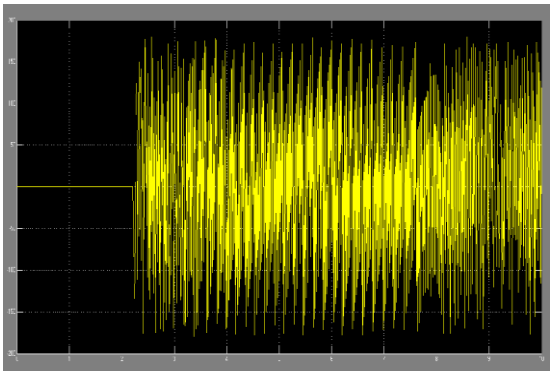

Fig 11: Output voltage in phase

V.NEW PROPOSAL FOR IMPROVEMENTS IN POWER SYSTEM PROTECTION

A. Local Breaker Backup (LBB)

Local Breaker Backup (LBB) is also known as Breaker Failure Protection. It is associated with Bus bar Protection. If breaker fails to operate due to its inoperable condition inspite of operation of protective relays, there will be damage to the system. LBB relay monitors this condition and the bus-bar protection will be initiated and the bus will be cleared.

The conditions considered during the operation of the LBB are:

- Lockout relay should operate.
- Current shall be more than 20% of normal current rating.
- The above currents shall persist after a time, generally 200ms.

When all the three conditions satisfy, it is considered that the breaker is stuck and LBB protection will operate to clear the bus.

B. Bus Bar Protection

In earlier days, for busbar protection only conventional overcurrent relays are used. But it is desired that if any fault occurs in feeder or transformer connected to the busbar should not disturb busbar system. In viewing of this time setting of busbar protection relays are made lengthy. So when faults occur on busbar itself, it takes much time to isolate the bus from source which may cause much damage in bus system. In recent days, the second zone distance protection relays on incoming feeder, with operating time of 0.3 to 0.5 seconds have been applied for busbar protection. But this scheme has also a main disadvantage. This scheme of protection cannot discriminate the faulty section of the busbar. Nowadays, electrical power system deals with huge amount of power. Hence any interruption in total bus system causes big loss to the company. So it becomes essential to isolate only faulty section of busbar during bus fault.

Another drawback of second zone distance protection scheme is that, sometime the clearing time is not short enough to ensure the system stability. To overcome the above mentioned difficulties, differential busbar protection scheme with an operating time less than 0.1 sec., is commonly applied to bus systems.

C. Smoke and Fire Detectors

Fire detection and protection system is required for the following reasons:

- To detect fire in the area during the initial stage.
- To alert occupants, so that they escape the building safely.
- Summon trained personnel to take charge of controlling the fire as quickly as possible.
- To initiate automatic fire control and suppression system.
- To support and supervise the fire control and suppression system.

A smoke detector is a device that senses smoke, and it is used as an indicator of fire.

Commercial security devices issue a signal to a fire alarm control panel as part of a fire alarm system, while household smoke detectors, also known as smoke alarms, generally issue a local audible or visual alarm from the detector itself.

VI. CONCLUSION

The Numerical relay is found to be more adavantageous than the Electromechanical relay in terms of both technical (less operating time) as well as the physical (construction wise- software device) aspects. If the proposed improvements are implemented in protection system then there will be continuous flow of energy in the power system.

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