Development of Power System Protection and Control by Advanced Numerical Relay

[1]Sowmya.P.S, [2]Kavitha.K.M, [3]Joysun D'souza

[1]PG Student, [2,3]Assistant Professor
Dept. of E & E Engineering, AIT
Chikmaglur, Karnataka, India

Abstract- **The design of protective relays has changed significantly over recent years, due to the advancement in microprocessor and signal processing technology. One of the major advancements in protection is the development of numerical relay and its usage over the conventional electromechanical and static relays. A multifunction numerical relay (Sepam series 80) is used to provide various protection features such as overload/over current, over/under voltage, over/under frequency and restricted earth fault (REF) protection which are employed in actual field. The use of numerical relays such as protection, control and monitoring, metering, network and machine diagnosis, in switchgear necessitates that the user be familiar with their design and functionality. This paper discusses the functional blocks of advanced numeric protective relay.**

Keywords- **Laboratory Prototype, Generator Protection, Numerical Relay Settings, Various Fault/abnormal Conditions.**

I INTRODUCTION

Power system protection emerged at the beginning of the last century, with the application of the first Electro-mechanical overcurrent relay. The majority of the protection principles currently Employed in protection relays were developed within the first three Decades of the last century, such as overcurrent, directional, Distance and differential protection. The development of modern science and technology, especially electronic and computer technology, Promoted the development of relay technology, such as Materials, components and the manufacturing process of the hardware structure of relay protection device. At The same time, great theoretical progress had been made in the relay protection software, algorithms, etc. the progress in modern technology stimulates the development in power system protection. Protection relays is designed for all protection applications on medium-voltage public and industrial distribution networks. Numerical Protection relays is designed for operating machines, the electrical distribution networks of industrial installations and utility substations at all levels of voltage. Numerical Protection relays are used for custom applications.

II MAIN CHARACTERISTICS OF NUMERICAL RELAY (SEPAM)

A) Numerical Protection relays offer these features

1) Protects closed ring networks or networks with parallel mains by means of directional protection and zone selective interlocking.
2) Directional ground fault protection for impedance-grounded and effectively ungrounded or compensated neutral systems (designed to compensate for system capacitance using a tuned inductor in the neutral. This is not common in North America).
3) Complete protection of transformers and machine-transformer units Stable, sensitive differential protection with neural network restraint Linked to all necessary backup protection functions
4) Complete protection of motors and generators
   a) Against internal faults:
   - Stable, sensitive machine differential protection, with starting and instrument transformer loss restraint
   - Field loss, stator ground fault
   b) Against network and process faults: pole slip, speed control, inadvertent energization.
5) sync-check between two networks before closing tie breaker.
6) Measurement of harmonic distortion, current and voltage, to assess network Power quality
7) 42 inputs / 23 outputs for comprehensive equipment control.
8) mimic-based UMI for local switchgear control.
9) SFT2841 parameter setting and operating software, a simple and complete tool that is indispensable for all Numerical relays users:
   a) Assisted preparation of parameter and protection settings
   b) Complete information during commissioning
   c) Remote equipment management and diagnostics during operation
10) Logic equation editor built into the SFT2841 software to adapt the predefined control functions.
11) Optional SFT2885 programming software (Logipam), to program specific control and monitoring functions.
12) Two communication ports to integrate Sepam™ in two different networks or redundant architectures.

13) Removable memory cartridge to get equipment in operation again quickly after the replacement of a faulty base unit.
14) Battery backup to save historical and disturbance recording data.

B) Functions of Numerical Relay

1) Protection of equipment against thermal damage caused by overloads.
This function is used to protect equipment (motors, transformers, generators) against overloads, based on measurement of the current drawn.

2) Backup protection if the circuit breaker does not trip.
If a breaker fails to open following a tripping order (detected by the non-extinction of the fault current), this backup protection sends a tripping order to the upstream or adjacent breakers.
The "breaker failure" protection function is activated by an O1 output tripping order received from the overcurrent protection functions which trip the circuit breaker (50/51, 50N/51N, 46, 67N, 67, 64REF). It checks for the disappearance of current during the time interval specified by the time delay T. It may also take into account the position of the circuit breaker, read on the logic inputs to determine the actual opening of the breaker. Wiring a volt-free closed circuit breaker position contact on the "breaker closed" equation editor input can ensure that the protection is effective in the following situations

3) Protection against over currents and overloads.

4) Protection against earth and with selective tripping according to fault current direction:
Earth fault protection based on measured neutral, zero sequence or earth fault (tank earth leakage protection) current.
The protection function has a definite or IDMT time delay. The protection function includes a harmonic 2 restraint which can be set to provide greater saturation stability of the CT phases when transformers are energized. When the residual current measurement is done by adding up to 3 TC phases or by an intermediate TC located in the common point of the 3 TC phases, the harmonic 2 restraint must be active with:
Iso > 10 % of In TC, if the protection is time-dependant (DT),
Iso > 5 % of IN TC, if the protection is IDMT.

5) Detection of excessive machine speeds to protect generators and processes.
Detection of machine overspeed to detect synchronous generator racing due to loss of synchronism, or for process monitoring.

6) Monitoring of under speeds and detection of rotor locking.
Detection of machine under speed after starting, for process monitoring. The protection function picks up if the speed measured drops below the speed set point after having first exceeded the set point by 5 %. Zero speed is detected by unit 1 and is used by protection function 48/51 LR to detect rotor locking. The protection includes a definite (DT) time delay T.

7) Phase-to-phase short-circuit protection for generators.

8) Protection function which checks the synchronization of the electrical networks upstream and downstream of a circuit breaker and allows closing when the differences in voltage, frequency and phase are within authorized limits.

9) Protection against phase-to-neutral or phase-to-phase voltage dips.

10) Motor protection against incorrect voltages.
Protection of motors against faulty operation due to insufficient or unbalanced network voltage. It is based on measurement of the positive sequence voltage Vd. It includes a definite time delay T. It does not operate when only a single phase-to-neutral or phase-to-phase voltage is connected. This protection also detects the phase rotation direction. The protection function considers that the phase rotation direction is reversed when the positive sequence voltage is less than 10 % of Unp and when the phase-to-phase voltage is greater than 80 % of Unp. When this is the case, the alarm message "ROTATION –" is generated.

11) Detection of the remanent voltage sustained by rotating machines.
Protection used to check that remanent voltage sustained by rotating machines has been cleared before allowing the busbars supplying the machines to be reenergized, to avoid electrical and mechanical transients. This protection is single-phase. It picks up when the U21 or V1 voltage is less than the us set point. The protection includes a definite time delay.

12) Protection against reverse power and overloads.
Two-way protection based on calculated active power, for the following applications:
a) Active overpowers protection to detect overloads and allow load shedding.
b) Reverse active power protection: against generators running like motors when the generators draw active power and against motors running like generators when the motors supply active power.

13) Protection against field loss on synchronous machines.

Two-way protection based on calculated reactive power to detect field loss on synchronous machines:
reactive overpower protection for motors which consume more reactive power following field loss and reverse reactive overpower protection for generators which consume reactive power following field loss.

14) Protection for pumps: Protection of pumps against the consequences of a loss of priming by detection of motor no-load operation.

15) Protection against heat rise in equipment by measuring the temperature with a sensor.

16) Protection against field loss on synchronous machines or generators.

17) Phase unbalance protection for lines and equipment.

18) Detection of excessive starting time and locked rotors for motor protection.

19) Protection of cables against thermal damage caused by overloads.

20) Generator protection against close short-circuits and Protection against phase-to-neutral or phase-to-phase over voltages.

21) Protection of three-phase windings against phase-to-earth faults and Phase-to-phase short-circuit protection, with selective tripping according to fault current direction.

22) Detection of abnormally high frequencies and Detection of abnormally low frequency for
Load shedding using a metric frequency criterion.

III BLOCK DIAGRAM OF NUMERICAL RELAY (SEPAM)

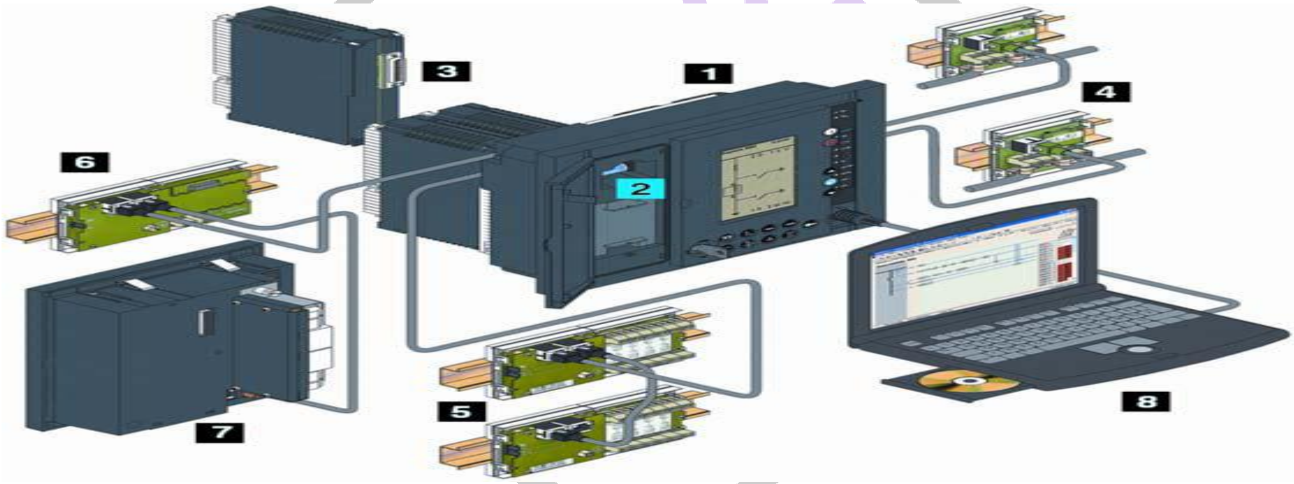

Fig 1 Modular Architecture of advanced numerical Relay.

1. Base unit, with different types of User Machine Interfaces (UMI):
i) Integrated mimic-based UMI
ii) Integrated or remote advanced UMI PE50286

2. Parameter and protection settings saved on Removable memory cartridge.

3. 42 logic inputs and 23 output relays
with three optional modules providing 14 inputs and 6 outputs.

4. Two independent communication ports
i) Direct connection to 2-wire RS485, 4-wire RS485 and fiber optic networks
ii) Connection to Ethernet TCP/IP network via PowerLogic Ethernet server (Transparent ReadyTM)

5. Processing of data from 16 temperature sensors, Pt100, Ni100 or Ni120.

6. 1 low level analog output, 0-10 mA, 4-20 mA or 0-20 mA

7. Sync-check module

8. Software tools
i) Sepam™ parameter and protection setting, and predefined control functions adaptation.
ii) Local or remote installation operation
iii) Programming specific functions (Logipam)
iv)Retrieval and display of disturbance recording data

IV SELECTION GUIDE

Specific Protection Functions Available	**Applications**					
General Performance	**Substation**	**Transformer**	**Motor**	**Generator**	**Bus**	**Capacitor**
Non-directional phase and ground faults	S80				B80	
Directional ground fault	S81	T81	M81			
Directional ground fault and phase overcurrent	S82	T82		G82		
Check on 3-phase voltages on two busses					B83	
Rate of change of frequency	S84					
Capacitor bank unbalance						C86
Transformer or machine differential		T87	M87	G87		
Machine-transformer unit differential			M88	G88		

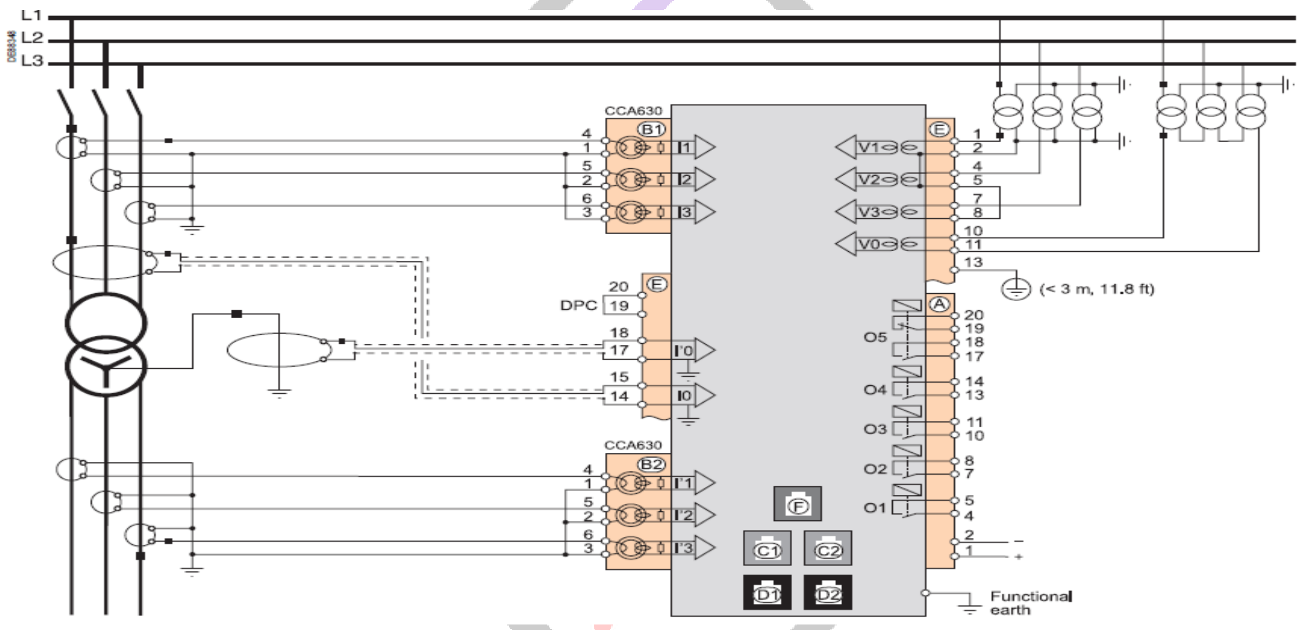

Fig 2 Circuit Diagram of advanced numerical Relay.

V COMMUNICATION NETWORKS AND PROTOCOLS

All Sepam relays communicate and can be integrated into communication architecture. All Sepam information can be accessed remotely.
Sepam relays can be connected to two types of networks, thus providing access to different types of information:

i. Supervisory local area network or S-LAN

An S-LAN is used for supervision functions concerning the installation and the electric network. It can be used to connect a set of communicating devices using the same communication protocol to a centralized supervision system. Sepam can be connected to an S-LAN using one of the following communication protocols such as Modbus RTU, Modbus TCP/IP and DNP3.

ii. An engineering local area network or E-LAN.

An E-LAN is intended for Sepam parameter-setting and operating functions. It can be used to connect a set of Sepam units to a PC running the SFT2841 software. In this configuration, the operator has remote and centralized access to all Sepam information, with no need to develop any special communication software. The operator can easily:

i. set up the Sepam general parameters and functions
ii. collect all Sepam operating and diagnostics information
iii. manage the protection system for the electric network

iv. monitor the status of the electric network
v. run diagnostics on any incidents affecting the electric network.

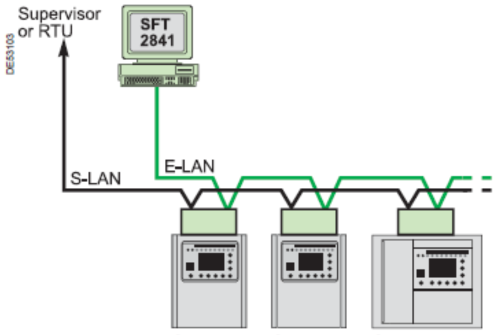

Fig 3 Sepam connection to two communication networks (S-LAN and E-LAN).

VI APPLICATIONS OF NUMERICAL RELAY (SEPAM)

1) Substations

a) Feeder Protection: no voltage and frequency monitoring, voltage and frequency monitoring and specific c feeder protection: 67N/67NC.

b) Main Protection

i. bus short-circuit protection
ii. no voltage and frequency monitoring,
iii. line voltage and frequency monitoring,
iv. specific line or source protection: 67, 67N/67NC,
v. Disconnection-specific functions: 27,59, 59N, 81L, 81R.
vi. line or source protection: 67, 67N/67NC

2) Transformers

i. transformer short-circuit and overload protection
ii. internal transformer protection: Thermostat / Buchholz (ANSI 26/63)
iii. RTD temperature monitoring (ANSI 49T).
iv. transformer directional phase overcurrent protection: 67
v. Transformer secondary ground fault protection: 50G/51G, 59N.

3) Motors

i. internal motor fault protection
ii. power supply fault protection
iii. driven load fault protection
iv. RTD temperature monitoring(ANSI 38/49T)

4) Generators

i. internal generator fault protection
ii. network fault protection
iii. driving machine fault protection
iv. RTD temperature monitoring (ANSI 38/49T)
v. Voltage and frequency monitoring.

ACKNOWLEDGMENT

I express sincere thanks to Dr. G.R Veerendra, Professor and Head, Mrs. Kavitha.K.M, Assistant Professor, Mr. Joysun D'souza Assistant Professor of Department of E & E Engineering for them valuable guidance.

VII CONCLUSIONS

A real time implementation of multifunctional Numerical relaying scheme in laboratory environment for scaled generator, transformers, substation and motors are presented in this paper. Numerical relays communicate and can be integrated into communication architecture. All Relay information can be accessed remotely. The 3-phase power circuit simulation and prototype implementation of various protection schemes applicable to generator transformers substation and motors has been carried out. The developed laboratory setup is capable of discriminating the normal and abnormal/faulty condition of generator transformers substation and motors. All other abnormalities such as overload/over current, under/over voltage phenomenon, Breaker failure, Earth fault, Under voltage (L-L or L-N), Directional reactive overpower, Synchro-check low frequency etc.. Have been detected by the prototype as per design criteria and relay setting. An average tripping time of the order of 0.1sec to 5sec is achieved for all kinds of internal & external faults and abnormalities. The experimental results confirm the satisfactory operation of the developed generator transformers substation and motors scheme with linear/non linear loads.

REFERENCES

[1] N. G. Chothani, B. R. Bhalja and R. P. Maheshwari, "Protection and switchgear", Oxford University press, New Delhi, Sep. 2011
[2] Technical guide, MiCom P341, Interconnection Protection Relay, Volume-1, online available: www.global-download.schneiderelectric.com/.../P341_EN_M_G74.pdf.
[3] Technical guide, Sepam series 80, Interconnection Protection Relay, Volume-1, online available: www.global-download.schneiderelectric.com.
[4] Khan, M. E., Biswas, A., Islam, M. R., "Restricted earth fault protection with superconducting fault current limiter for 100% stator winding",International conference on Electrical information and communication technology (EICT), 2013, Khulna, pp.1-5.
[5] D. Uthitsunthom, Kulworawanichpong, T. , "Optimal overcurrent relay coordination using genetic algorithms," in 2010 International Conference on Advances in Energy Engineering, ICAEE 2010, 2010, pp. 162-165.
[6] L. Hewitson,"Practical Power System Protection for Engineers and Technicians," Rev. 8.1, IDC Technologies, 2011.
[7] P. P. Bedekar, Bhide, S.R., Kale, V.S., "Optimum time overcurrent relays in distribution system using Big-M (penalty) method," WSEAS Transactions on Power Systems, vol. 4, pp. 341-350, 2009.
[8] Rodporn, S., Uthitsunthorn, D., Kulworawanichpong, T., Oonsivilai, R., and Oonsivilai, A., "Optimal Coordination of Over-Current Relays using Differential Evolution", in 2012 9th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON), 2012.
[9] Y .S. Qudaih, Y. Mitani,"Power Distribution System planning for Smart Grid Applications Using ANN", Energy Procedia, vol. 12, pp. 3-9, 2011
[10] Bo, Z.Q., Wang, Q.P., Wang, L., Zhou, F.Q., Ge, S.M., & Zhang, B.M."Architecture design for integrated wide area protection and control systems", APPEEC, April 14 2015, The 7th Asia-Pacific Power and Energy Engineering Conference(APPEEC2015).