Course 3:- Training Program Agenda
Electrical Power System Protection Training

Contents:

- **Protection System Overview.**
    - Types of faults / abnormal conditions & their effect on electrical system and its stability and safety of equipment/persons.
    - Protection overview, need for protection, protection zones, primary and backup protection.
    - Performance requirements of protection (Speed/Sensitivity/ Selectivity/ Reliability)
    - Protection philosophy for LV/HV Electrical System.
    - Selection of protection function
    - Application and selection of relay characteristics and application of overcurrent, earth fault as well as directional overcurrent and earth fault relays.
    - Effect of source grounding on protection system
    - Standard protection function in conventional relays/ enhanced protection functions extended by numerical versions, Advantages of numerical versions (Data acquisition / continuous self-supervision etc)

- **Instrument Transformers (CT / VTs)**
    - CT Types, Standard specifications for metering / protection class CT.
    - Equivalent circuit of CT, Selection & Sizing of CT from view point of ratio, error, composite error, saturation factor, knee point voltage, magnetising current, CT secondary burden etc.
    - Relationship between ALF and connected burden for protection class CTs
    - CT requirements for various protections.
    - CT AC & DC Saturation during symmetrical steady state and transient symmetrical and asymmetrical short circuit and CT sizing to account for saturation
    - Class 5P & Class X/PS CTs – Requirement / Specifications.
    - CT Polarity, Choice of 1A and 5A. CT secondary rating
    - VT Types, Standard specifications for metering / protection class /VT.
    - Significance of Voltage Factor (V.F.) for VTs
    - Type of VT connections (Star, V and Open Delta)
    - High & Low CT ratio Excel CT sizing calculations.
    - Review of CT & VT international standards.

P.Nandakumar, C-203 Akshata Apartments, Tilak Nagar Building No. 1, P.O Tilak Nagar, Chembur Mumbai 400089. email: nanda57@gmail.com; Mobile:-+919821871436

- **System earthing and relaying**

    - Introduction
    - Unearthed system:- Earth faults and earth fault detection in unearthed systems.
    - Resistance earthed system:- High & Low resistance earthing and earth fault detection in unearthed systems.
    - Unearthed system:- Earth faults and earth fault detection in unearthed systems.
    - Sensitive earth relaying with conventional CT, and with core balance / Zero Sequence Current Transformers

- **Transformer Protection**

    - Review of transformer protection standards.
    - Protection Classification
    - Overview of transformer biased differential relaying application.
    - Need for bias due to various factors affecting differential protection such as due to transformer vector group, OLTC, CT ratio mismatch/errors, zero sequence current mismatch, and magnetization switching inrush.
    - Need for Harmonic bias, Practical Differential Relay, Vector Groups and their influence of Differential CT connections, Practical Differential CT connections,
    - Insight into numerical differential protection, Pickup and Bias setting criteria
    - Restricted E/F Protection, High impedance principle, Practical CT connections, Basis for selecting stabilizing resistor, Need for Metrosil (Nonlinear Resistor)
    - IDMT Backup (O/C, E/F) protection for transformer, Ideal backup for Star/star, Delta/Star Transformers, Setting criteria for IDMT /High Set Instantaneous Over current elements,
    - Over fluxing protection (V/f), Principle, Setting criteria vis a vis practical over fluxing relay.
    - Over load protection- Definite time O/L, Thermal O/l Protection, Setting criteria.
    - Non-electrical Protections – Buchholz, PRV, Oil / Winding temperature relays/Indicators,
    - Different relay e EXCEL calculations of different makes related to high impedance, low impedance biased differential protection settings.
    - Typical transformer protection SLD

P.Nandakumar, C-203 Akshata Apartments, Tilak Nagar Building No. 1, P.O Tilak Nagar, Chembur Mumbai 400089. email: nanda57@gmail.com; Mobile:-+919821871436

- **Generator Protection.**

    - Review of generator protection standards.
    - Classification of Protection.
    - Generator overcurrent protection covering scenarios such as for single generation operation, parallel generator direct connected to plant distribution bus, generator with unit generator transformer connected to plant HV or grid.
    - Type of neutral earthing and connections (Unit / Direct connection)
    - Internal fault protections – Differential protection of generator (Biased / High Impedance), Over-all differential for generator / GT,
    - Generator core damage/withstand during internal earth faults, Stator earth fault protection (95% / 100%) – Operating principle / setting criteria,
    - Generator differential and REF protection & Inter turn fault protection
    - Rotor earth fault protection, Effect of rotor E/F on the generator, 1st and 2 nd Rotor E/F relays – Operating principle and connections.
    - External fault backup protection – Voltage controlled / restrained O/C, Impedance type protection, setting criteria, Armature reaction and consequent decrement in sustained short circuit current, Sub-transient / transient / synchronous reactances – concept.
    - Protection against abnormal operating conditions – Effect of unbalanced load on rotor, NPS O/C protection against unbalanced loading, Behaviour of defaulting machine on field failure, Field failure or loss of excitation protection (Off set MHO / DC Under Current), Out of step operation of generator (cause and effect), Pole slipping phenomena, Terminal impedance locus on Pole slip condition, Protection against pole slipping, Setting criteria for practical pole slip relay, Effect of prime mover failure on turbine and quantum of motoring power, Anti motoring or reverse power protection, Under / Over frequency protection. , Under / Over voltage protection. Dead machine energisation protection.
    - Standard tripping logics (Class A, Class B, Class C), typical protection arrangement drawing and preferred CT locations.
    - Different relay e EXCEL calculations of different makes related to generator protection settings.
    - Typical generator protection SLD

P.Nandakumar, C-203 Akshata Apartments, Tilak Nagar Building No. 1, P.O Tilak Nagar, Chembur Mumbai 400089. email: nanda57@gmail.com; Mobile:-+919821871436

- **Motor Protection**

    - Review of motor protection standards.
    - Differential protection for large capacity motors.
    - Standard protection function in conventional relays/ enhanced protection functions extended by numerical versions, Advantages of numerical versions (Data acquisition / continuous self supervision etc)
    - Thermal Over load protection, Current / time setting criteria, Thermal reset / current Clipping/ bypass features to permit hot restart. Start up supervision.
    - S.C. Protection, Current setting criteria, application for contactor controlled motors.
    - Start/Stall protection, Excessive start time /Locked rotor protection, Current / time setting criteria, Speed switch control for locked rotor element.
    - Number of starts protection.
    - Unbalance/Single phasing protection, Effect of NPS current, setting criteria or Negative phase sequence current protection.
    - Earth fault protection, Residually connected / CBCT operated E/F relays, Setting criteria, Special precautions for CBCT application, CBCT specifications.
    - Under and over voltage protection.
    - Under current or loss of load protection.
    - RTD temperature protection
    - Additional protection required for synchronous motors such as power factor and out of step protection, loss of excitation protection, protection against sudden restoration of supply, under frequency protection, low forward power protection.
    - Different relay EXCEL calculations of different makes related to motor protection settings.
    - Typical motor protection SLD

P.Nandakumar, C-203 Akshata Apartments, Tilak Nagar Building No. 1, P.O Tilak Nagar, Chembur Mumbai 400089. email: nanda57@gmail.com; Mobile:-+919821871436

- **Bus Bar Protection and Breaker Fail Protection.**
    - Overview of busbar configuration/ arrangements and protection. Bus protection requirements of speed, sensitivity, stability, redundancy,
    - Types, Operating principles of High Impedance and Biased low impedance protection and their performance requirements.
    - High Impedance version – Setting workout, Effect of magnetising current on sensitivity, Need for non-linear resistors (Metrosils)
    - Location of bus protection CTs and bus zoning
    - CT supervision, CT switching, Practical Bus Diff. Scheme – AC / DC circuits.
    - Breaker fail protection – Operating principle, Practical scheme - AC /DC circuits.
    - Current and time setting criteria for current check relay.
    - Bus protection calculation of stability and effective primary EF protection sensitivity.
    - Different relay EXCEL calculations of different makes related to bubar protection settings.
    - Typical busbar protection SLD

- **Distribution Feeder Protection**
    - Types of protections used (Fuses, IDMT / Definite time O/C, Pilot wire differential) and relative merits / demerits.
    - IDMT characteristic, Standard IEC variations and their equations / applications
    - Current / time grading – example, Time grading margin – influencing factors.
    - Example of IDMT Co-ordination for a typical system.
    - Application of directional O/C, E/F relays, CT/PT connections for directional element, Max. Torque Angle (MTA) or Characteristic Angle – significance & choice.
    - Insight in to Numerical protection.
    - Dual end digital differential protection with fibre optic communication channel.
    - Pilot wire protection- Principle/ types, Pilot supervision, Pilot specifications.

P.Nandakumar, C-203 Akshata Apartments, Tilak Nagar Building No. 1, P.O Tilak Nagar, Chembur Mumbai 400089. email: nanda57@gmail.com; Mobile:-+919821871436

- **Miscellaneous Industrial protection applications**

    - LV ACB feeder with relay, ACB or MCCB releases (Long time, short time and instantaneous LSI release)
    - Basis of requirement for grid Islanding and load shedding protection based on captive inhouse generators in parallel with grid with power export or import from,
    - Benefits of grid islanding to both grid and industrial plant generation.
    - Classification of grid disturbances related to under voltage, over voltage, under frequency, over frequency, rapid fall or rise in frequency (+dF/dT or -dF/dT), power failure in the grid, fault in the grid
    - Grid Islanding protection with calculation of under and over voltage, under and over frequency protection and df/dt, directional Over current + directional E/F relay with under voltage relay. Grid reverse power with under frequency setting, vector surge relay for detecting grid mains failure.
    - Multistage under voltage and under frequency load shedding principles

- **Protective Device Time & Current Coordination Using Graphical Techique Based On Typical Software**
    - Principle of coordination of non unit O/C & E/F relays and releases in a example system with multi circuits.
    - Coordination in Time Current Curve (TCC) Plot of a simple example circuit
    - Sequence of operation check of set relays for various location and times of fault
    - Radial with single direction fault current & Loop system with multi direction fault current
    - Need for directional OC
    - Generator voltage restraint or voltage control OC relay coordination
    - Evaluation of Multistage under voltage and under frequency load shedding principles
    -

P.Nandakumar, C-203 Akshata Apartments, Tilak Nagar Building No. 1, P.O Tilak Nagar, Chembur Mumbai 400089. email: nanda57@gmail.com; Mobile:-+919821871436