PCS-985B/AW

Generator-Transformer Unit Relay

PCS-985 generator-transformer unit protection can be applied for turbo-dynamo, gas-turbine, hydro, pumped storage and nuclear power generator with different connection modes. It supports conventional CT/VT and ECT/EVT, and provides interfaces for power plant automation.

For medium to large generator, two sets of PCS-985 protections can be used to achieve duplicated protection configuration. Two PCS-985 protections use different CT groups, and main and backup protection in one PCS-985 share one group of CTs.

PCS-985B provides complete protection scheme for a turbo-dynamo or nuclear power generator-transformer unit which usually comprises generator, main transformer, step-down transformer and exciter or excitation transformer.

PCS-985AW can be applied for large-scale hydro or pumped storage generator-transformer unit with different connection modes.

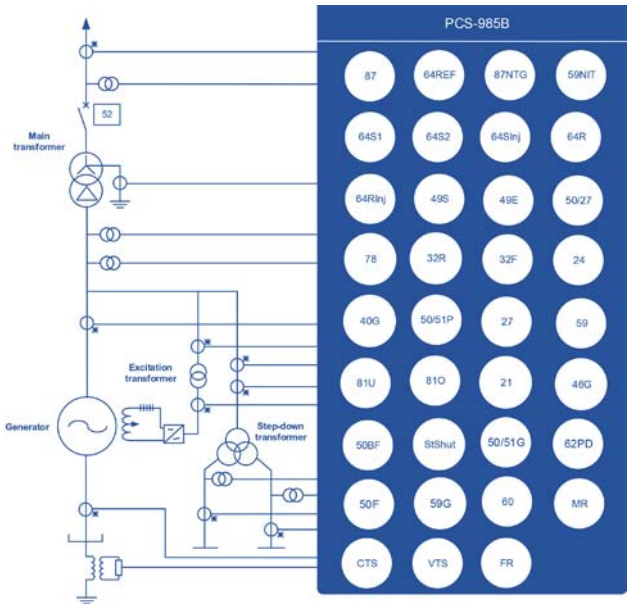

Figure 1 PCS-985B Functional Block Diagram

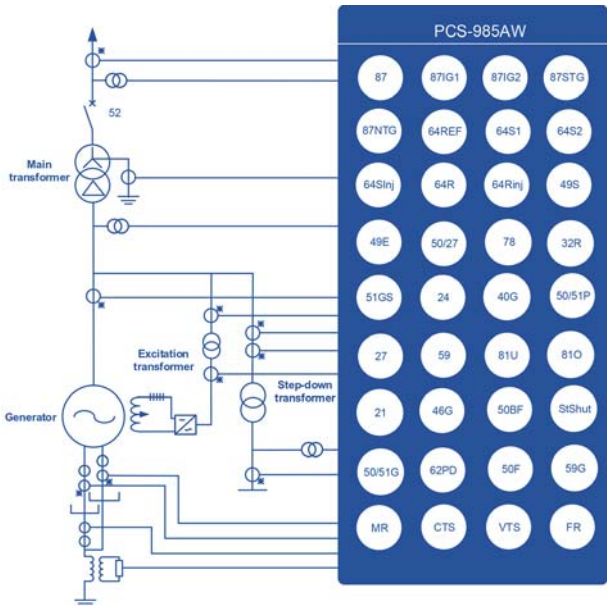

Figure 2 PCS-985AW Functional Block Diagram

Functions

Current Differential Protection

- Current differential protection of generator-transformer unit (87GT)
  Percentage restraint current differential element is variable slope differential element. Advanced “asynchronous method” CT saturation detection algorithms can prevent the protection from mal-operation caused by CT saturation during external fault. The fast detection of CT circuit abnormal condition can avoid mal-operation. Unrestrained instantaneous differential element provides high speed tripping against internal serious fault. Inrush current can be detected via second harmonic restraint principle or waveform distortion discrimination principle. The fifth harmonic of differential current is used as criterion of overexcitation discrimination.

- Current differential protection of generator (87G)
  Percentage restraint current differential element is variable slope differential element. Advanced “asynchronous method” CT saturation detection algorithms can prevent the protection from mal-operation caused by CT saturation during external fault. The fast detection of CT circuit abnormal condition can avoid mal-operation. Unrestrained instantaneous differential element provides high speed tripping against internal serious fault. DPFC current differential element can fully reflect the change of differential current and restraint current, and it is not affected by the load current and is sensitive to small internal fault current within the generator, its performance against CT saturation is also good.

- Current differential protection of main transformer (87T)
  Percentage restraint current differential element is variable slope differential element. Advanced “asynchronous method” CT saturation detection algorithms can prevent the protection from mal-operation caused by CT saturation during external fault. The fast detection of CT circuit abnormal condition can avoid mal-operation. Unrestrained instantaneous differential element provides high speed tripping against internal serious fault. DPFC current differential element can fully reflect the change of differential current and restraint current, and it is not affected by the load current and is sensitive to small internal fault current within the transformer, its performance against CT saturation is also good. Inrush current can be detected via second harmonic restraint principle or waveform distortion discrimination principle. The fifth harmonic of differential current is used as criterion of overexcitation discrimination.

- Current differential protection of step-down transformer (87T)
  Percentage restraint current differential element is variable slope differential element. Advanced “asynchronous method” CT saturation detection algorithms can prevent the protection from mal-operation caused by CT saturation during external fault. The fast detection of CT circuit abnormal condition can avoid mal-operation. Unrestrained instantaneous differential element provides high speed tripping against internal serious fault. Inrush current can be detected via second harmonic restraint principle or waveform distortion discrimination principle.

- Current differential protection of excitation transformer or exciter (87E)
  Percentage restraint current differential element is variable slope differential element. Advanced “asynchronous method” CT saturation detection algorithms can prevent the protection from mal-operation caused by CT saturation during external fault. The fast detection of CT circuit abnormal condition can avoid mal-operation. Unrestrained instantaneous differential element provides high speed tripping against internal serious fault.

Generator Protection

- Phase segregated transverse differential protection (87STG)
  It is mostly utilized for hydro-generator inter-turn faults, and it adopts currents of the branches at neutral point to detect stator inter-turn fault and phase-to-phase fault.

- Incomplete current differential protection (87IG)
  The protection is utilized for hydro-generator stator inter-turn fault or phase-to-phase fault by measuring current inputs from terminal and neutral point of branch.

- High sensitive neutral point transverse differential protection (87NTG)
  The protection is the main protection for generator stator winding internal (phase-to-phase, different branches of the same phase and inter-turn of the same branch) short-circuit fault and branches welding open fault. It is installed on a connection between two neutral points of a generator.

- Generator inter-turn protection (59NIT)
  Generator inter-turn protection includes three operation elements: longitudinal zero-sequence voltage inter-turn element, negative-sequence DPFC direction inter-turn element and calculated longitudinal zero-sequence voltage inter-turn element.

  For longitudinal zero-sequence voltage inter-turn element, the device adopts frequency tracking, digital filtering and full cycle Fourier algorithm, so the filtered ratio of the zero-sequence voltage relative to the 3rd harmonic is larger than 100, and the protection only reflects the fundamental component. For the increase of longitudinal unbalance zero-sequence voltage for other normal operation conditions, a floating threshold is adopted for longitudinal zero-sequence voltage inter-turn element.

  Negative-sequence DPFC direction inter-turn element adopts generator terminal voltage and current directly, so dedicated VT is not needed for it. If the negative-sequence voltage variation, the negative-sequence current variation and the negative-sequence power direction conditions are all met, negative-sequence DPFC direction inter-turn element will operate.

- Phase-to-phase impedance protection (21)
  Two stages of impedance protection are equipped at the

generator terminal as phase-to-phase backup protection. Full impedance, directional impedance or shifted impedance characteristics can be selected for these two stages.

- Voltage controlled overcurrent protection (50/51P)
  There are two stages with two separate time delays. Stage 1 is used to trip bus coupler breaker or other breakers, and stage 2 is to shutdown the generator. Composite voltage element consists of phase-to-phase undervoltage element and negative-sequence overvoltage element.

- Fundamental zero-sequence voltage stator ground fault protection (64S1)
  Fundamental zero-sequence voltage stator ground fault protection can detect the ground fault of 85%~95% of stator winding of generator terminal side. The device adopts frequency tracking, digital filtering and full cycle Fourier algorithm, so the filtered ratio of the zero-sequence voltage relative to the 3rd harmonic is larger than 100, and the protection only reflects the fundamental component.

- Generator 3rd harmonic stator ground fault protection (64S2)
  Generator 3rd harmonic stator ground fault protection includes two operation elements: 3rd harmonic ratio stator ground fault element and 3rd harmonic differential stator ground fault element. 3rd harmonic ratio stator ground fault element can detect the ground fault of approximately 25% of stator winding of generator neutral point side. Fundamental zero sequence voltage stator ground fault protection coordinate with 3rd harmonic ratio stator ground fault element can constitute 100% stator ground fault protection. 3rd harmonic differential stator ground fault element can reflect the ground fault of the whole stator winding, but it is very sensitive, so generally it is only for alarm.

- Generator stator ground fault protection with 20Hz voltage injection (64SInj)
  The stator earth fault protection with external voltage injector PCS-985U can detect 100% earth faults in the stator windings of generator. The protection contains two criteria: resistance criterion and zero-sequence current criterion. Via injecting 20Hz voltage, the protection can judge whether a ground fault happens at the circuit of generator stator winding side, it can detect the single-phase ground fault of 100% of the stator winding. It will not be affected by generator operation condition, even during shutdown condition, the protection still can monitoring the insulation condition of the stator winding.

- Generator Ping-Pang type rotor ground fault protection (64R)
  Generator Ping-Pang type rotor ground fault protection includes three operation elements: sensitive stage of rotor one-point ground fault element for alarm, insensitive stage of rotor one-point ground fault element for tripping or alarm, and rotor two-point ground fault element for tripping.

  Rotor one-point ground fault element reflects the decline of the insulation resistance between rotor winding and the shaft, two stages are equipped, the sensitive stage for alarm and the insensitive stage for alarm or trip. Rotor two-point ground fault element reflects the change of rotor ground position, it can operate to trip.

- Rotor ground fault protection with low-frequency square-wave voltage injection (64RInj)
  The low-frequency square-wave voltage is injected between the generator rotor winding positive/negative pole leading-out terminal and the shaft, via measuring the leakage current, the rotor one-point ground resistance is calculated, it can reflect the decline of insulation resistance that between the rotor winding (includes the directly connected excitation circuit) and the rotor shaft.. If double-ends injecting wiring is adopted, it can detect the location of rotor winding ground fault. When the calculated rotor ground fault location changes, it will be considered that a two-point ground fault happens.

- Stator overload protection (49S)
  Generator stator overload protection comprises definite-time overload protection and inverse-time overload protection. The low-setting stage of definite-time overload protection is used for alarm and the high-setting stage of definite-time overload protection is used for tripping. Inverse-time overload protection can simulate the heat accumulation process of the stator winding.

- Excitation winding overload protection (49E)
  Generator excitation winding overload protection comprises definite-time overload protection and inverse-time overload protection.

- Generator inadvertent energization protection (50/27)
  The protection utilizes the characteristics of voltage, frequency, circuit breaker state and current before and after the generator is closed inadvertently to detect inadvertent energization condition.

- Generator out-of-step protection (78)
  Generator out-of-step protection is used to detect the asynchronous operation due to generator out-of-step. Out-of-step protection judge whether out-of-step swing occurs via the locus of calculated impedance, and judge whether the out-of-step swing center is within the generator. Out-of-step protection can operate to trip or alarm.

- Generator reverse power protection (32R)
  Generator reverse power protection includes two operation elements: conventional reverse power element and sequence tripping reverse power element. It is configured to prevent the turbine blades or gas turbine gears from damage when the generator changes into motor operating mode due to loss of its motive power.

- Low forward power protection (32F)
  Low forward power protection responds to low forward

power flow. It can be released by the binary input for non-emergency shutoff or the binary input indicating that the valve of the steam turbine is in the closed position.

- Generator shaft overcurrent protection (51GS)
  Generator shaft overcurrent protection detects the shaft current of generator rotor shaft, it can prevent the bearing from damage. The function is mainly used for hydropower unit.

- Overexcitation protection (24)
  Overexcitation protection is used to check the over-flux phenomenon during operation of the generator. The ratio of voltage and frequency is adopted to check overexcitation. Definite-time over-excitation protection consists of two stages: one is for alarm, the other is for tripping. Inverse-time over-excitation protection realizes inverse-time characteristic by linear processing on given inverse time operation characteristic, obtaining multiple of over excitation by calculation, and calculating corresponding operation time delay by sectional linear insertion. It reflects heat accumulation and radiation.

- Loss-of-excitation protection (40G)
  Loss-of-excitation protection represents abnormal operation of the generator due to excitation failure. It includes three criteria: undervoltage criterion, stator-side impedance criterion and rotor-side criterion. The voltage at the generator terminal or high voltage side of main transformer can be selected as undervoltage criterion. Static stability impedance circle and asynchronous impedance circle can be selected as stator-side impedance criterion.

- Overvoltage protection (59)
  Two stages of overvoltage protection can be used for tripping or alarming.

- Undervoltage protection (27)
  Undervoltage protection reflects the reduction of three phase-to-phase voltages, and it is blocked by the binary input of synchronous condenser operation.

- Underfrequency protection (81U)
  Underfrequency protection will issue an alarm or trip if the accumulated time delay or once duration time delay exceeds its setting.

- Overfrequency protection (81O)
  Overfrequency protection will issue an alarm or trip when it operates.

- Negative-sequence overload protection (46G)
  Generator negative-sequence overload protection can reflect the over-heating condition of generator rotor surface, it can also reflect the other abnormalities that caused by negative-sequence current. Generator negative-sequence overload protection comprises definite-time overload protection and inverse-time overload protection.

- Generator startup and shutdown protection (StShut)
  The protection includes low-frequency zero-sequence overvoltage element and low-frequency overcurrent element. Low-frequency zero-sequence overvoltage element is used to reflect single-phase ground fault during startup and shutdown process of generator. Low-frequency overcurrent element is used to reflect phase-to-phase short-circuit fault during startup and shutdown process of generator.

- Breaker failure protection (50BF)
  When there is an internal fault of the generator, the protection operates to trip but the breaker at the generator terminal fails, it needs to initiate breaker failure protection and trip adjacent breakers in time.

- Voltage balance protection (60)
  For some generator, two groups of VT are equipped, the two groups of VT can be connected into the generator protection device simultaneously, via comparing, the VT of which abnormality is detected can be identified, if abnormality happens to one VT, all the protections that use the VT will be switched to another normal VT automatically, so the performance of the voltage related protections will not be affected.

Main Transformer Protection

- Transformer restricted earth fault protection (64REF)
  Transformer restricted earth fault protection is the main protection for the internal earth fault of transformer winding. It has the independent CT saturation criterion.

- Phase overcurrent protection of HV side (50/51P)
  Two-stage transformer phase overcurrent protection with independent current and time delay settings are available. Voltage controlled element can be selected to control each stage of transformer phase overcurrent protection.

- Phase-to-phase impedance protection of HV side (21)
  Three kinds of impedance characteristics can be selected, i.e. full impedance, directional impedance and shifted impedance.

- Ground overcurrent protection of HV side (50/51G)
  Two-stage definite-time ground overcurrent protection and one stage inverse-time ground overcurrent protection with independent current and time delay settings are available. Residual voltage, direction element and second harmonic blocking element can be selected to control each stage of ground overcurrent protection.

- Gap zero-sequence overvoltage/overcurrent protection of HV side.
  Gap zero-sequence protection of HV side is used for the transformer with neutral point grounded through a gap or small reactance.

- Overexcitation protection (24)

Overexcitation protection is used to check the over-flux phenomenon during operation of the transformer. The ratio of voltage and frequency is adopted to check overexcitation. Definite-time over-excitation protection consists of two stages: one is for alarm, the other is for tripping. Inverse-time over-excitation protection realizes inverse-time characteristic by linear processing on given inverse time operation characteristic, obtaining multiple of over excitation by calculation, and calculating corresponding operation time delay by sectional linear insertion. It reflects heat accumulation and radiation.

- Pole discrepancy protection of HV side (62PD)
  Pole discrepancy protection of HV side adopts phase current, negative-sequence current, and zero-sequence current as criteria to detect the abnormal situation of pole discrepancy.
- Breaker flashover protection (50F)
  For the large-scale generator-transformer unit in higher voltage level system, during the process of preparation synchronization or just out of operation, flashover in circuit breaker is possible when phase angle difference between the voltages of two sides of the circuit breaker is around 180°. Breaker flashover protection is used in case of this situation, and one phase and two phase flashover are considered. Breaker flashover protection includes two criteria: circuit breaker position auxiliary contact criterion and current criteria.
- Zero-sequence voltage alarm of LV side (59G)
  Zero-sequence voltage alarm of LV side can be provided for the main transformer as the supervision of earthing fault when generator terminal circuit breaker is not closed.
- Overload alarm
- Initiating cooling

Excitation Transformer/Exciter Protection

- Overcurrent protection (50/51P)
- Overcurrent protection includes two stages used as backup protection.

Step-down Transformer Protection

- Voltage controlled overcurrent protection of HV side (50/51P)
- Voltage controlled overcurrent protection of two branches of LV side (50/51P)
- Residual overcurrent protection of two branches of LV side (50/51G)
- Overload alarm
- Initiating cooling

Miscellaneous

- Mechanical protection (MR)
- Fault detector (FR)
- Voltage and current drift auto adjustment.
- VT circuit supervision (VTS)
- CT circuit supervision (CTS)
- Self diagnostic
- GPS clock synchronization
- Fault recorder
- IEC61850 MMS & GOOSE for station bus
- IEC60870-5-103 protocol
- MODBUS protocol

Features

- Parallel calculation of double DSP system
  The hardware of the device comprises a 32-bit microprocessor and two 32-bit digital signal processors (DSP). Those processors can operate in parallel companied by fast A/D converter. The 32-bit microprocessor performs logic calculation and the DSP performs the protection calculation. High performance hardware ensures real time calculation of all protection relays within a sampling interval.

  On the premise of 24 samples per cycle, all data measurement, calculation and logic discrimination could be done within one sampling period. The event recording and protection logic calculation are completed simultaneously.
- Independent fault detector
  Independent fault detectors in fault detector DSP module for connecting power supply of output relays. The relay can drive a tripping output only when protection element on protection DSP module operates with the fault detector in the fault detector DSP module operating simultaneously. This kind of independent supervision of tripping outputs using fault detectors can avoid any mal-operation possibly caused by any hardware component failure. This highly increases the security.
- Configurable tripping output
  The tripping output contacts can be configured by tripping matrix and suitable to any mode of tripping.
- Fault recording function
  Event records include 1024 binary input events and 1024 alarm events. Disturbance records including 64 fault reports, and 64 disturbance waveforms, and file format of waveform is compatible with international COMTRADE91 and COMTRADE99 file. Analog inputs and binary inputs can be recorded, and three oscillography triggering mode are supported, which are protection pickup triggering, manual triggering on keypad of device, and remote triggering through PCS-Explorer software.
- Integration of main and backup protection
  Main and backup protection are integrated in one set of protection device. Protection information is shared by all parts. The device can record all relevant waveforms of any fault.
- Reliable CT saturation detection
  Based on the operation sequence of DPFC restraint current element and DPFC differential current element of differential protection, external fault with CT saturation or internal fault can be distinguished correctly.