

Digital Relay Reference Guide

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Introduction

The process of designing any protection scheme requires a basic understanding of short-circuit analysis, selective coordination and zones of protection. The *IEEE Protection and Coordination of Industrial and Commercial Power Systems* is a good source as are the many available protective relay design books that can aid in computations. Below is a link to a GE publication:

Art and Science of Protective Relaying

<http://www.gedigitalenergy.com/multilin/notes/artsci/index.htm>

Digital relays (sometimes called microprocessor-based or numerical relays) can more precisely and economically manage system protection, coordination and communication as compared to traditional analog electrical-mechanical relays. The digital relay is a multifunctional device using numerical algorithms that can easily duplicate any of the ANSI protection functions with simple software modifications. The advantages of digital relays are numerous and not limited to the following:

- Transient over-reach code can prevent nuisance trips
- CT saturation can be managed
- One digital relay can replace a bank of analog devices
- Custom functions can be programmed
- Communication over a PMCS
- Time stamped event recording
- Self-monitoring
- Reduced panel space
- Lower burden
- Improved performance
- High seismic withstand

Fault Characteristics

The sudden change from normal power flow to a fault condition cannot be completely predicted but framing parameters within cascading protection schemes can control the uncertainty. The goal is to trip only when necessary and block in permissible stable conditions. The following fault characteristics and system design choices should be considered:

Fault Currents: system modeling starts with understanding faults current magnitudes and coordination objectives. Below is a link to GE's fault current calculation and selective coordination guides:

http://www-test.geindustrial.com/solutions/engineers/selective_coordination.html

Note: asymmetric fault current calculations are often not performed. Most device manufactures design around an X/R ratio that will result in an asymmetric RMS magnitude of 1.6 times the symmetric fault current. This assumption is normally sufficient; however, care must be taken when electrical systems are located close to large generators or contain synchronous motors since higher than expected X/R can exceed equipment duty ratings. Positive, Negative and Zero Sequence components should be determined in applications that require precise settings such as loss of phase (negative) or ground fault (zero) protection.

Ground Faults: system grounding normally takes one of the following forms and requires different protection schemes:

- Solid grounding – no added ground resistance, normally used on low voltage systems
- Low-resistance grounding – used on medium voltage systems
- High-resistance grounding – typically measured through a transformer & resistor connected between neutral & ground for large generator protection.
- Ungrounded systems – uncommon but sometimes used when reliability is more important than protection.

To maximize selectivity, ground fault protection would have to be applied on every protective device from the main to the load. Pick-up settings and delays calculated to react faster and at a lower threshold closest to the load. If the only ground fault protection is provided at the main, then a small ground fault on a distant branch circuit could cause the main to trip.

Ground fault protection schemes include one or combination of the following:

- Residually connected relays
- Core balance sensing or zero sequencing
- Ground return sensing
- Differential relaying

Refer to the below ground-protection guide for more information:

<http://www.geindustrial.com/publibrary/checkout/38652.30055.7388.64898/PDF/GET-6533A.pdf>

Arcing short-circuits: low impedance, three phase bolted-faults (less likely but most severe) are customarily used for maximum fault current calculations. However, the magnitude of these faults does not always predict the worse arc-flash hazards. Arc-flash (HiZ) protection is available on advanced multi-function relays for high impedance fault protection. However, the most common scheme involves differential relay protection to detect unbalance current between two ct's. Differential relays can also look deep inside transformers and generators for low magnitude problems that usually go undetected.

Protection Relay Design

Below are links to traditional one-line representations for incoming service, feeder, transformer, motor and generator protection as well as auto throw-over schemes:

Relay protection layout: <http://www.geindustrial.com/multilin/notes/GET-8048A.pdf>
<http://www.geindustrial.com/publibrary/checkout/Application%20and%20Technical|GET-6600G|generic>

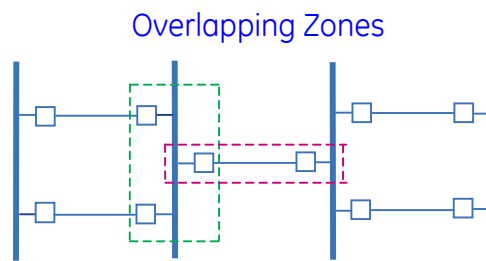
ANSI device numbers: http://www.gedigitalenergy.com/multilin/notes/ref/Product_ANSI.pdf

Medium voltage one-line: http://www-test.geindustrial.com/solutions/engineers/specifiers_online_mv.html

Low voltage one-line: http://www-test.geindustrial.com/solutions/engineers/specifiers_online_lv.html

Zones of protection

Zones of protection dissects the distribution system into groups which, when responding to a fault, limits the outage to the smallest number of devices. Every device must fall into at least one zone. Each zone can share information with other zones, either to block or expand the tripping of breakers; and zones often overlap.



To increase protection and coordination the system should be designed to anticipate failure of devices. Backup schemes can detect problems in an adjacent zone. A back-up zone usually involves timers or looking for a block signal (as seen in zone selective interlocking). Local zone backup is accomplished by redundant relays within the zone but react to different parameters and often controlled by separate power supplies.

System Approach

At times it is necessary to look outside of the zones to anticipate problems from utilities or other upstream transmission lines or substations. Furthermore, faults outside of differential relay protection simple pass through with out detection.

Measuring voltage and current can create impedance tripping ($V/I = Z$) at a calculated value (distance) from the system. Hence the name distance or impedance relays. Mho distance relays measure admittance thus providing a directional element to distance sensing.

GE Multilin Selection Guide <http://www.gedigitalenergy.com/multilin/index.htm>

GE's multifunction digital relays and associated equipment are divided into the follow categories:

Universal Relay Protection (UR) – modular design allows for updated technology. Can be equipped with distance, dynamic, differential, high impedance arc-flash (HiZ)

along with standard protection. UR's communicates in IEC 61850 & Ethernet as well as relay-to-relay ring communication.

SR Relays – drawout multifunction relay communicating in Modbus RTU or Ethernet.

650 Relays – F650 is a double-bus multi-feeder protection bay controller. W650 is the recently added wind-drive turbine as well as any distributed generator protection.

M Relays- economical small package basic protection

Metering: PQM & EPM

<http://www.gedigitalenergy.com/multilin/catalog/meters.htm>

Software

EnerVista, a downloaded free software package that allows easy access to Multilin brochures, application and installation guides:

<http://www.gedigitalenergy.com/multilin/enervista/launchpad/index.htm>

Instrument Transformers – current and voltage instrument, control power & auxiliary transformers.

<http://www.gedigitalenergy.com/ITI/products.htm>

Distribution Feeder Protection

Product description <http://www.gedigitalenergy.com/multilin/catalog/distribution.htm>

Product - function matrix <http://www.gedigitalenergy.com/multilin/selector/distfeed.pdf>

(Arranged from basic to advanced functions)

SR735/737 - SR family drawout relay performing basic three-phase and ground feeder protection at any voltage.

<http://www.gedigitalenergy.com/multilin/catalog/735737.htm>

MIFII – Three phase, single phase & ground protection with reclosure at any voltage or serves as backup protection for transformers, generators and motors.

<http://www.gedigitalenergy.com/multilin/catalog/mifii.htm>

F35 – UR relay providing feeder protection and metering for up to 5 breakers with bus monitoring. Stand alone or a component of an automated substation control system.

<http://www.gedigitalenergy.com/multilin/catalog/f35.htm>

SR 750/760 – SR drawout relay with complete protection for industrial and utility feeders and can be used for power management and backup protection of busses, transformers, and power lines.

<http://www.gedigitalenergy.com/multilin/catalog/750.htm>

F650 – protects HV/MV feeders, bus couplers, transformers and capacitor banks. The F650 is the first feeder relay with remote I/O capabilities via the CIO module.

<http://www.gedigitalenergy.com/multilin/catalog/f650.htm>

F60 - UR relay providing high performance feeder protection, control, monitoring and metering along with high impedance fault detection for fast and reliable detection of faults caused by downed conductors.

<http://www.gedigitalenergy.com/multilin/catalog/f60.htm>

Incoming Protection

Protection for the incoming service generally uses the same relays as those for feeder protection. The instantaneous function on the main can be removed or set higher than the feeders to increase selectivity. Additional meter functions, high-level communications and HMI devices are typically used at the incoming service.

Often one central PLC element can coordinate automatic throw-over between two utility sources and/or generators more efficiently than the individual PLC elements in relays alone. For example: 3 - SR735 (or F-30) Main-Tie-Main relays coordinated by a 9030 PLC may be more cost effective than 3-SR 750 relays, depending on the complexity of the throw over scheme.

Fanuc PLC Link:

http://www.gefanuc.com/as_en/products_solutions/controllers_io/series_9030.html

Bus Protection

Product description <http://www.gedigitalenergy.com/multilin/catalog/bus.htm>

Product – function matrix <http://www.gedigitalenergy.com/multilin/selector/bus.pdf>

(Arranged from basic to advanced functions)

Bus2000 – basic differential bus protection at any voltage.

<http://www.gedigitalenergy.com/multilin/catalog/bus1000.htm>

MIB – High impedance bus differential protection providing zero sequence restricted ground fault protection.

<http://www.gedigitalenergy.com/multilin/catalog/mib.htm>

B30 - Universal relay providing bus and up to 6 feeders and zone protection ideal for breaker and a half schemes with back-up feeder protection and metering.

<http://www.gedigitalenergy.com/multilin/catalog/b30.htm>

B90 – Universal relay providing multi-section bus and up to 24 feeder protection with sub-cycle tripping time average of .75 cycles.

<http://www.gedigitalenergy.com/multilin/catalog/b90.htm>

Transformer Protection

Product Description <http://www.gedigitalenergy.com/multilin/catalog/transformer.htm>

Product – function matrix <http://www.gedigitalenergy.com/multilin/selector/transformer.pdf>

(Arranged from basic to advanced functions)

T35 – Universal relay protecting any size three-phase transformer up to six windings/restraint.

<http://www.gedigitalenergy.com/multilin/catalog/t35.htm>

745 – Draw-out three-phase, two or three winding protection of small, medium and large transformers. Monitors transformer health and load monitoring.

<http://www.gedigitalenergy.com/multilin/catalog/745.htm>

T60 – Universal relay providing for any size transformer including a full featured set of functions, I/O, data logging and communication capabilities.

<http://www.gedigitalenergy.com/multilin/catalog/t60.htm>

Motor Protection

Product Description <http://www.gedigitalenergy.com/multilin/catalog/motor.htm>

Product – function matrix <http://www.gedigitalenergy.com/multilin/selector/motor.pdf>

(Arranged from basic to advanced functions)

MMII – provides motor control and protective fitting in a standard MCC bucket.

<http://www.gedigitalenergy.com/multilin/catalog/mm2.htm>

LM10 – designed for medium sized motor control and protection with advanced motor health & fault diagnoses.

<http://www.gedigitalenergy.com/multilin/catalog/lm10.htm>

269 – small and medium motor control and protection with 239 monitoring features.

<http://www.gedigitalenergy.com/multilin/catalog/269p.htm>

369 - Comprehensive protection and control for medium sized motors and their driven equipment. Equipped with advanced motor health & fault diagnostics.

<http://www.gedigitalenergy.com/multilin/catalog/369.htm>

469 – SR protective relay for medium to large motors and driven equipment. Including advanced vibration, torque, overload and rotor protection perfect for two speed motors, motors with high inertia loads where reduced voltage starting is required.

<http://www.gedigitalenergy.com/multilin/catalog/469.htm>

M60 – Universal relay protection for medium and large motors with an enhanced thermal model, standard and custom thermal limit curves, current unbalance biasing, cooling curves, optional RTD modules, and hot/cold motor compensation.

<http://www.gedigitalenergy.com/multilin/catalog/m60.htm>

Generator Protection

Product Description <http://www.gedigitalenergy.com/multilin/catalog/generation.htm>

Product – function matrix <http://www.gedigitalenergy.com/multilin/selector/generator.pdf>

(Arranged from basic to advanced functions)

MIG – provides basic three-phase small generators and motors.

<http://www.gedigitalenergy.com/multilin/catalog/mig.htm>

G650 - small to medium generator protection and management with external communication and distributed I/O capability.

<http://www.gedigitalenergy.com/multilin/catalog/g650.htm>

489 – SR family or protection providing economical monitoring and metering functions, can be used as a primary or back-up protection for synchronous, inductive generators or co-generators.

<http://www.gedigitalenergy.com/multilin/catalog/489.htm>

G30 – universal relay protection for small to medium generators including unit transformer protection.

<http://www.gedigitalenergy.com/multilin/catalog/g30.htm>

G60 – UR family of any size generator protection driven by steam, gas, etc.

<http://www.gedigitalenergy.com/multilin/catalog/g60.htm>