Comprehensive Testing Considerations for Generator Protection Systems

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imagination at work

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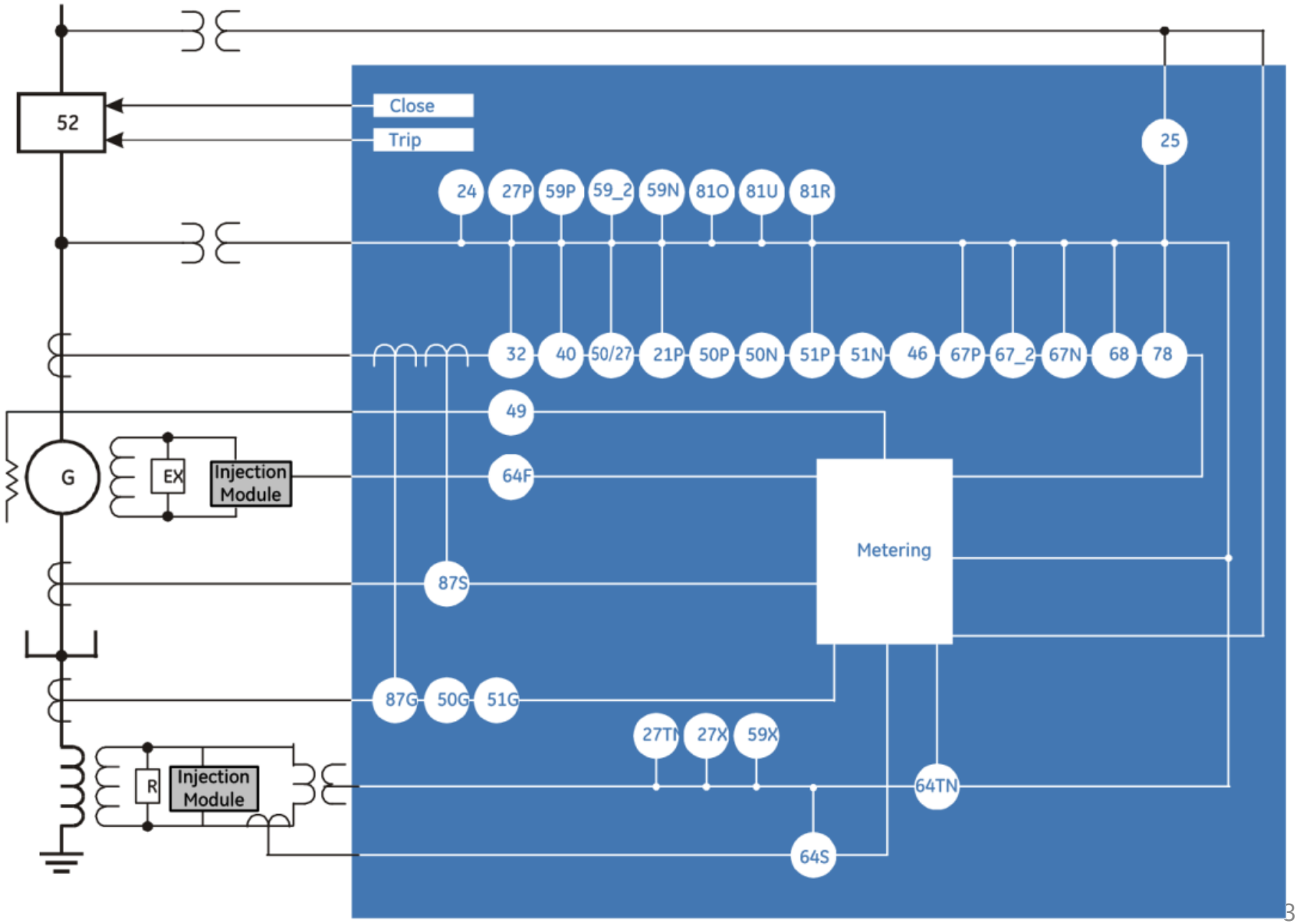
    - Considerations
    - How interval can be set?
  - Troubleshooting
    - Field examples

A Typical Generator Protection IED



A Typical Generator Protection IED

Additional functions
Breaker control
VT fuse failure
In-built Phasor Measurement Unit (IEEE C37.118)
Communications (IEC 61850, DNP3.0, IEC 60870-5-104, Modbus) with advanced cyber security features
Event recorder
Data logger
Oscillography
Metering
Contact I/Os
Analog/Transducer I/Os (DCMA, RTD, etc.)
Flexible/Programmable Logic schemes
Flexibility of user-defined protection & control schemes/ elements
Self-testing and setting Targets/Flags
Trip circuit monitoring
Multiple groups of protection functions (user-defined protection group transition)

Testing of Generator Protection

Classification of Testing (IEEE C37.233-2009, CIGRE WG 34.10 report-2000)

1. Certification/Functional/Type tests
2. Commissioning tests
3. Periodic maintenance tests
4. Troubleshooting tests

- Other sub-categories/nomenclatures
  - application tests, performance tests, acceptance tests, conformance tests, upgrade tests, etc.

Certification/Functional Testing

- Performed by relay manufacturers before shipping

- Objectives
  - Validate the entire design of generator protection system
  - Confirm specifications over the entire ranges of operating conditions
  - Check the performance of developed protection & control elements in various scenarios

Certification/Functional Testing

- Sub-categories
  - Functional and system type tests
    - Steady state functional test
    - Transient/dynamic performance tests
  - Physical and electrical environment tests
    - Compliance standard list provided by manufacturers
  - Pilot project tests

Certification/Functional Testing

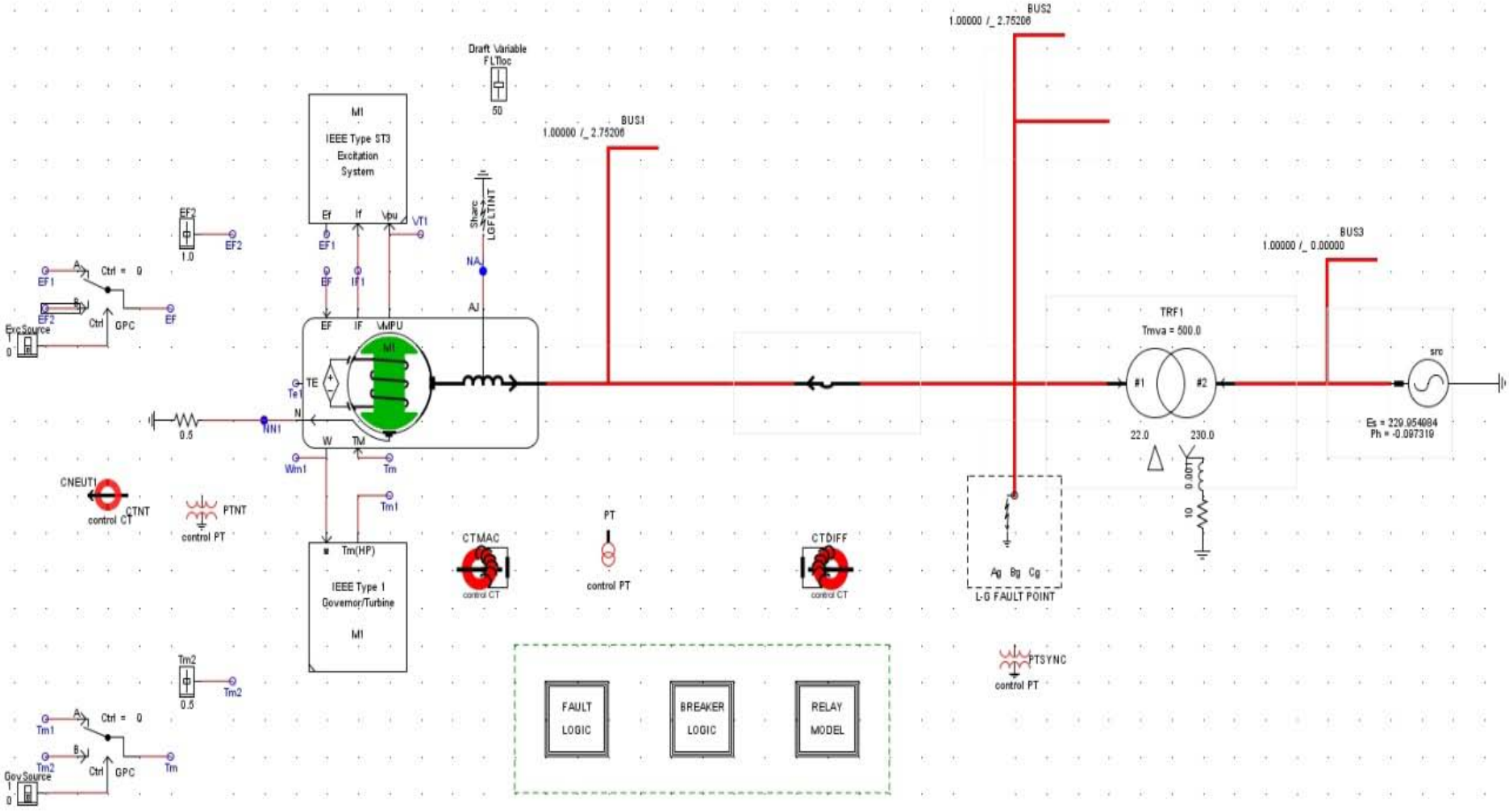
- Few examples – Steady state functional tests
  - each specified product feature with specification
  - compatibility tests among system revisions, as well as other product devices
  - Processing performance/stress tests
  - destructive system testing
  - communication protocol conformance
  - cyber security compliance (simulated cyber attacks)
  - product configuration tool testing
  - normal run time for longer period (months) and after several times power-up the device

Certification/Functional Testing

Examples-Transient simulation testing

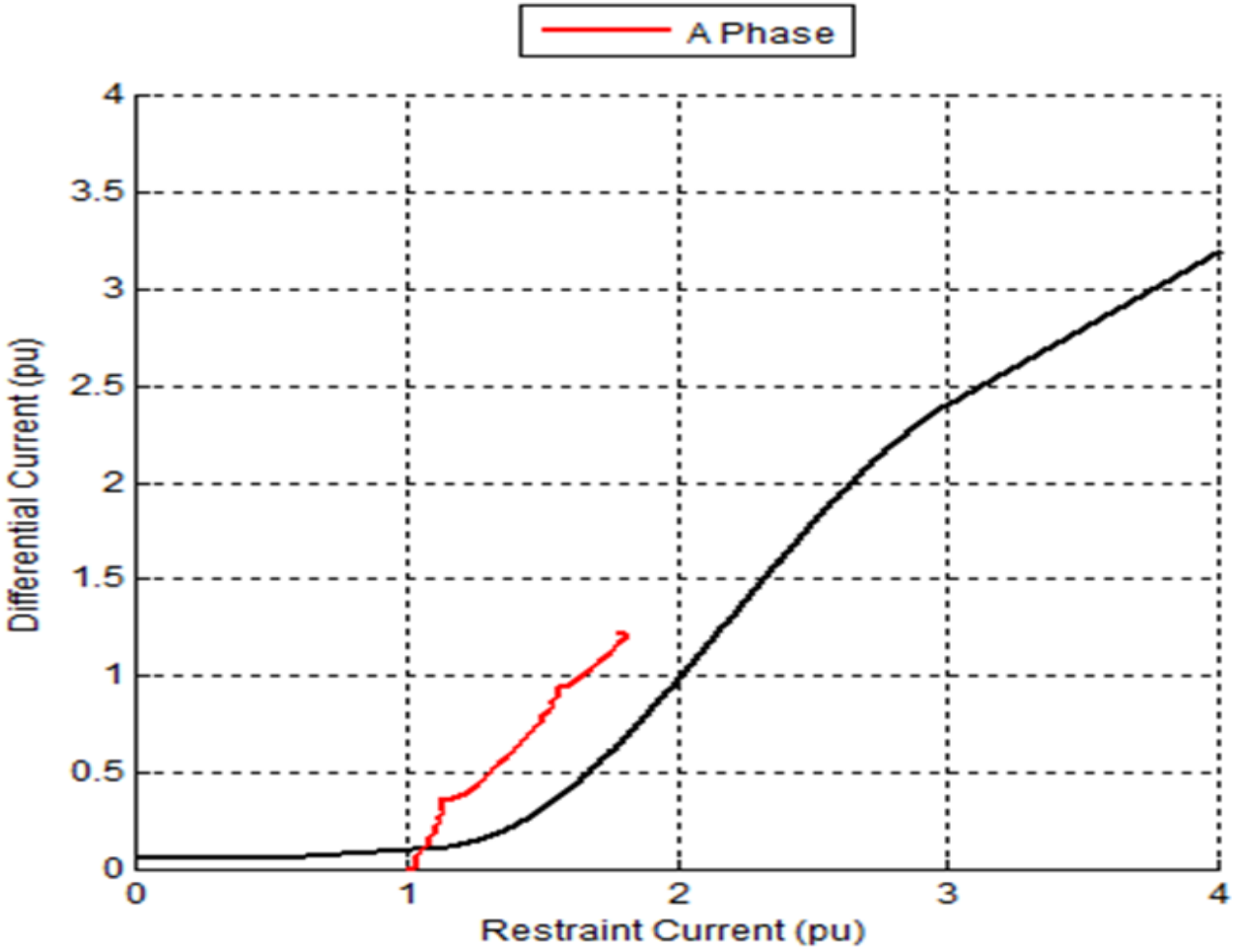
Certification/Functional Testing

500MVA, 22 kV synchronous generator model is connected to a power grid through a 22/230 kV GSU transformer



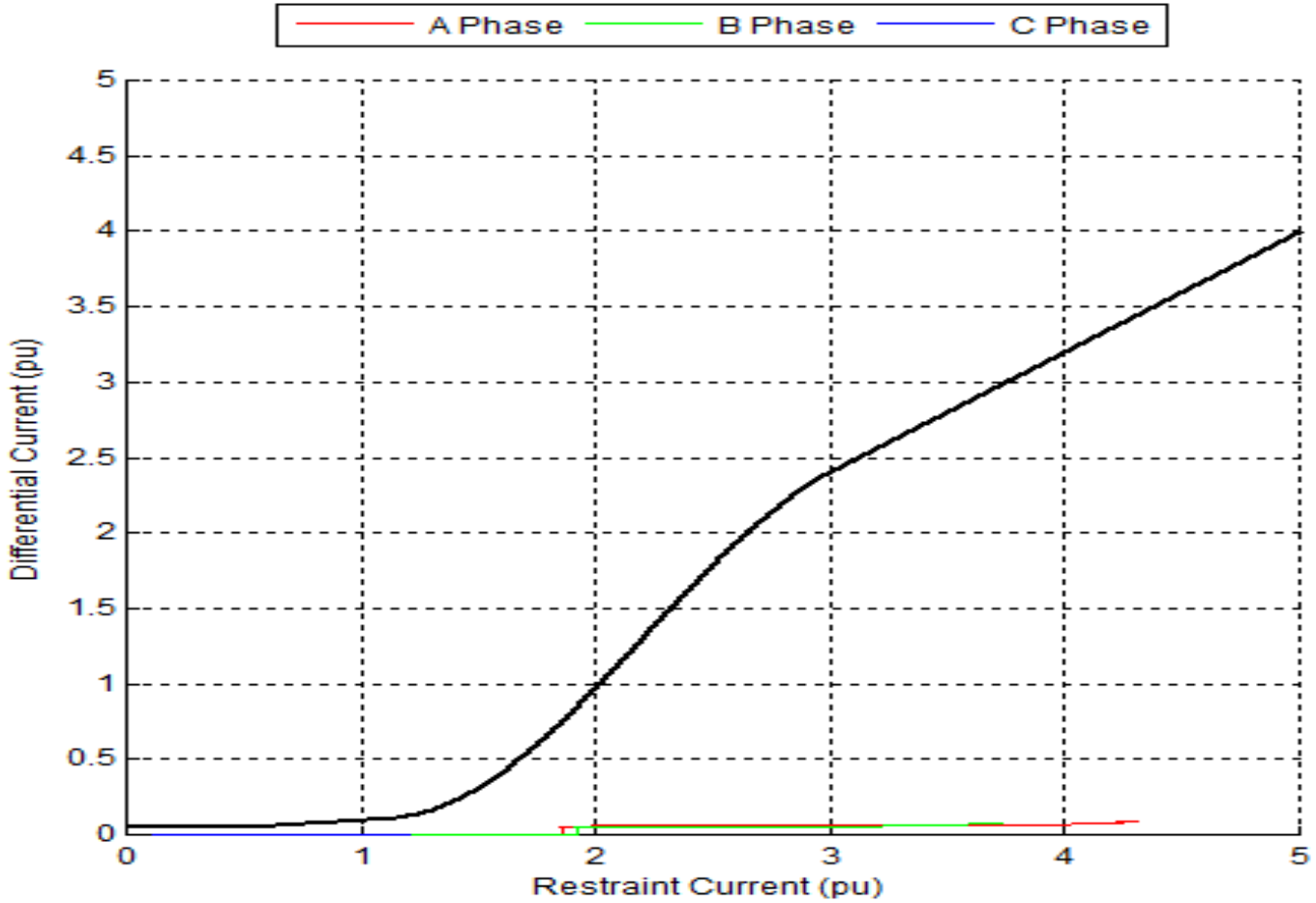
Certification/Functional Testing

Examples-Differential element (87S)



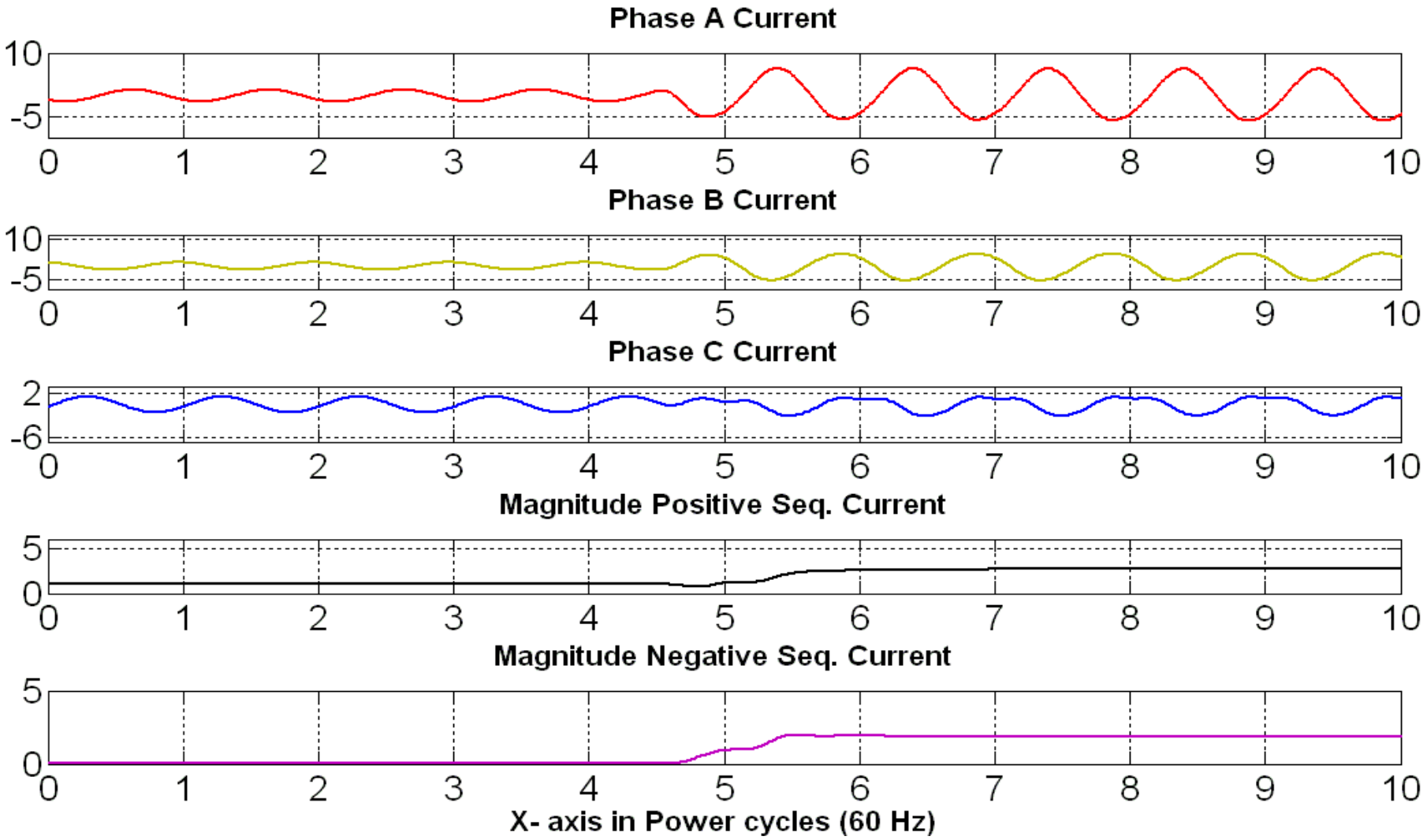
Certification/Functional Testing

Examples-Inter-turn fault (46)



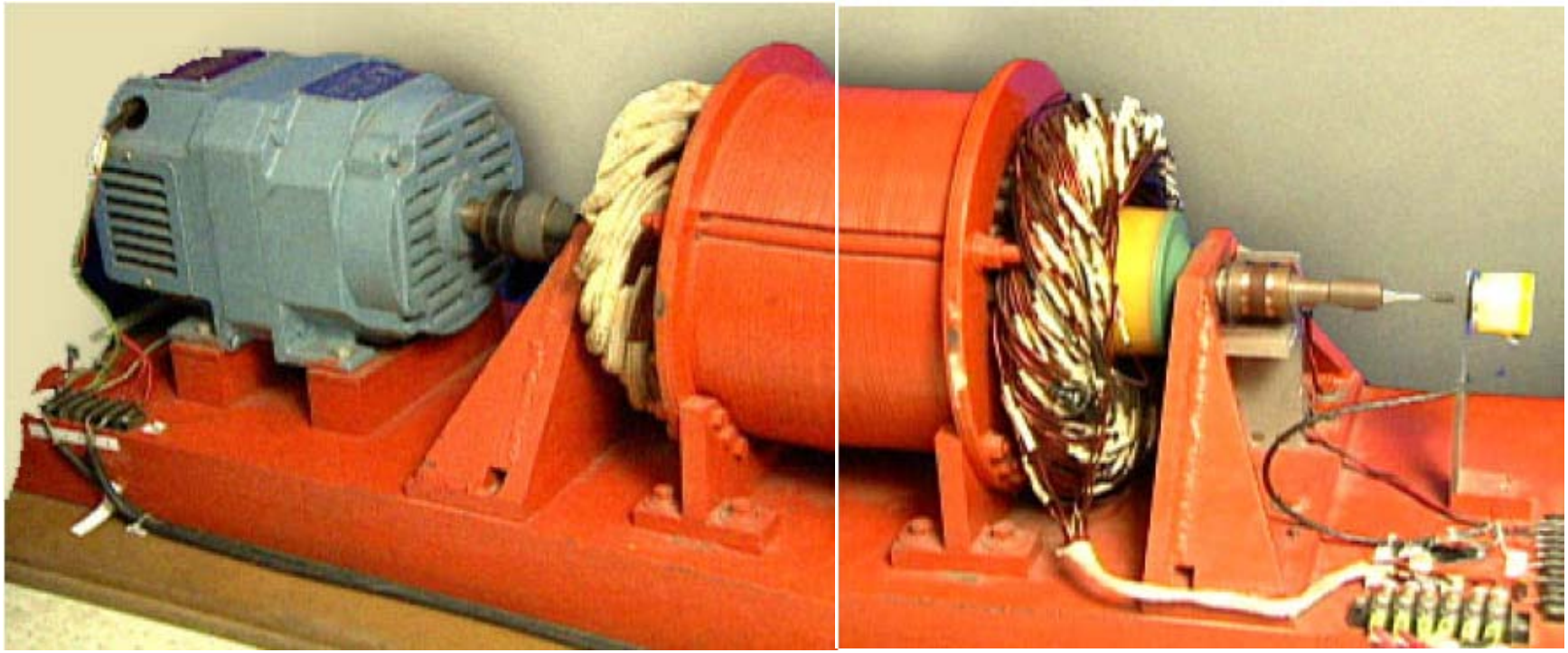
Certification/Functional Testing

- Examples-Inter-turn fault (46)



Certification/Functional Testing

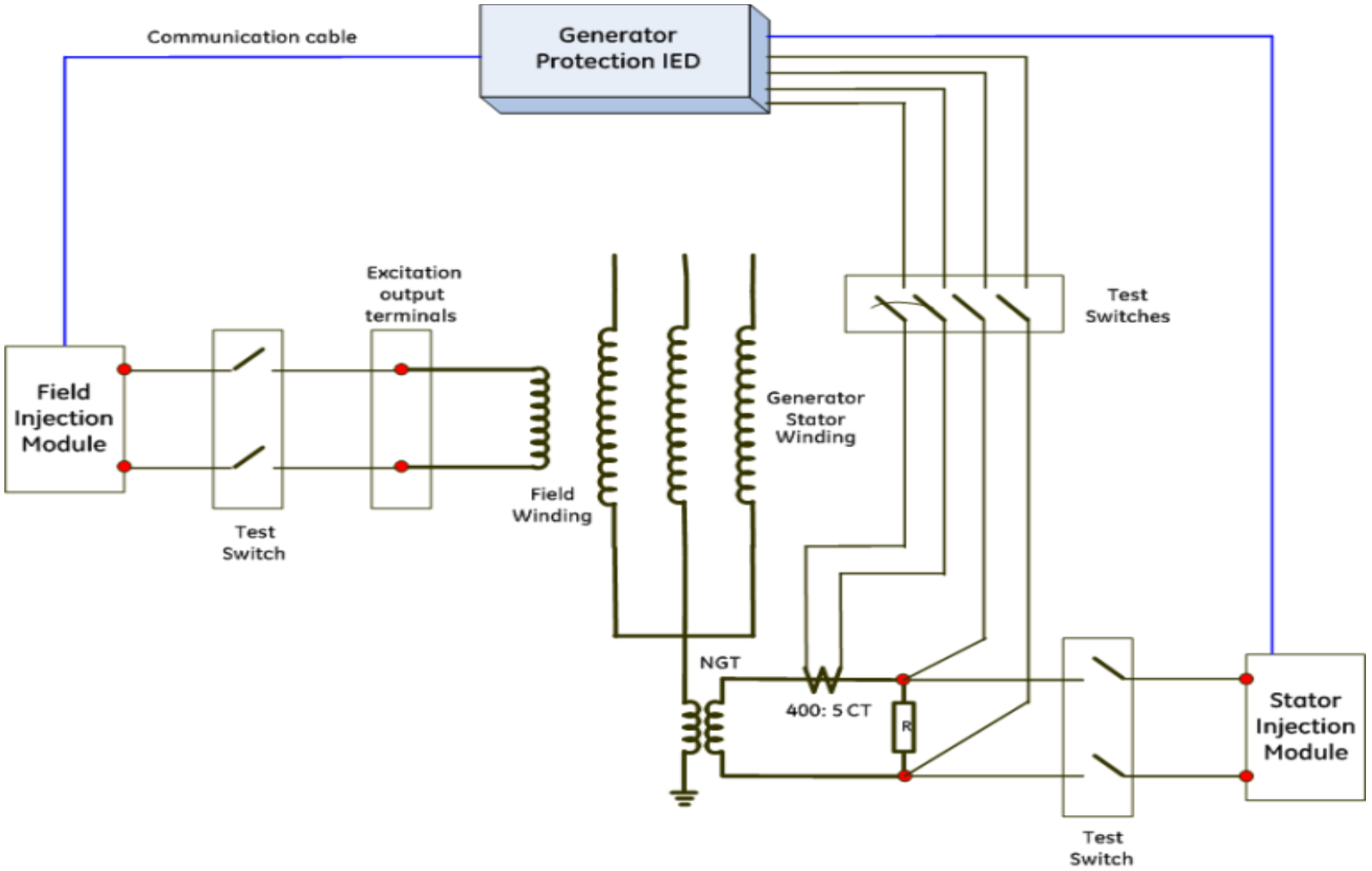
Testing using Analog Model Generator



"Dynamic testing of generator protection using a model generator platform," by D. Finney, M. Adamiak, B. Kasztenny, in 56th Georgia Tech Protective Relaying Conference, May 2002.

Certification/Functional Testing

- Pilot Installation & Testing - Example of Injection based stator/rotor ground protection at 35 MVA, 13.8kV natural gas fired generator



Application Testing

- Performed by power utility alone or sometime in collaboration with manufacturers
  - System parameter specific application tests
  - Product pre-qualification tests

- Functional versus Application Testing
  - Objective versus Subjective testing

Commissioning Testing

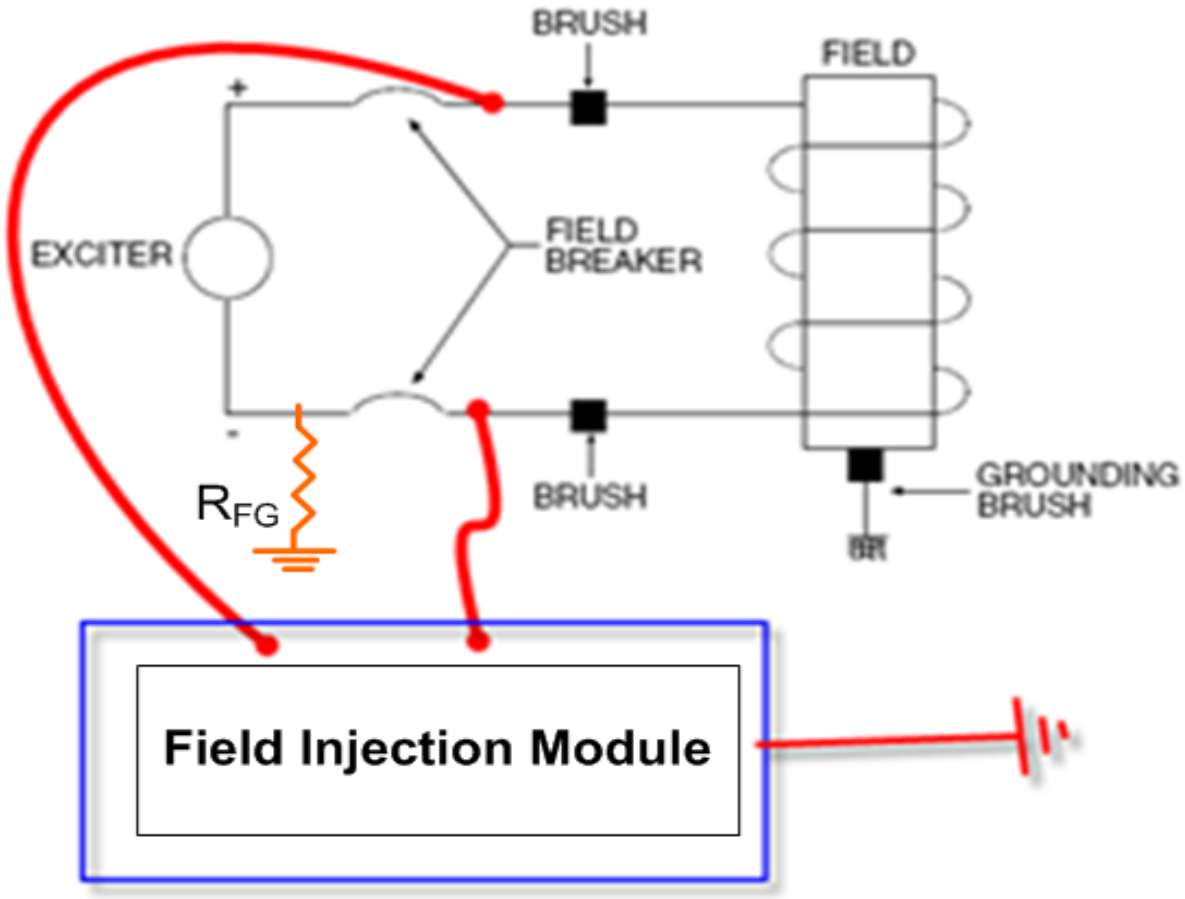
- Performed by Power Generation Utility
- Objectives
  - Check if received protection systems is intact after shipping
  - Verify the installation and proper wiring/connections
  - Confirm protection functions selection in multifunctional devices, setting and their setting groups
  - Check interconnection with existing system devices/equipment at the site

Commissioning Testing

- Considerations
  - Visual-verification of wiring/circuit
  - Secondary injection testing
    - including IED settings and setting groups
  - Primary injection testing
  - Logic scheme testing
    - including SIPS and WASA
  - Trip circuit testing
  - Monitoring & metering on first time running

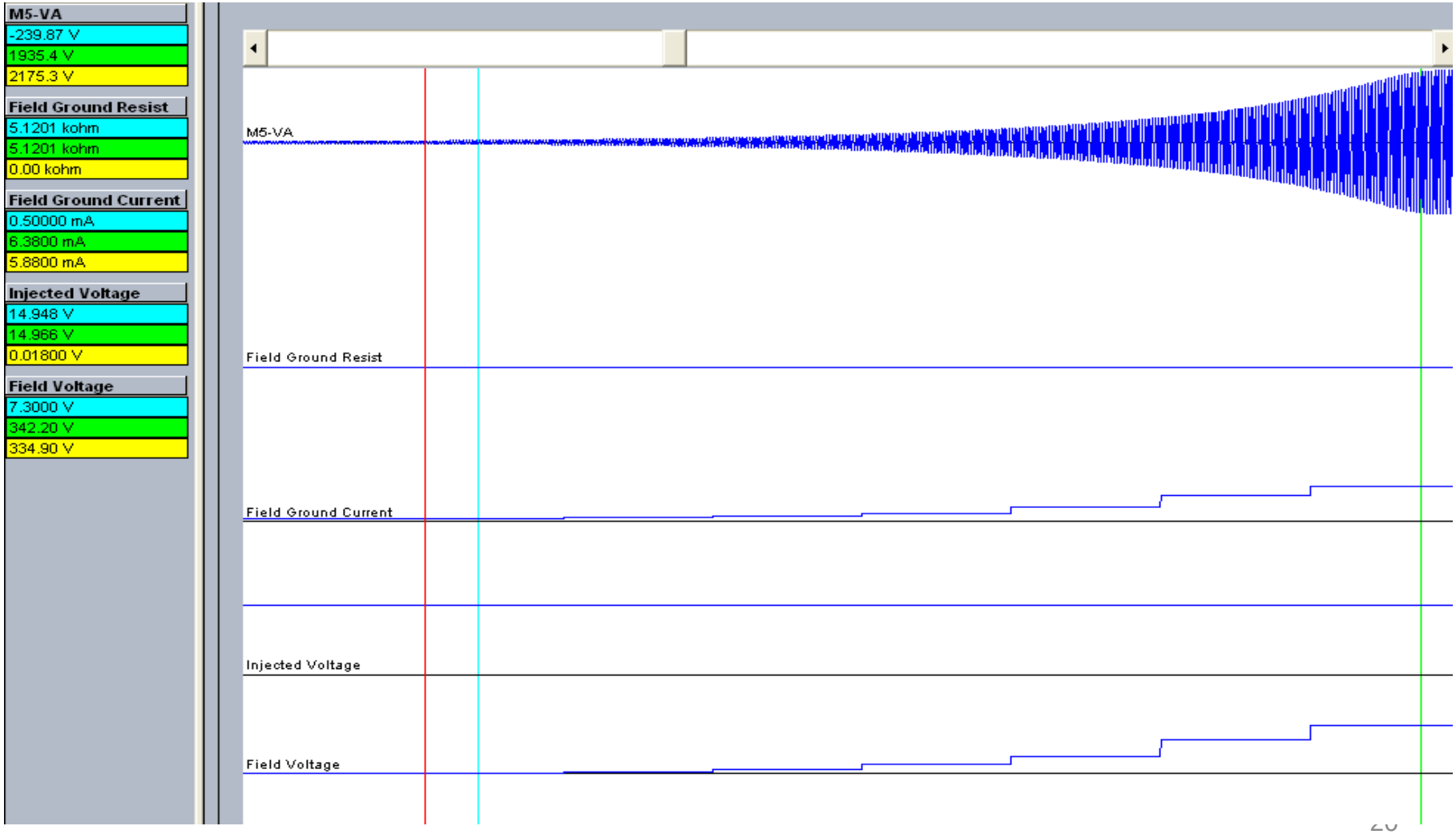
Commissioning Testing

- Field example - Rotor ground protection 125 MW Hydro Generator



Commissioning Testing

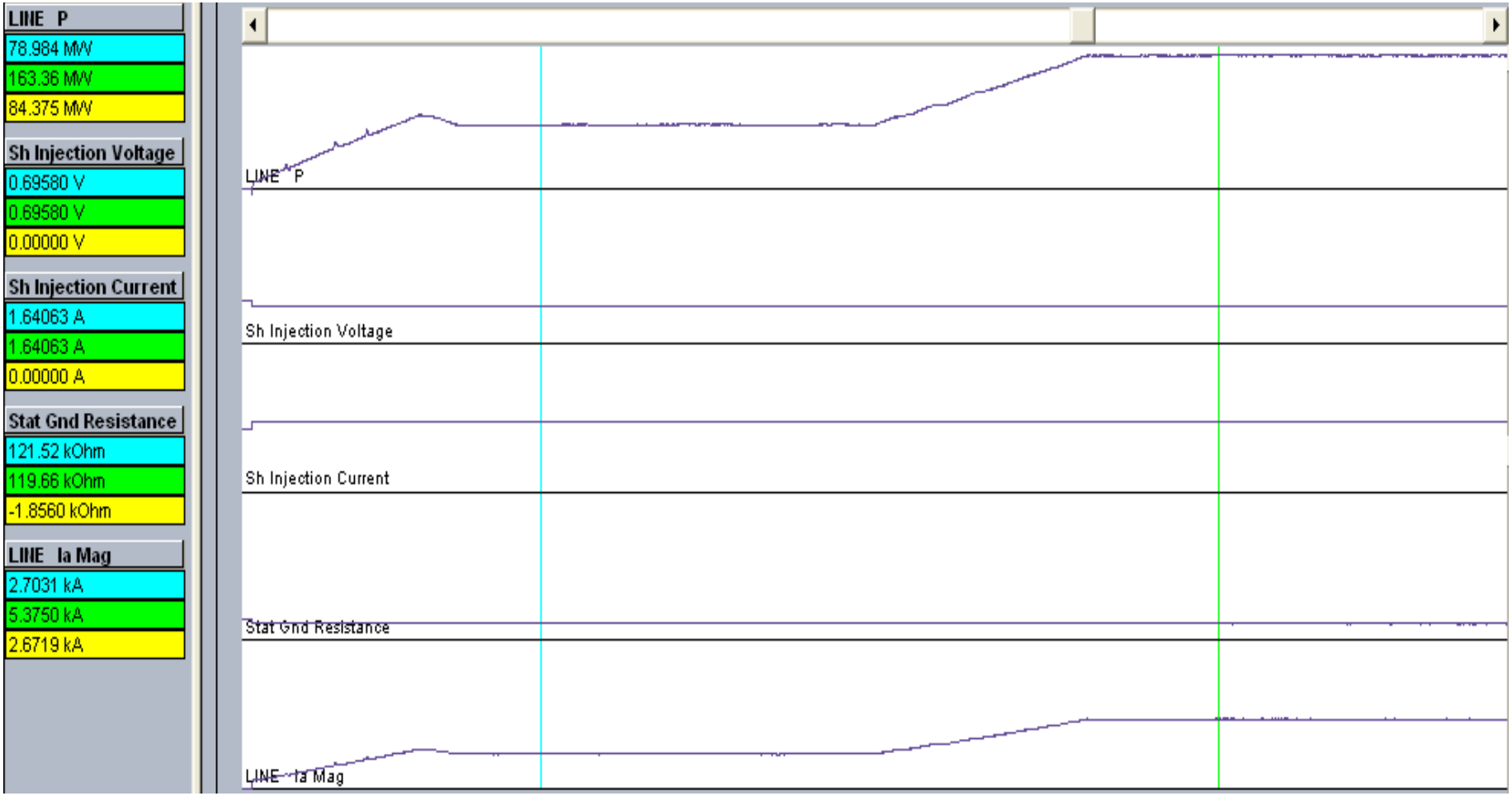
- Field example- Rotor ground protection



Commissioning Testing

- Field example- Stator ground protection

  (224MVA 18 kV generator)



Periodic Maintenance

- Objectives
  - validate the generator protection system is working as expected
  - detect if there is any failed components in generator protection system
  - Calibration is not required for digital protection devices, however, Targets/flags from self-check feature can be verified

Periodic Maintenance

- Regulatory Requirements
  - May mandate for an effective maintenance program
  - Example, NERC-PRC 005 requirements
- Periodic Monitoring
  - even while IED is ONLINE
  - Visual-verification using diagnosis/troubleshooting tools from generator protection IED

Periodic Maintenance

- Period/interval for maintenance
  - Time-based maintenance interval
    - Optimum interval can be derived from reliability analysis
  - Performance-based maintenance interval
  - Cost-based maintenance interval
  - Condition-based maintenance interval
- Co-ordinated with scheduled generator shutdown

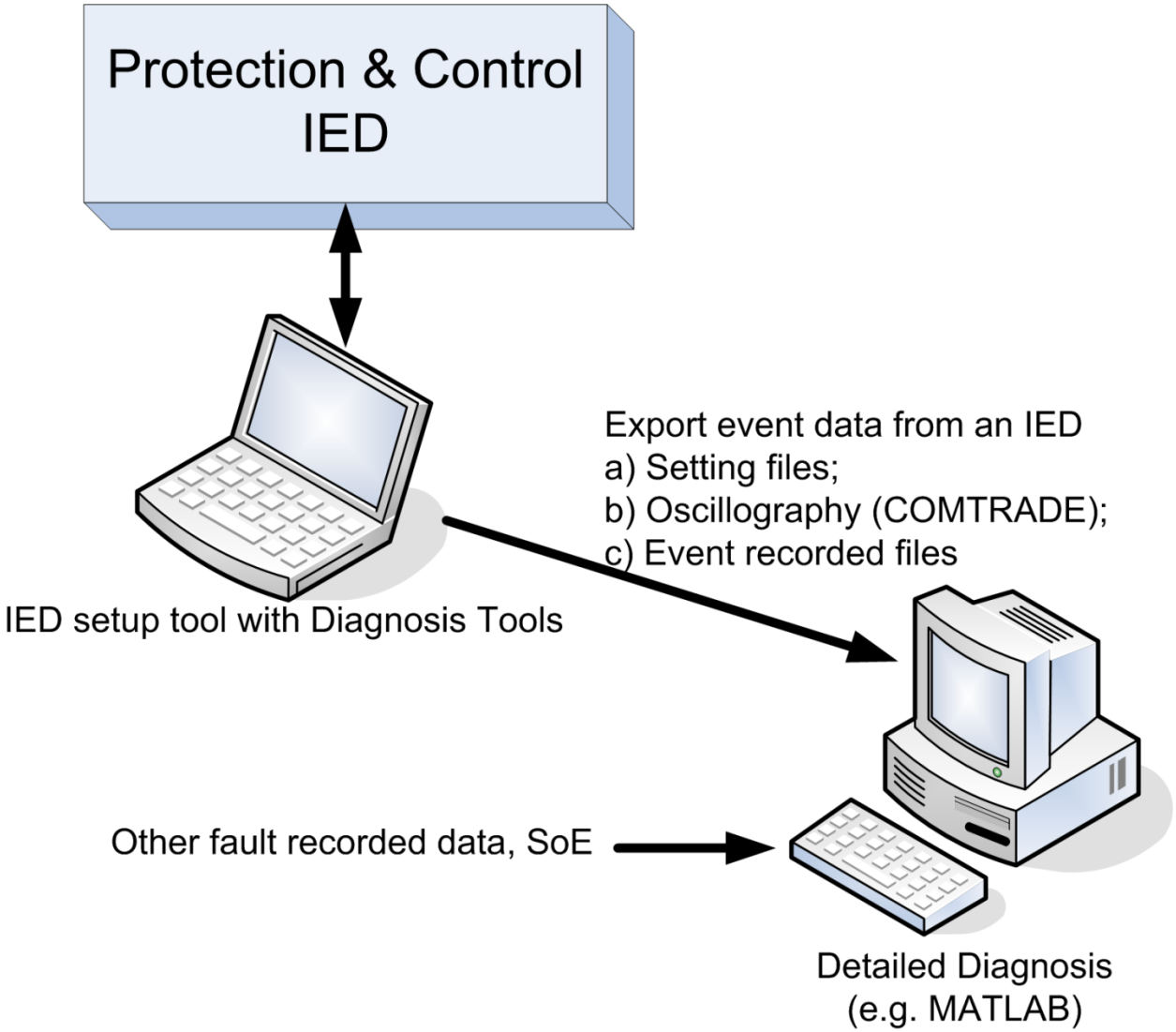
Troubleshooting

- Objectives
  - Check unexpected behavior of the protection system
    - Detail analysis of expected operation
    - Collect all possible data and status after any system event
  - Derive performance parameters of protection
    - Security (Does not operated when not required)
    - Dependability (Operated when required)
- Report improvements and learning from the event
    - Prevent repetition in the future

Troubleshooting

- Troubleshooting using Diagnosis Tools of Multifunctional IEDs
  1. Event recorder for SoE (Sequence of Events)
  2. Oscillography: High-speed event capture
  3. Data logger: continuous monitoring
  4. Vector diagram representation
  5. User-programmable fault reports

Troubleshooting



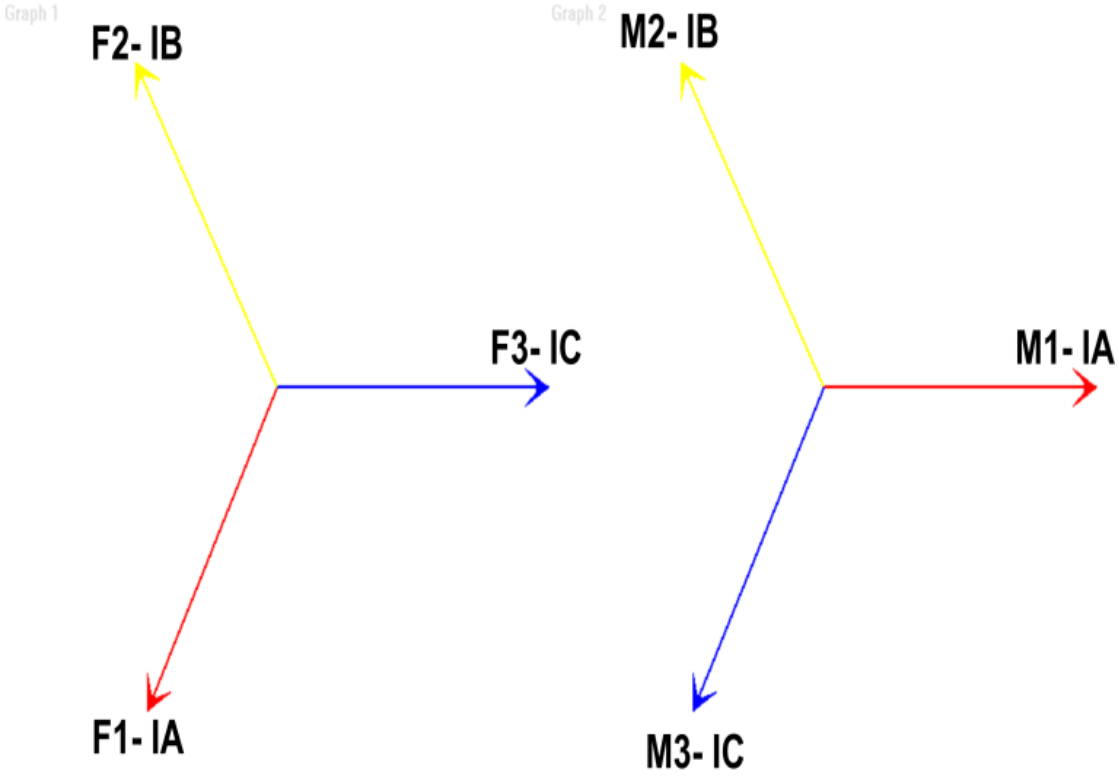
Troubleshooting

- Field example – 8 MW, 4.16kV diesel standby generator unit at nuclear power plant

Event recorder

Event Number	Date/Time	
10	Dec 03 2009 10:22:28.426431	94-R11TRIP Off
9	Dec 03 2009 10:22:27.424963	STATOR DIFF DPO C
8	Dec 03 2009 10:22:27.424963	STATOR DIFF DPO A
7	Dec 03 2009 10:22:27.335471	94-R11TRIP On
6	Dec 03 2009 10:22:27.335471	OSCILLOGRAPHY TRIG'D
5	Dec 03 2009 10:22:27.335471	STATOR DIFF OP C
4	Dec 03 2009 10:22:27.335471	STATOR DIFF PKP C
3	Dec 03 2009 10:22:27.335471	STATOR DIFF OP A
2	Dec 03 2009 10:22:27.335471	STATOR DIFF PKP A
1	Dec 02 2009 15:05:38.694117	EVENTS CLEARED

Vector diagram representation



Thank You

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