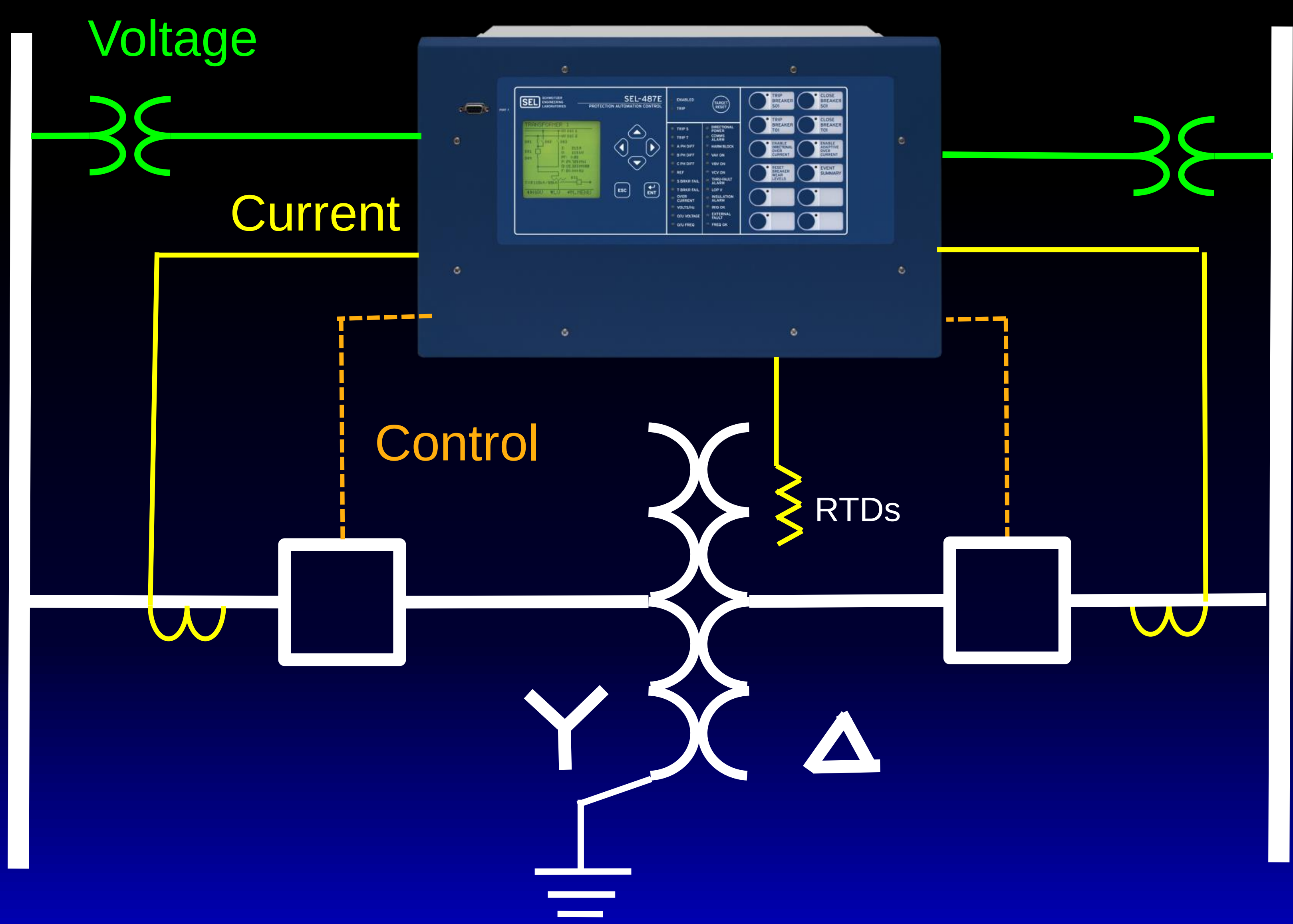
Detecting and Managing Geomagnetically Induced Currents With Relays

Making Electric Power Safer, More Reliable, and More Economical®

Transformer Relay Connections



Transformer Protective Relay

- Measures differential current
- Harmonic blocking or restraint for security
- Volts/Hz (overexcitation) protection
- RTD inputs monitor top oil, “hot spot,” tank temperatures

Transformer Protection Functions

- Trip for internal faults
- Restrain for external faults
- Alarm and trip for overload
- Monitor thru-faults for cumulative mechanical damage
- Trip if overexcited or overheated
- …and, trip for excessive GIC, if desired

Detecting GIC Events

- Transformer relays measure fundamental, harmonics, and RMS quantities.
- Relays can also produce GIC alarms.
- Information is continuously available to show harmonics, and is available to SCADA.
- It’s possible to incorporate data from USGS magnetometers and NOAA solar activity reports, to change settings and in logic.

Transformer Metering Report

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=>>MET DIF <Enter>

Relay 1                                      Date: 04/12/2008  Time: 06:06:31.366
Station A                                    Serial Number: 2008030645


Operate Currents (per unit)        Restraint Currents (per unit)
IOPA       IOPB       IOPC         IRTA       IRTB       IRTC
 1.32       1.32       1.32         3.91       3.91       3.91

2nd Harmonic Currents (percentage of IOPA, IOPB, IOPC)
IOPAF2     IOPBF2     IOPCF2
 0.08       0.09       0.01

4th Harmonic Currents (percentage of IOPA, IOPB, IOPC)
IOPAF4     IOPBF4     IOPCF4
 0.05       0.10       0.06

5th Harmonic Currents (percentage of IOPA, IOPB, IOPC)
IOPAF5     IOPBF5     IOPCF5
 0.06       0.11       0.04

Enabled Windings:  S, T
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Transformer Volts/Hertz Report

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=>>MET SEC T <Enter>

Relay 1                                     Date: 04/20/2008  Time: 06:47:23.494
Station A                                   Serial Number: 2008030645



  Secondary Meter: Winding T

               Phase Currents                     Sequence Currents
           IA         IB         IC          I1         3I2        3I0
MAG(A,sec)    4.37       4.37       4.36        4.37       0.01       0.01
ANG(deg)    164.23      44.32     -75.60      164.32     118.41      63.71

            Phase Voltages - PT V                 Sequence Voltages
           VA         VB         VC          V1         3V2        3V0
MAG(V,sec) 62.922     62.937     62.924      62.928      0.324      0.353
ANG(deg)    -0.13    -120.07     120.19        0.00     -40.24    -138.95

Line-to-Line Voltage
                  PT - V                               PT - Z
           VAB        VBC        VCA         VAB        VBC        VCA
Mag(V,sec) 108.962    108.850    109.171     109.014    108.946    109.126
ANG(deg)    29.89     -89.94     150.03       29.95     -89.95     150.03

FREQ (Hz) 59.991          Frequency Tracking = Y
VDC (V)   115.81          V/Hz       99.56%
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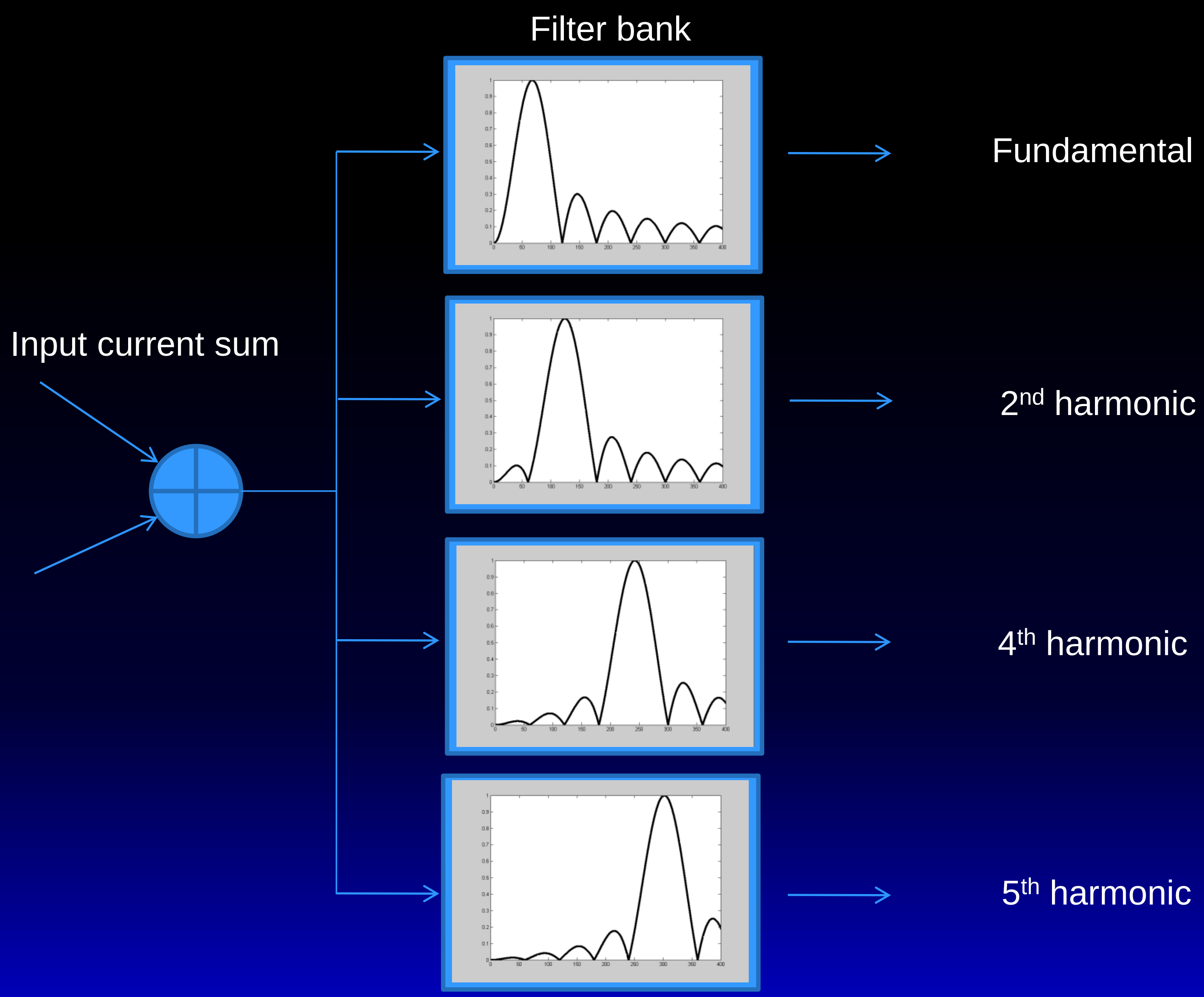
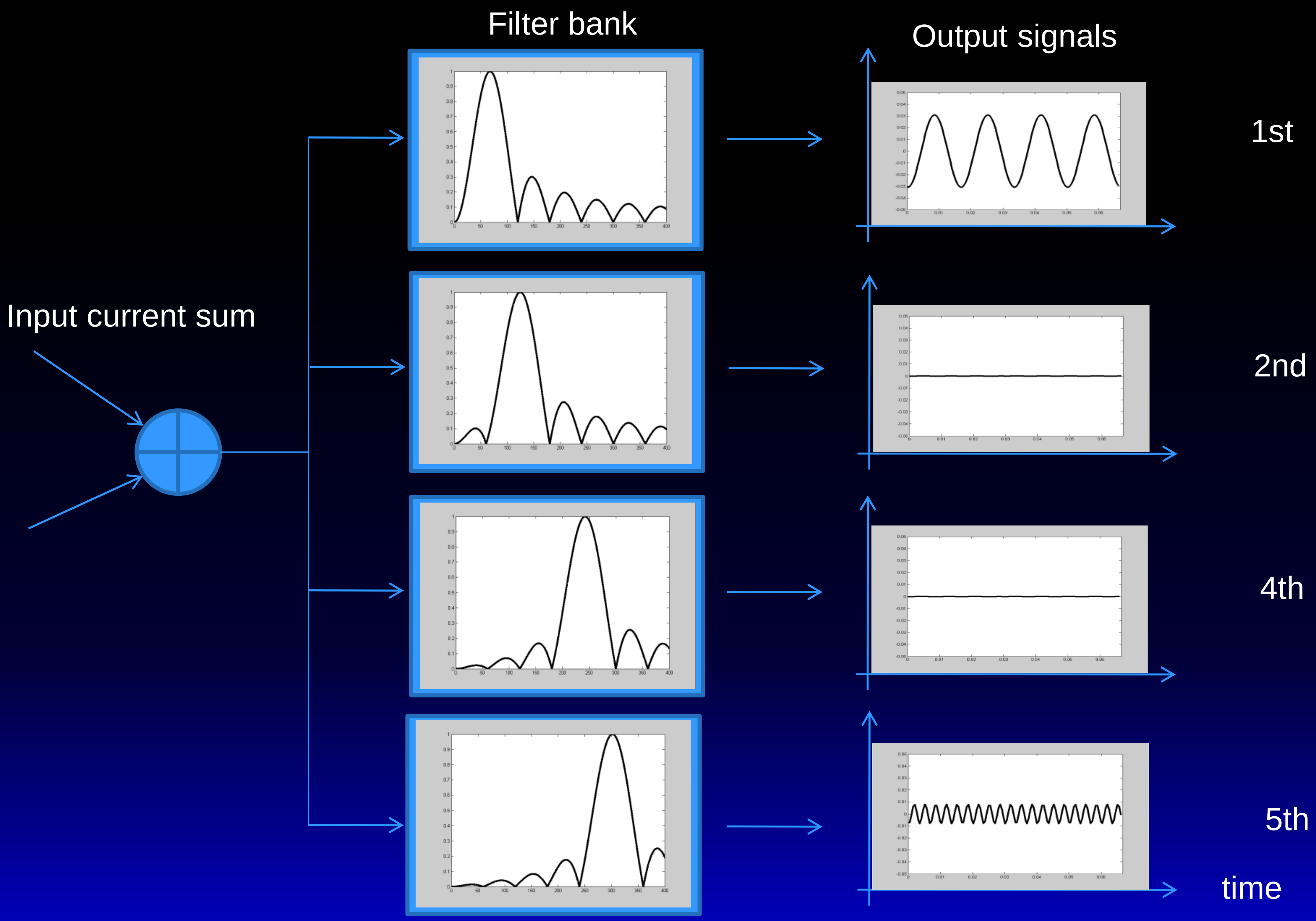
Transformer Relay Detection Features

- Harmonic Measurements – 2^{nd}, 4^{th}, and 5^{th}
- Volts/Hz
- Programmable Logic w/ Analog Quantities
- SCADA interfaces and alarms

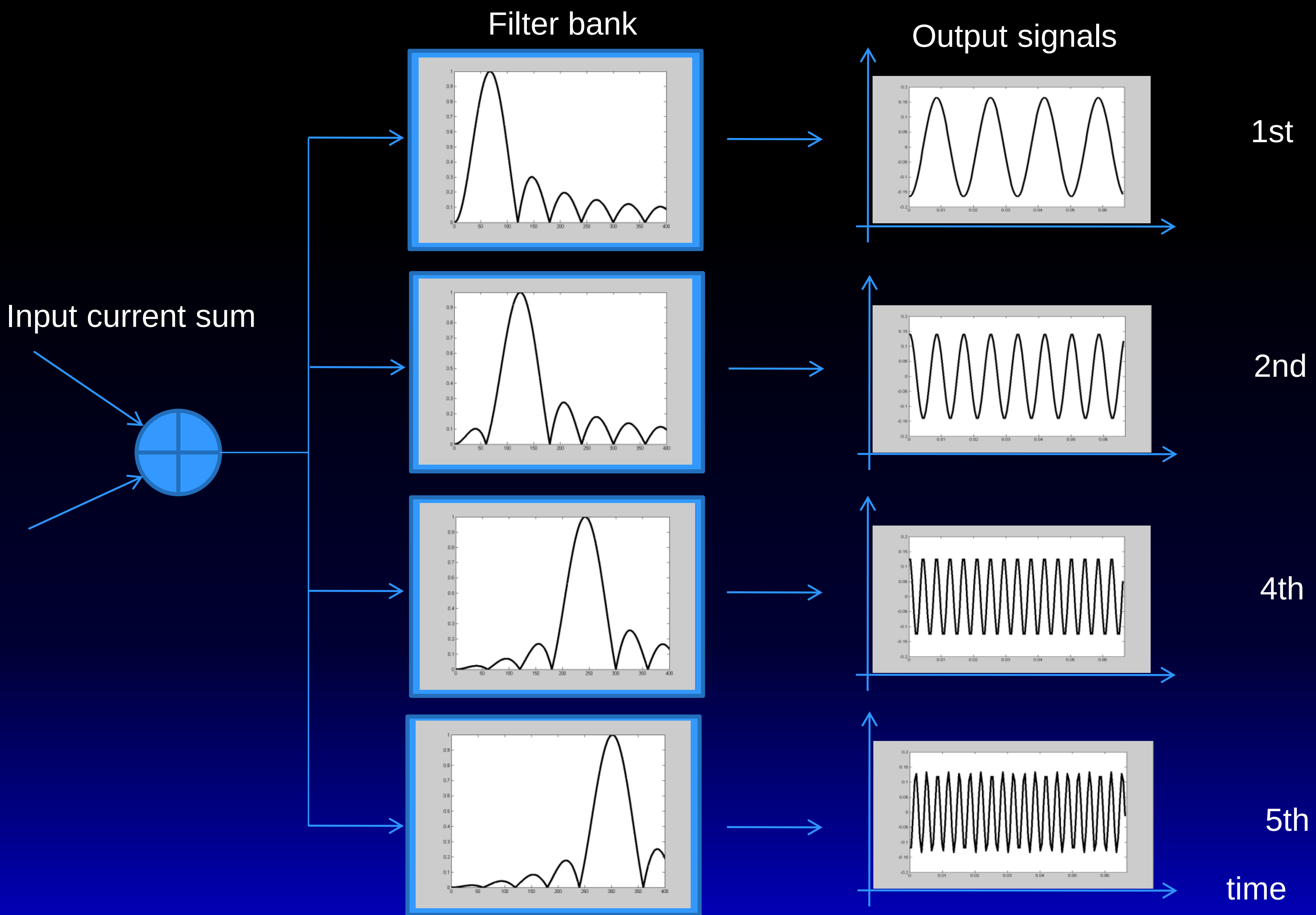
Relay Filter Bank



Normal Harmonic Content



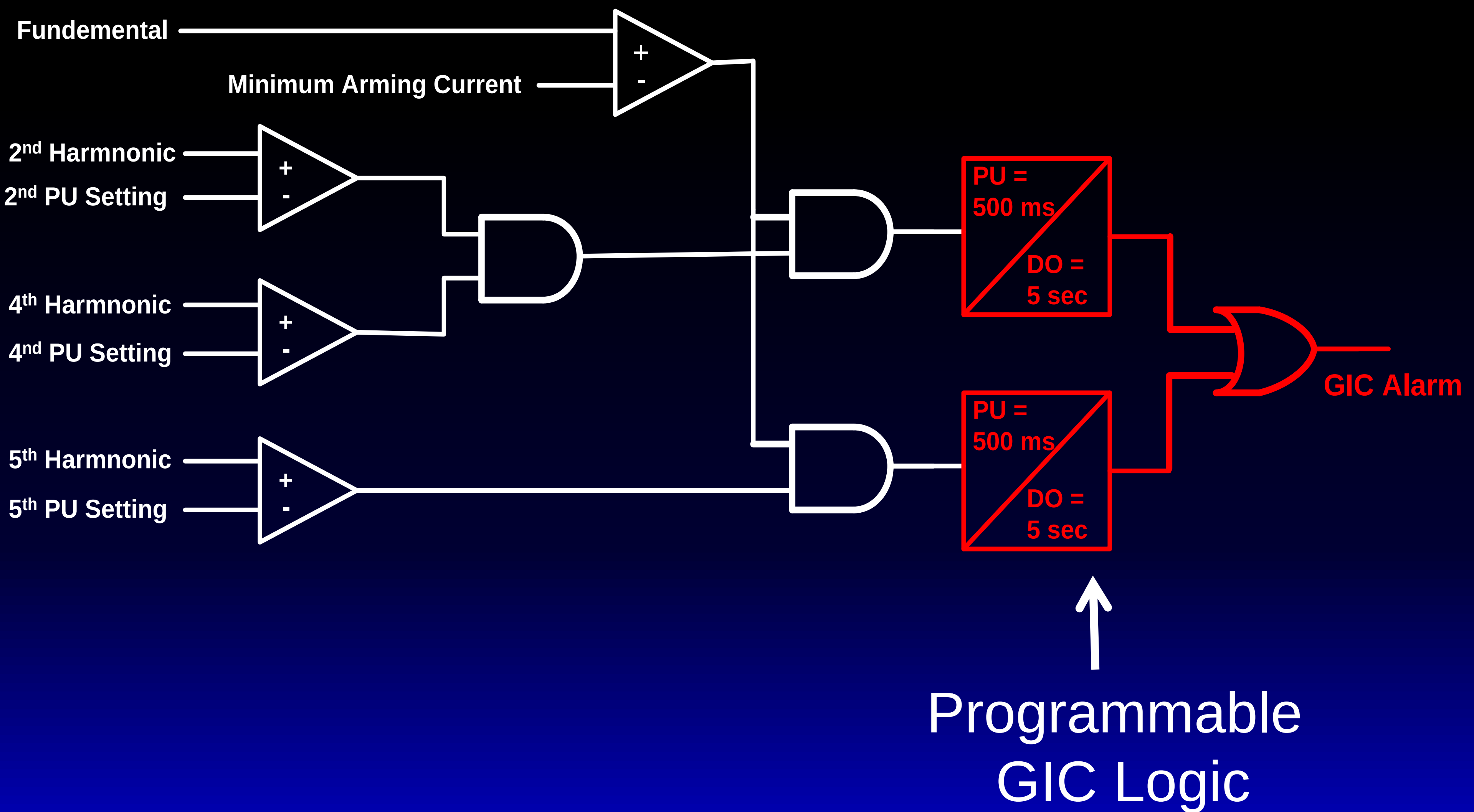
GIC Harmonic Content



Detecting and Tripping for GIC

- Relay calculates vector sum of currents, using instantaneous values.
- Presence of operating current, rich in harmonics, for prolonged time, on all three phases indicates GIC.
- A time-overcurrent element, driven by Irms, and controlled by 2^{nd} harmonic, with a long time curve could be used.

Programmable GIC Logic Alarms



What Do You Trip?

- Internal faults: trip *all* sources to transformer.
- GIC: trip all *GIC* sources to transformer: e.g., don’t trip series-compensated lines.

Avoid GIC Blocking the Detection of Internal Faults

- Disable harmonic blocking, but use harmonic restraint.
- The large level of fault currents will exceed harmonic restraint.
- Harmonic restraint is still necessary for inrush protection.
- Relays also provide unrestrained differential elements, operating on the fundamental, which are not affected by harmonics.

Avoiding False Trips Due to GIC

- Differential elements are not a problem, when properly set.
- Residual overcurrent elements which measure fundamental will not respond.
- GIC element may be enabled only when second harmonic is present, when warnings are received, or for high transformer temperatures.

Send Harmonic Alarms to Operators

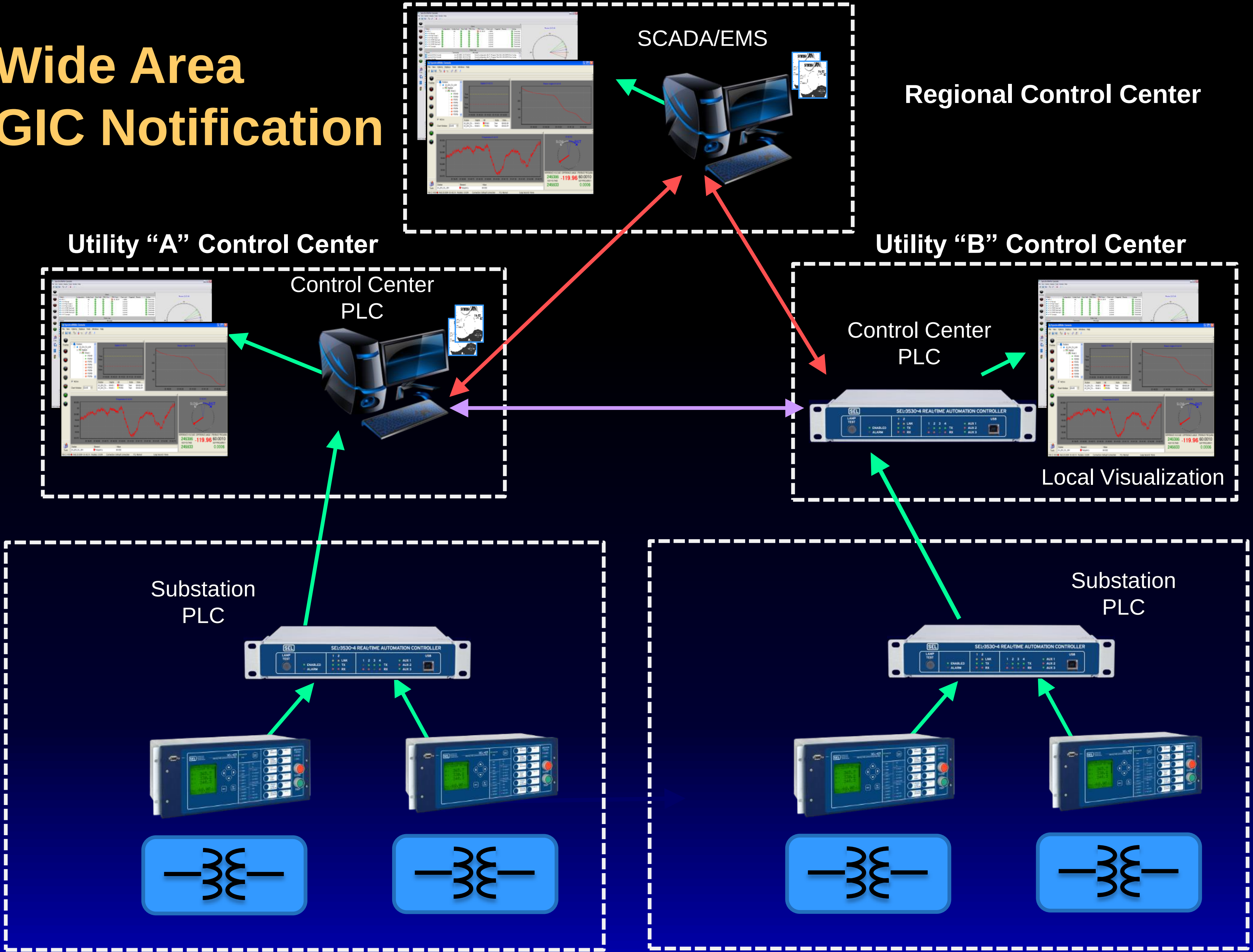
Relays have many capabilities to signal operators:

- Contact outputs wired to PLCs/RTUs
- Communication – DNP3, IEC-61850, FM

Substation Computation Devices

- Substation computing devices can automate GIC mitigation strategies
  - Collect and process harmonic information
  - Send information alarms to SCADA
  - Using solar weather info, arm GIC mitigation strategy
- GIC substation strategy includes
  - Insert series compensation capacitors
  - Turn on transformer fans to pre-cool transformer

Wide Area GIC Notification



Other IEDs Can Be Used for GIC Detection

Power Quality Meters

Line Current Differential Relays

GIC Effects on Other Protection

- Distance relays filter out everything except the fundamental: little or no effect.
- Overcurrent relays filter out everything except for the fundamental: little or no effect.
- Line-current differential relays are based on Kirchoff’s Current Law, using instantaneous quantities, and no new path is created by GIC.

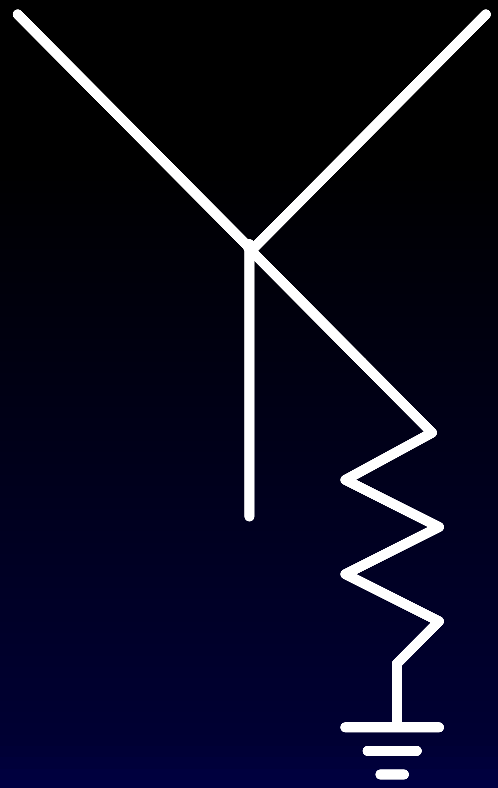
GIC Effects on Instrument Transformers

- CCVT's block DC: no effect.
- Wound VT's: not frequently used on major transmission.
- Transmission CT: roughly 0.2% per amp DC, so 100 amps "uses up" around 20% of CT. Normal operation of CT needs only 5% of the core. Plenty left; relays are designed to manage some CT saturation anyway, due to much larger effects of "DC offset," the decaying exponential current.

GIC Mitigation Options

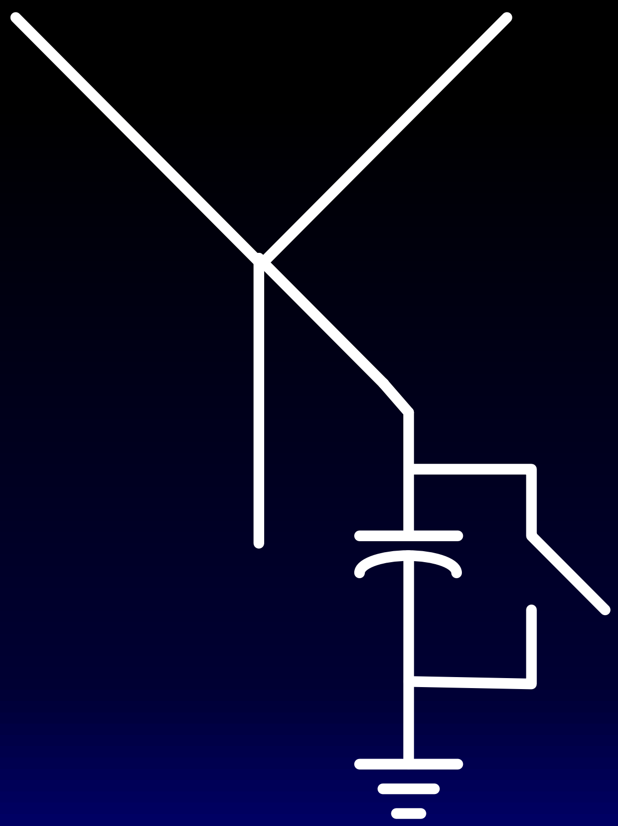
- Use redundancy of power system to lower power level through redistribution.
- Series capacitors can be used to block GIC.
- Monitor power system, via harmonics, and isolate areas with high GIC.
- Trip lines contributing to GIC, try a reclose after a few minutes.
- Don’t trip series-compensated ones.

GIC Fix to Avoid – R in the Neutral



- Does not fully eliminate GIC
- Protection schemes impacted
- Overvoltage on unfaulted phases could cause flashovers

GIC Fix to Avoid – Caps in the Neutral



- Zero Sequence impedance impacts
- Requires fast bypass during fault condition
- Ferro-resonance concerns

Summary

- Your relays can detect and alarm for GIC.
- Get to know GICs on your system by monitoring info in the relays and meters.
- Transformers protection can detect GIC: temperature sensors, differential protection, excessive harmonics for extend period of time.
- Ensure 2nd harmonic doesn't block your protection.
- Trip lines that contribute to GIC; restore them after a few minutes.