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PRACTICAL ASPECTS OF DESIGNING SAFE AND COMPACT MV SWITCHGEAR USING "AIR CORE CT", "RESISTOR VOLTAGE DIVIDER VT" AND MODERN INTELLIGENT MICROPROCESSOR RELAYS

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Abstract

- Traditionally, medium voltage switchgear with rating 5kV-38kV uses iron cores, current transformers, and voltage transformers.
- With the new approach, iron core current transformers are replaced with air-core-current-transformers (aCT), popularly known as Rogowski Coil, and voltage transformers are replaced with capacitive or resistive voltage divider (VD).
- IEC 61850 GOOSE and Sample Value communication technology further improves the efficiency and reliability of protection and control schemes
- This paper discusses practical aspects and advantages of the new technologies and design considerations of an MV switchgear line-up, emphasizing conformance testing.

Introduction

- The latest generation of compact, medium voltage switchgear, also called “digital switchgear,” has several distinguishable differences from the traditional switchgear designs. The footprint is smaller, equipment safer, components are universal, and all modifications for different applications are more software-related than hardware.

Background

- The low-energy-analog (LEA) output signal device such as the Rogowski coil is built in 1912, and LEA voltage dividers are even older than that.
- The wide commercial use of LEA devices in switchgear industry started in the late 1990s, after introducing a set of communication rules wrapped under the IEC 61850 standard.

Air-core Current Transformer (aCT)

- The air-core transformers are used of measuring AC current.
- They offers numerous benefits: size, exceptional dynamic range, LEA output, high accuracy, safety.
- Some drawbacks: need of integrator circuit, inability to drive multiple devices, (all drawbacks are resolved with IEC 61850 and new relays)

Traditional current transformers

Air-core current Transformers aCT

Voltage Dividers (VD)

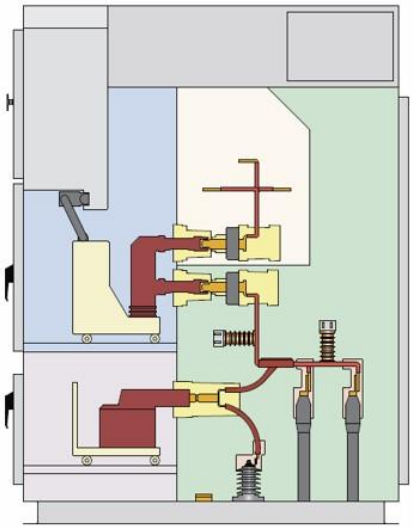
- The VD is a passive device that reduces primary voltage level using resistive and capacitive elements connected as a voltage divider.
- Some features are: a light-weight construction, zero footprint, safe, high linearity, wide dynamic range, wide frequency band, LEA output, maintenance free.
- Some drawbacks: inability to drive multiple devices, only Y-connection scheme (all drawbacks are resolved with IEC 61850 and new relays)

Traditional voltage transformers

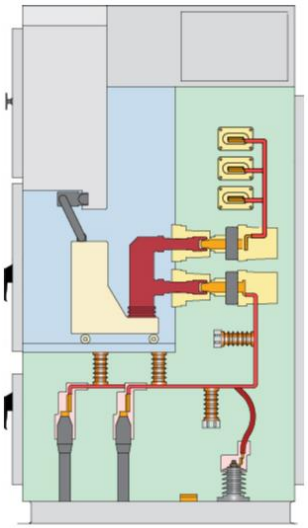
Voltage dividers

Switchgear Design Approach

- Some design features of digital switchgear : smaller footprint, safer, easier manufacturing, less wiring, better conformance testing, clean and minimalistic design, reduced cost of ownership.



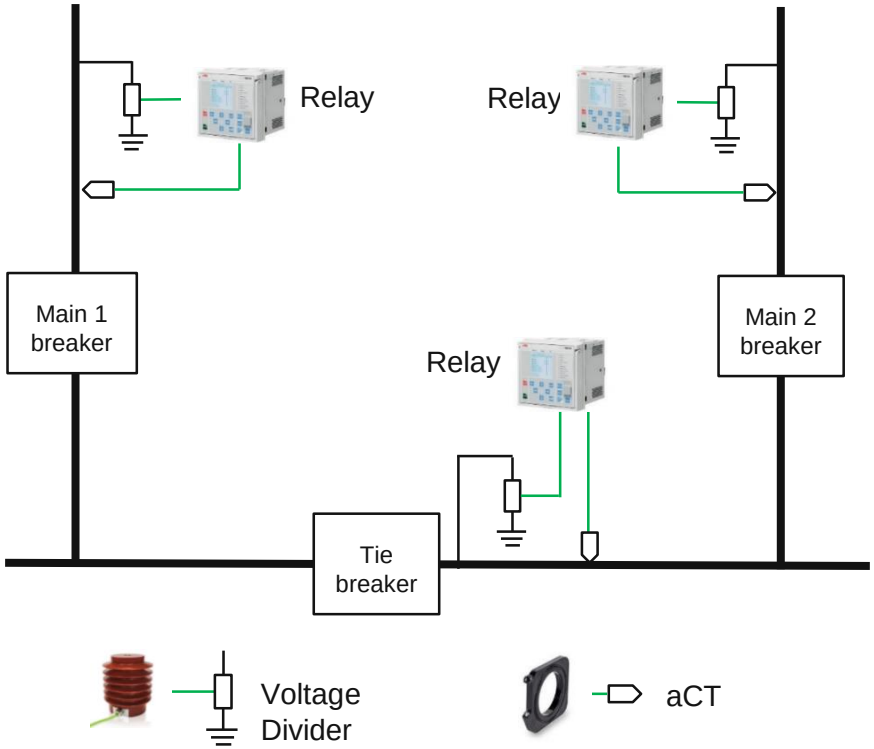
Traditional switchgear



Digital switchgear

Digital Main-Tie-Main Demo Unit

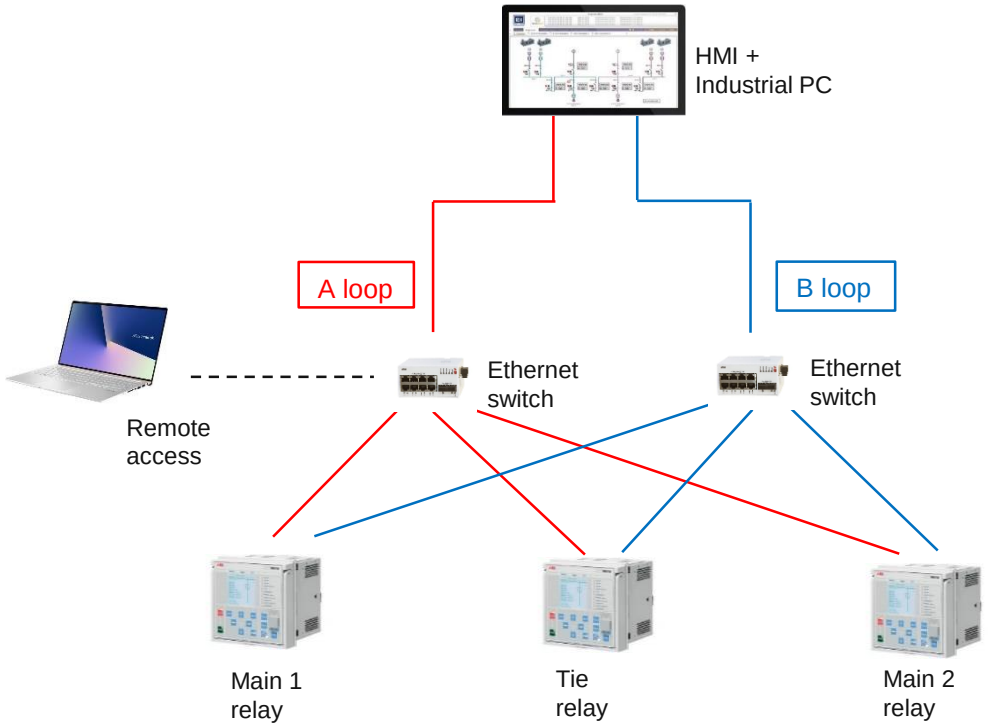
- To demonstrate easy conformance testing and the communication ability over IEC 61850, the authors created the medium voltage demo unit with Main-Tie-Main scheme.



Main-Tie-Main scheme

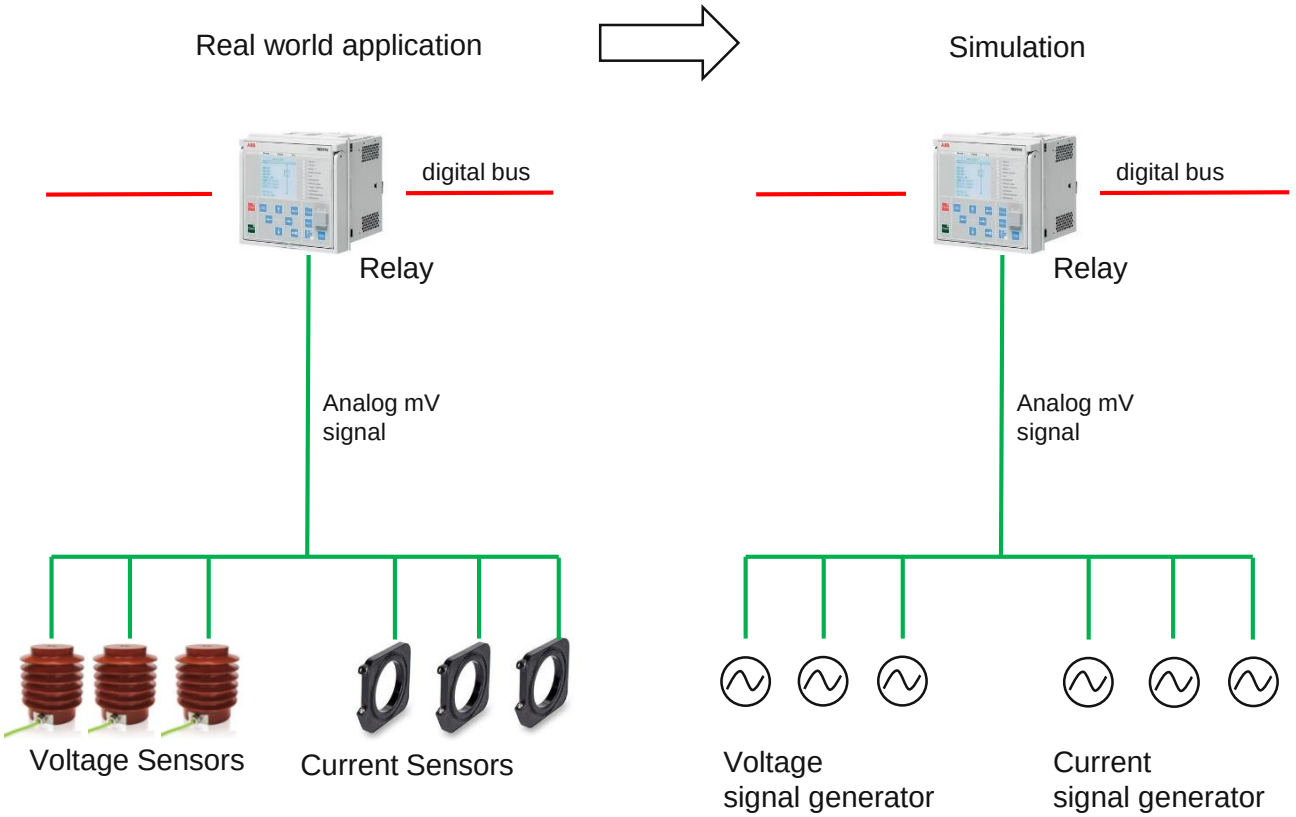
Parallel Redundancy Protocol (PRP)

- The protective relays are star-connected into the industrial network switches and optical cables connected to the industrial PC, which is embedded under HMI. Two redundant loops A, and B, are created to simulate a loss of one loop.



Signal Generator

- The circuit's primary side had a projected rating of 12kV and 1,000A, and on the secondary side, the signal level was in mV (1.2V and 0.74V)
- Signal generation was accomplished by FPGA hardware and software



Challenge of creating mV signal generator

The Custom Relay Adaptor Board

- Simulating signal from aCT and VD through custom relay adaptor board, attached to the FPGA hardware.

VD and aCT

Simulated aCT and VD signals coming from the custom relay adaptor board

Completed Demo Unit

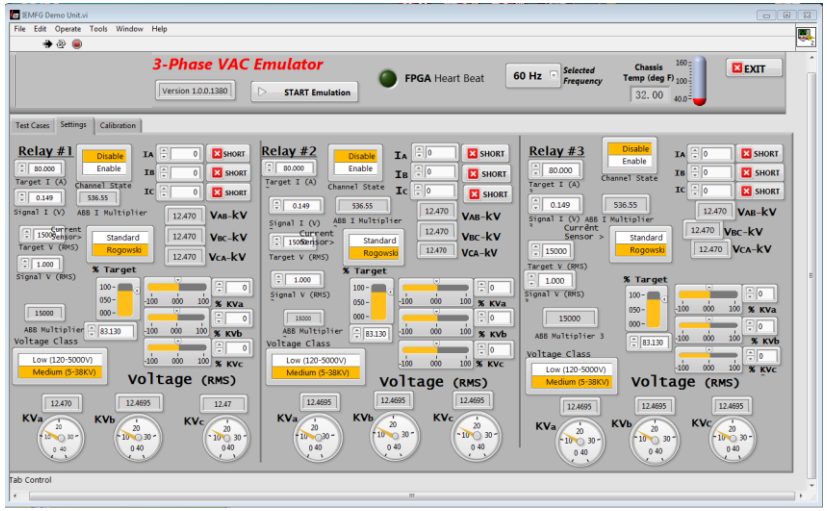
- The Demo Unit assembled in the aluminum section and placed on wheel for easy demonstration purpose.

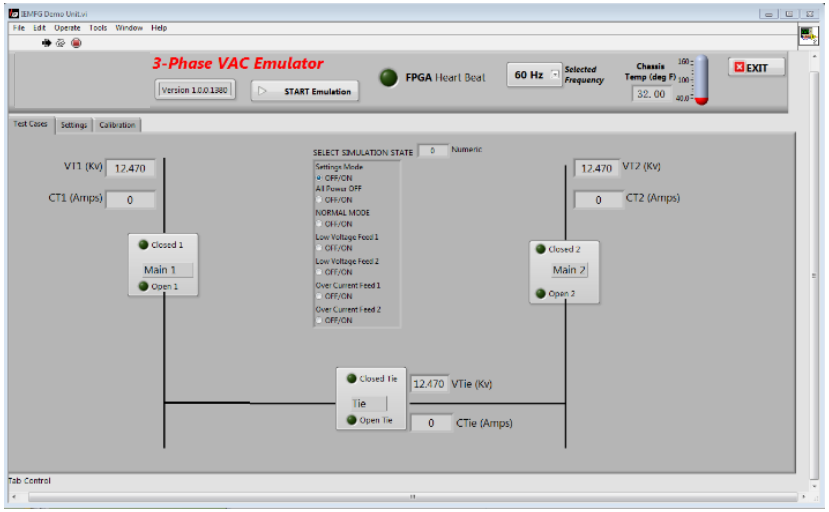
Demo unit, front view

Demo unit, back view

Operating the Demo Unit

- The GUI program operated on a laptop and provided the operator with a menu of both nominal and a six fault conditions.
- The fault conditions involved both single and multiple phase under-volt, 3-phase overcurrent, and single-phase short-circuit.
- Upon selection of desirable scenario, the relays on the Demo Unit operated according to the logic.





Conclusion

- Using air-core current transformers and voltage dividers with IEC 61850 offers great switchgear design features such as footprint reduction, manufacturing cost reduction, less wiring, increased measurement accuracy, safety, and modularity.
- The authors found that low energy analog signals coming from the aCT and VD could be easily and cost effective simulated using NI hardware with user-programmable FPGA
- Such approach greatly help conformance testing, short trouble shooting, and change the way how traditional protective automation assembly process works.
- Also, this approach offers scalability for desirable amount of relays, a feature not practical in traditional switchgears.