Study Committee B5

PROTECTION AND AUTOMATION

Paper 10802

Experiences with the deployment of centralized protection systems using virtual protection relays for substations with large power electronic converters

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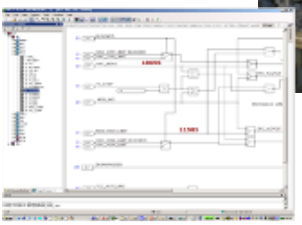
THE EARLY YEARS

- Emergency Power Controller in Skagerrak 1&2
  - A very early Special Protection Scheme (SPS)
    - 100 % microcontroller based
    - measured the frequencies in Danish and Norwegian networks
    - supported the network with power
      - up to 1000 MW/sec
    - placed in commercial operation in 1976
    - worked for 31 years without any maloperations (replaced in 2007)

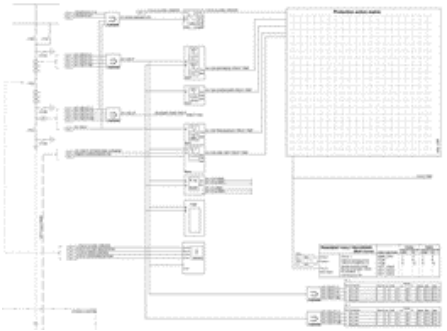
PROGRAMMING METHOD

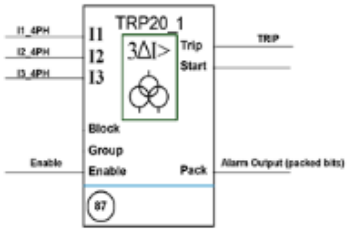
- Very early adaption of function block programming
  - since 1979
  - automatic code generation since 1987 (HiDraw)
    - automatic page references for navigation
    - all signal values readable on-line

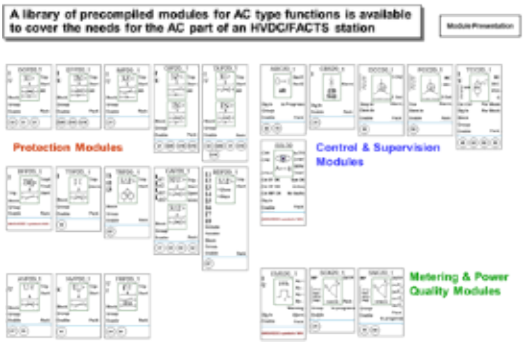


CENTRALIZED AC PROTECTIONS FOR SUBSTATIONS

- a comprehensive selection of precompiled AC protection modules were developed
  - executing in redundant industrial PCs
  - used commercially for 4 distribution substations in Sweden
    - these have now been in operation for around 20 years
- The solution with virtual centralized protections may have been too early for the market in 2002
- But these modules were continued to be successfully used in the AC substations connected to HVDC and Statcoms
  - Now over 100 AC susbstations (130-500 kV) are protected using these virtual protections in countries like Sweden, Poland, Italy, Greece, Denmark, Norway, Germany, Brazil, US, Canada, South Africa, India, China, Congo and Australia







- The most common protections are
  - transformer differential protections
  - transformer restricted earth fault protections
  - overcurrent protections
  - busbar differential protections
  - breaker failure protections
  - over-voltage protections
  - ac filter protections
    - over current
    - capacitor failure detection
    - component overload

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TESTING

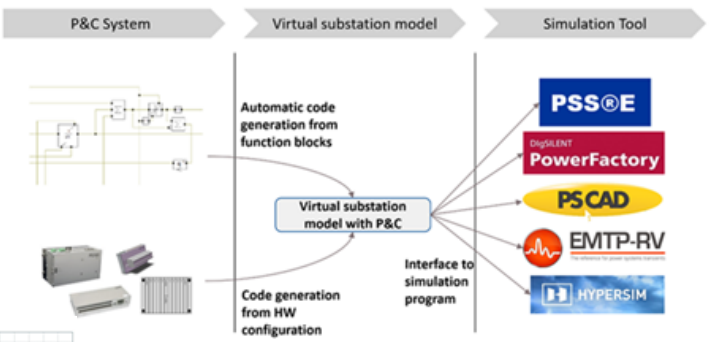
- using virtual protections opens exiting new advanced possibilities to fully test and adjust the protections before installation/commissioning

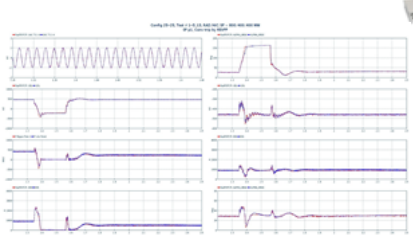
Factory testing

- For HVDC/Statcom testing the standard method is to connect the protection and control systems to a real time digital simulator (RTDS)
- This, of course, works equally well for the AC protections and is the most common method for testing centralized virtual AC protections up to this point

Virtual Protection Testing

- For the latest deliveries a very exiting and convienient testing method has been developed
- As the exact precompiled code for the protections are available, it can be executed in a different virtual environment (server or cloud based servers)
  - maintaining the exact sampling rates and execution order
  - the setup of the I/O system is used to generate models of the HW including measurement resolution and communication delays etc.
- The field measurements are provided by an appropriate simulation program like PSCAD, EMTP or Hypersim. Also detailed CT and PT models in the simulation model should be used
- This provides the ideal test-bench for protections that can easily be kept for future adjustments or extension of the switchyard or network





Comparison of a staged DC line fault in the field and in a simulation

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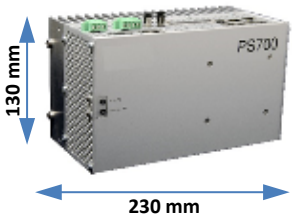
IMPROVEMENTS DURING THE LAST 15 YEARS

- much more powerful computers
  - multicore
  - lower power less heat, means no fans needed
  - smaller
- distributed I/O units (merging units) for voltage, current measurement or breaker control

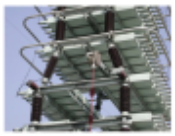


powerful compact server type computer
DIN rail mounted, fan less
12 core XEON processors, applications separated using real time hypervisor

Distributed I/O unit
hardened so it can be placed in junction boxes or on transformers or breakers

LOOKING INTO THE FUTURE

- Effects of a wider use of process-busses
  - the ultimate vision for the use of process busses would be that all main circuit apparatuses can be delivered complete and pretested with two redundant process bus connections
    - transformers
    - Breakers
    - disconnectors
    - CTs (optical or conventional)
    - PTs
  - This will
    - eliminate all copper signal cables
      - 16 tons for a small project
    - minimize wiring termination work
    - eliminate "green lining"
    - improve safety, no current circuits



- New sensor technologies
  - The wider application of process busses also make it easy to digitize the measurement signal at the source
    - optical current sensors are already widely used in HVDC stations and has been used for the centralized virtual protections
    - also, CTS and CVTS can be simplified if the digitalization is performed within the devices

CONCLUSIONS

- This paper presents 20 years of very successfully usage of centralized virtual protection solutions for AC substations connected to large HVDC/Statcom converters
- With all the savings and advantages possible, I'm convinced that virtual centralized protections in servers will become more and more accepted also in the more conventional AC substations