Grid Technologies Collaborative (GTC)
Interface & Communication Protocols

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Background

The Grid Technologies Collaborative (GTC) is an industry-university-government integrated research and development (R&D) group that advances the state-of-the-art in transmission and distribution (T&D) system level power electronics technologies. Participants in the collaborative include industry partners and researchers from the National Energy Technology Laboratory-Regional University Alliance (NETL-RUA). The five GTC university members, University of Pittsburgh, Carnegie Mellon University, Penn State University, Virginia Tech, and West Virginia University. The GTC executes a comprehensive program of fundamental research; technology development, simulation, testing, and commercialization; and professional training for the advanced grid technologies sector. The GTC focuses on advanced power grid technologies and power electronics systems and offers a range of technology R&D and training services for all sector participants, from equipment suppliers to system operators to electric utilities.

This R&D initiative focuses on modeling and simulation to develop validated steady-state and dynamic models of system interactions at the converter-grid interface. In addition, a model will be developed for the next-generation power converter, which will be established as a scalable bi-directional three-phase AC-DC interface for utility scale high-power applications at the (T&D) levels. Initial system applications for this advanced power electronics based converter topology will address T&D grid performance including advanced control methodology development, interface and communications protocols, and integration of various resource and load entities. It will also contribute to aspects of power system stability, security, and reliability.

The Next Generation Power Converter will serve as a key interface to power grid modernization and advancement, providing an efficient, bidirectional connection and control point. Initial application of the converter will be at the utility-scale distribution level with extension of control concepts and interfaces to the transmission system. The basic focus of the modeling efforts will be on, but not limited to, the following:

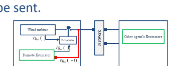
- Renewable energy integration
- Energy storage interconnection
- Various traditional and emerging AC and DC loads

Protocol/ Strategy

- Both a communication protocol and a communication strategy are described to specify **the "Power System Communication Interface (PSCI)"**
- Communication Protocol is defined by
  - Data Format => Data Modules
  - Rules for Connection Initiation and Termination
  - Error Dependency & Recovery
  - Authentication (outside the scope of this work)
  - Data Exchange Rules => Ack, No Ack
- Communication Strategy is defined by
  - Rules for data exchange: rate of sampling, topology of the network, etc.

Error-Dependency Policy/ Strategy

- Scheduling message generation only when the estimation error at remote agents is perceived to be high.
- "remote estimator" has been added to sender, replicating the estimator that is running at the receivers
- Estimator is fed with the same messages that are transmitted over the network
- The sender can at any time read the output of the "remote estimator" to know the estimation error (of its own power) at the remote agents.
- Estimation error is used in a message generation scheme to decide whether a new message should be sent.
- The accuracy of estimation is related to:



- the rate of messages
- how fast the Wind turbine power is changing.
- Faster change of Wind turbine power requires higher message rates for precise tracking of the turbine power.
- The error dependent policy has been shown to yield significant reduction in the required rate of message generation.

WVU Scope of work

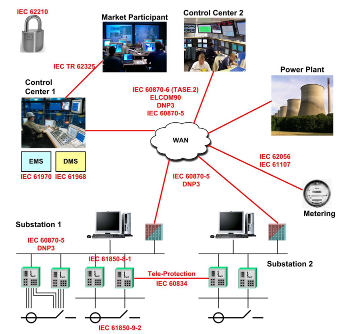
WVU Task Requirements

Interface & Communication Protocols. In close coordination with the GTC Team, this task will primarily focus on communication protocols and interface model development, using PSCAD and MATLAB, for selected equipment and network facilities and the distribution and transmission/distribution interface, including generation sources and power electronic converters at connection points. Specific requirements include the specification of communication architecture including rate control scheme based on error sensitivity and simulation of model communications including aggregation methods. It is expected that the Principal Investigator (PI) will serve as the Lead on a joint conference and/or journal publication on the model development and main aspect of program.

This task will receive direct support/input from the University of Pittsburgh, Carnegie Mellon, Virginia Tech, and NETL. This task will also provide input to the GTC Team selection and details of network model topology to be studied for converter development and applications; support system level modeling; support smart control methodology development; provide input to converter topology design; and provide input to the demonstration site plan.

Existing Methods/Protocols

Power system with communication module



S. Mohagheghi,J. Stoupis, Z. Wang, "Communication protocols and networks for power systems-current status and future trends"

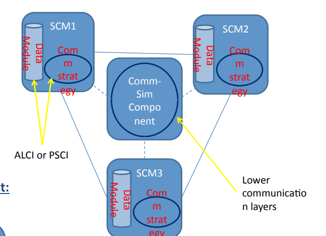
Comparison

Protocol	Physical Channel	Communication Method	Application Layer	Other Futures
DNP3	RS232,RS422 RS485,Ethernet	• Client/Server • Multiserver • Multi master • hierarchical	TCP/IP	• Involved IP suite for the transport and net layers
Modbus	RS232,RS422, RS485,RF,Fiber Optic	• Client/Server	TCP/IP	• Coexistence of different implementations with gateways
IEEE 61850	Ethernet, serial unidirectional multi-drop P2P link	• Client/Server • P2P	Mapped using SCSM to: • MMS • Ethernet LL	• Comm within the substation • Object Oriented Model • Substsion Configuration Language (SCL)

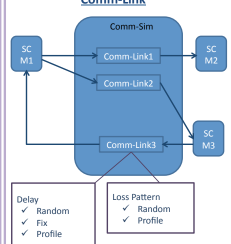
Communication Simulator in PSCAD

- CommSim module enhanced and expanded to include two new configurable components:
  - CommLink
  - CommRouter
- The idea is to allow PSCAD users to easily create a network with minimal networking/ comm knowledge

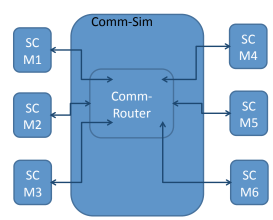
Sensor and Control Modules (SCM) Communicating via Comm-Sim module



Configurable component: Comm-Link



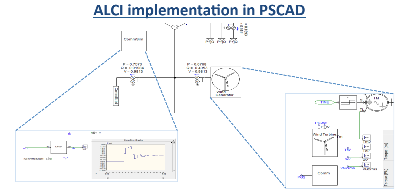
Configurable Component: Comm-Router



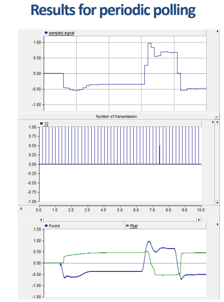
PSCAD Test-Bench (IEEE 13-nodes Test Feeder)

- IEEE 13 nodes test feeder implementation
- Wind Generator
  - Communicated Signal (Will be extended to Data Module definition)
- Variable Load Component

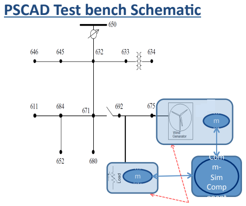
ALCI implementation in PSCAD



Results for periodic polling

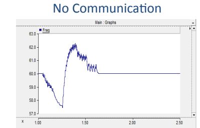


PSCAD Test bench Schematic



Frequency Effect

No Communication



Communication 0.5 sec delay (sampling rate of 10Hz)