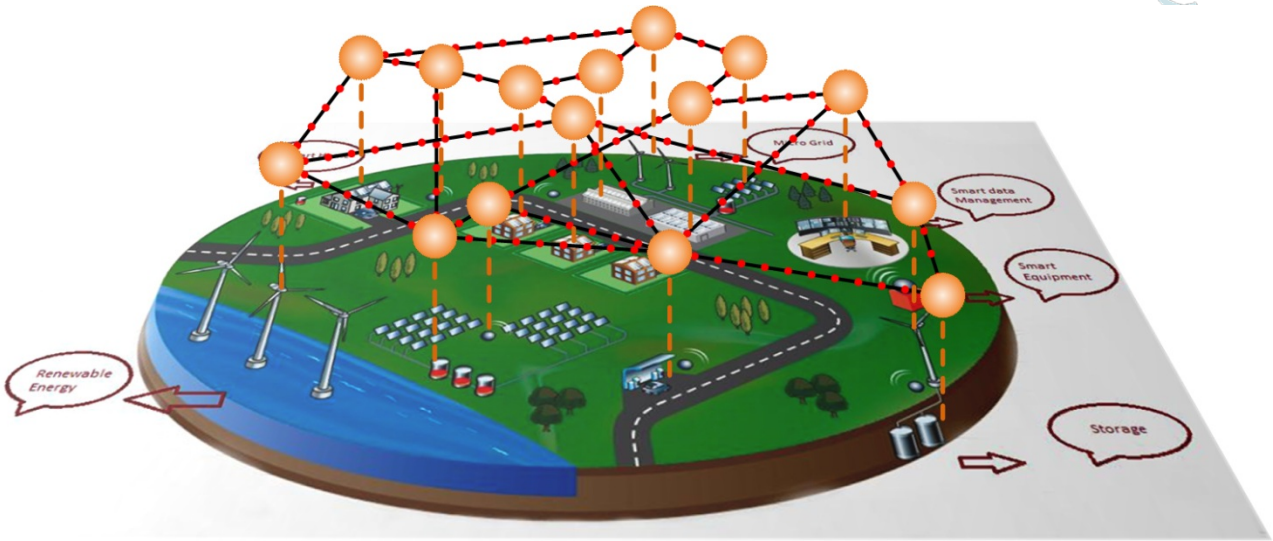
IEC61499 Function Block implementation of distributed Load Balancing for FREEDM System

Sandeep Patil
Valeriy Vyatkin
Chen-Wei Yang
Gulnara Zhabelova

Smart Grid as Energy Internet

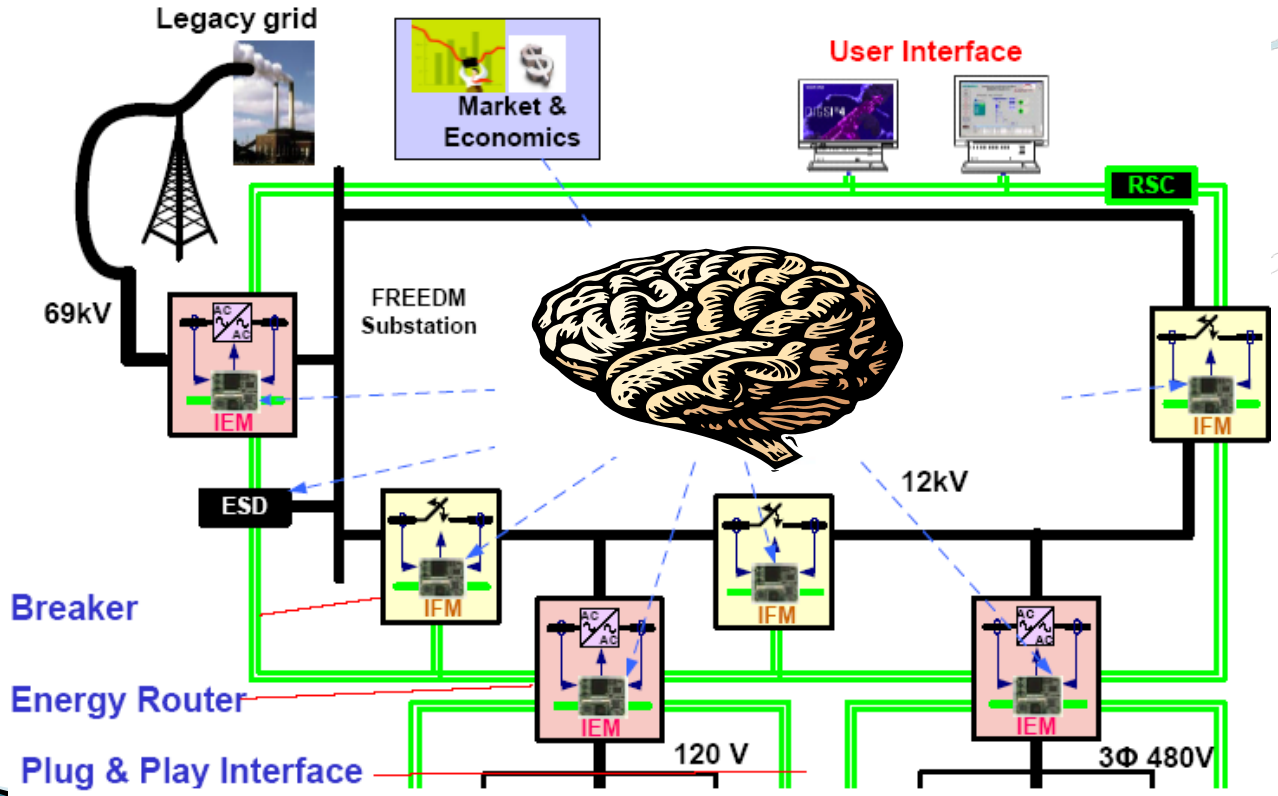


FREEDM NSF Project

FREEDM Industrial partner

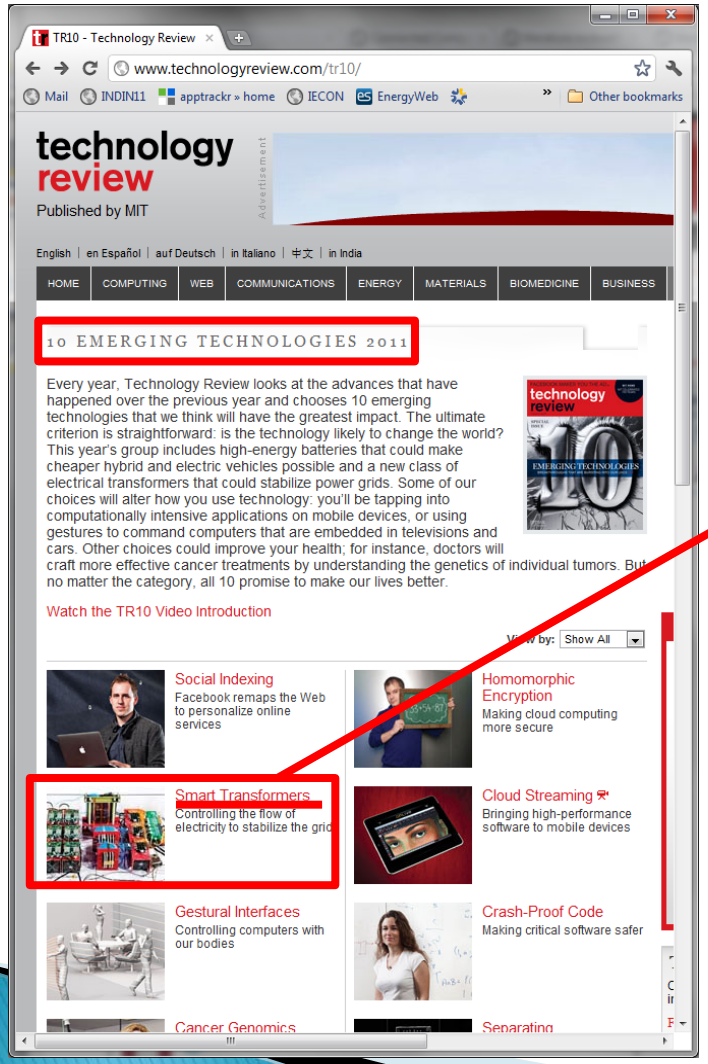
SmartGrid Intelligence Engineering:

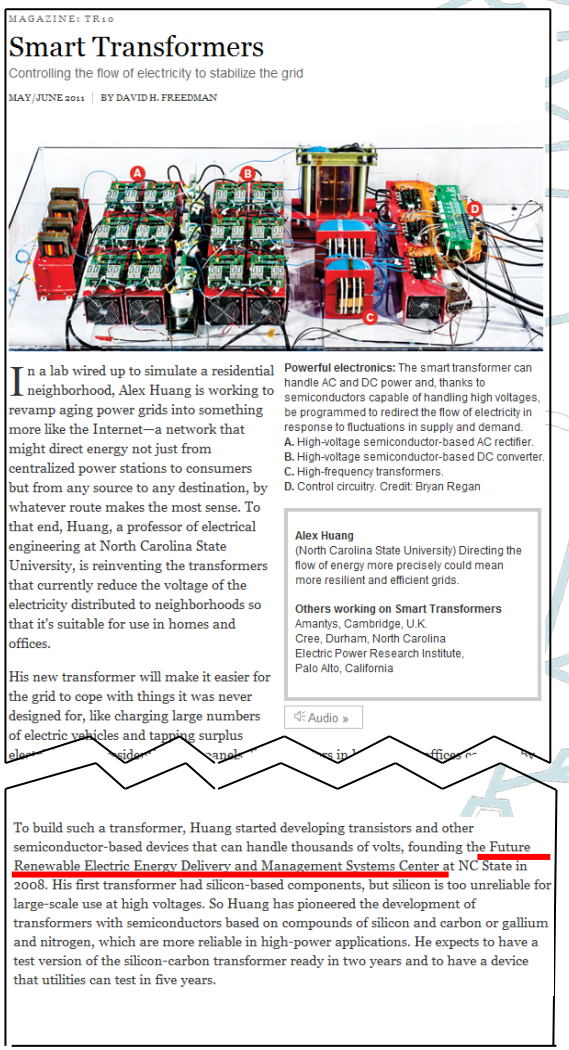
- How to design and validate distributed intelligence?
- Where and how to deploy it?



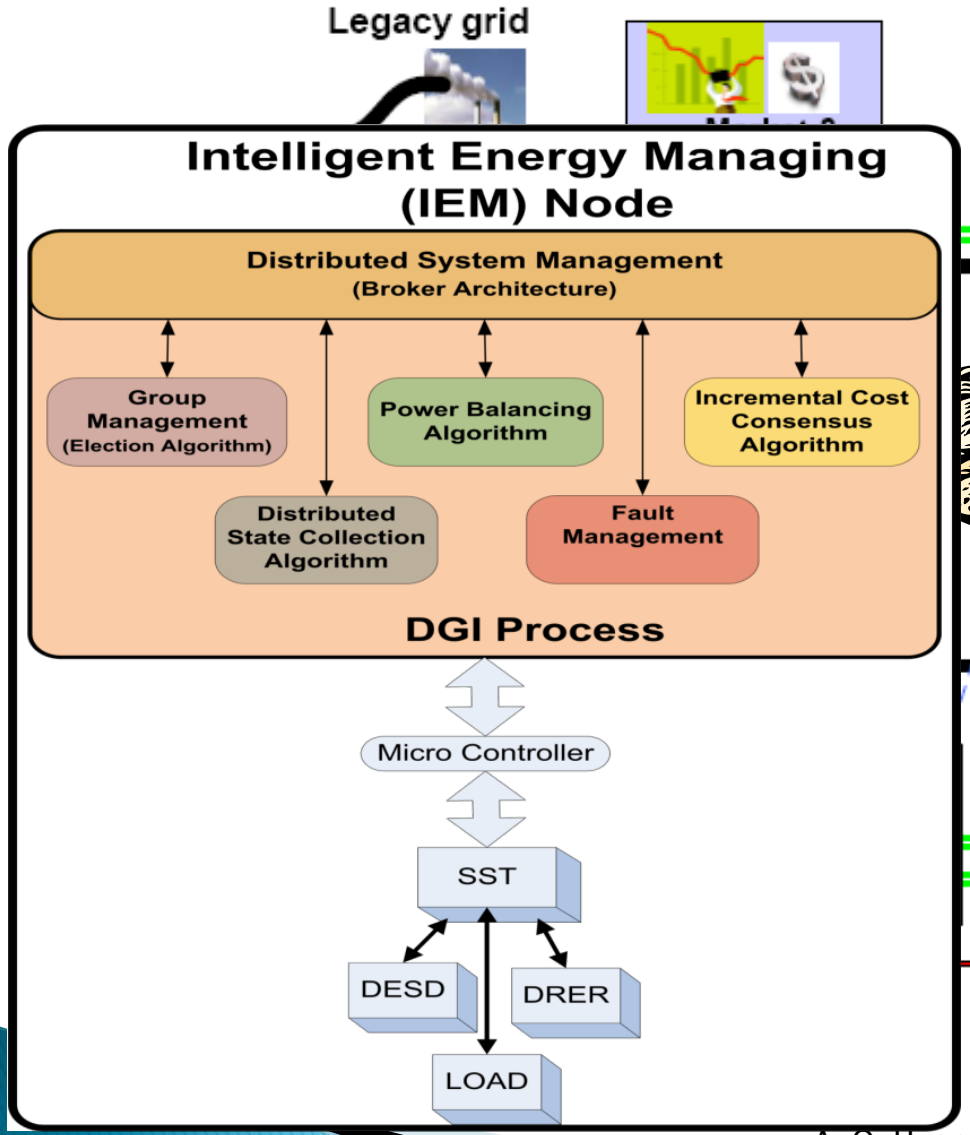
MIT Technology Review 2011 about FREEDM

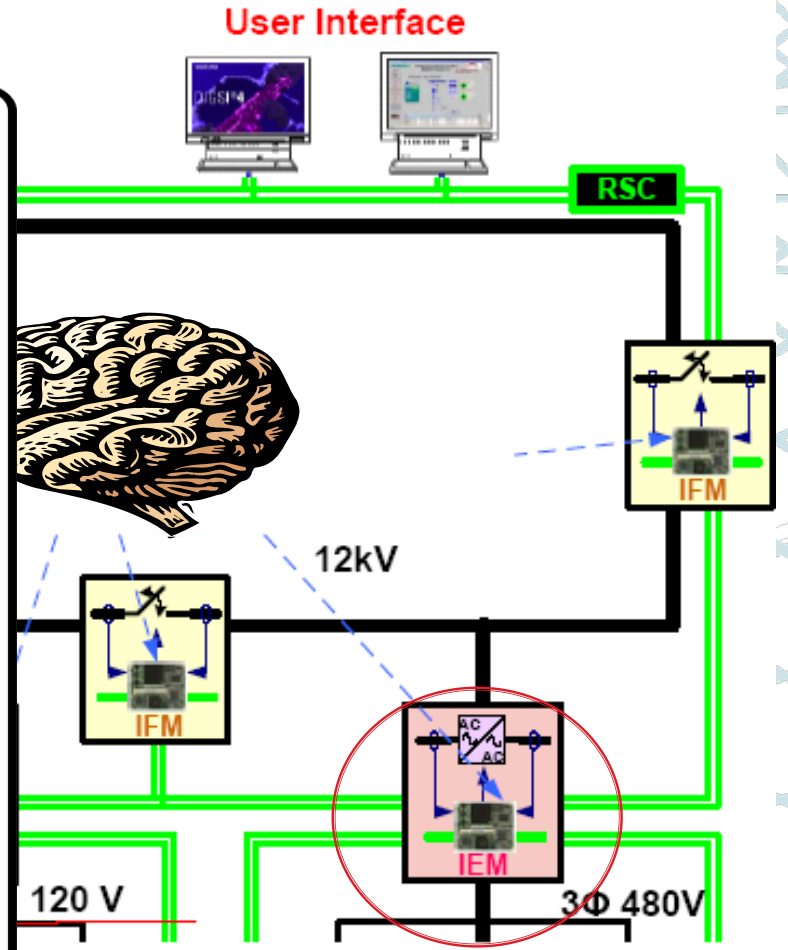
"One of the 10 most important technologies being developed worldwide"





Distributed Grid Intelligence





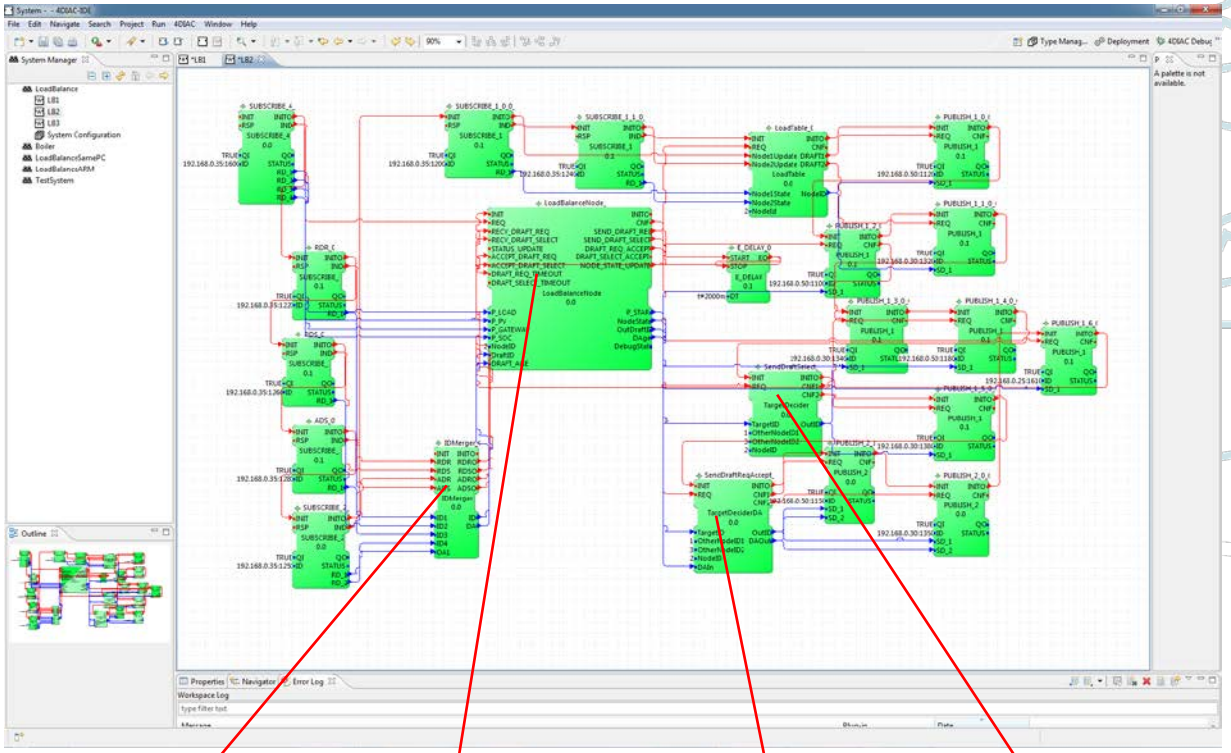
A. Q. Huang, M. L. Crow, G. T. Heydt, J. P. Zheng, and S. J. Dale, "The Future Renewable Electric Energy Delivery and Management (FREEDM) System: The Energy Internet," *Proceedings of the IEEE,* vol. 99, pp. 133-148, 2011

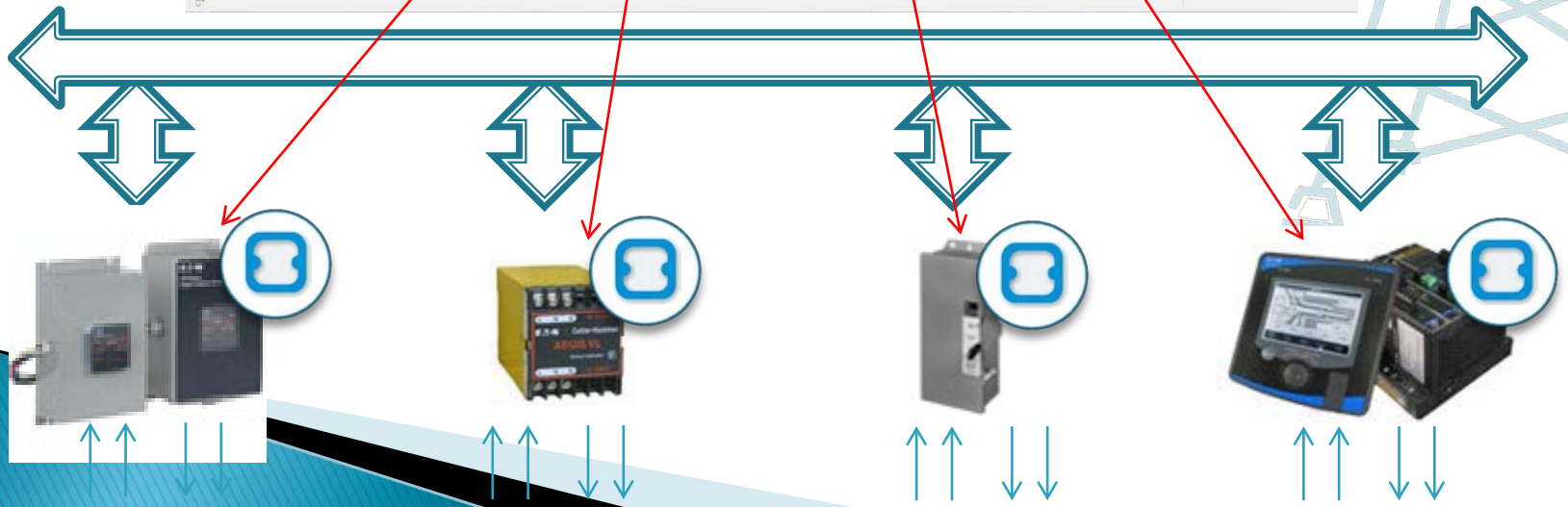
Why IEC 61499 ?

- Need a software platform for distributed automation system development
- Other options:
  - Implementing agents with hand-made APIs
  - Existing platforms like JADE

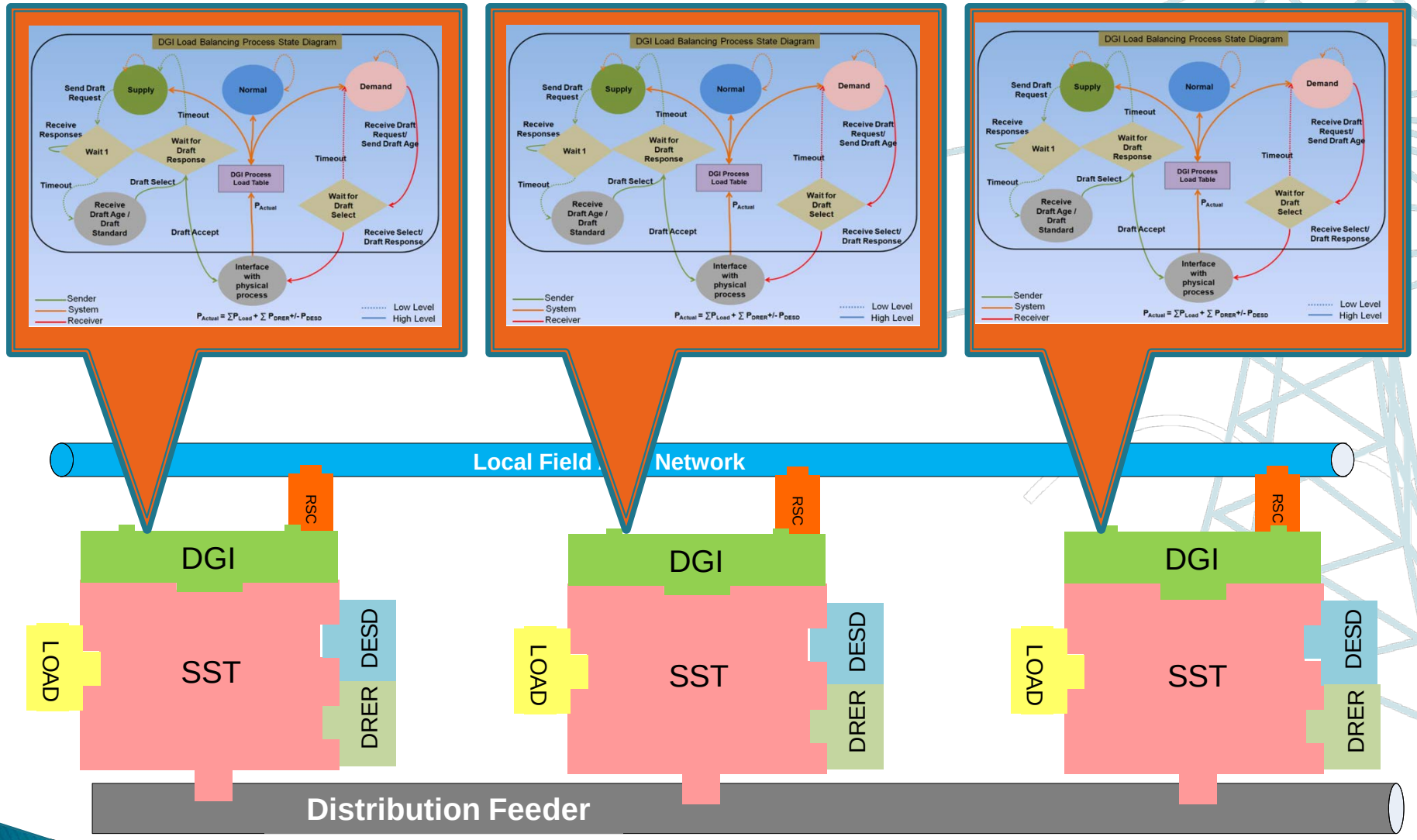
  Are not likely to succeed due to dependability and maintainability requirements of automation
- Verification and validation of distributed behavior
- Autonomous behavior can be encapsulated into function blocks

Direct Distributed System Programming + System-level Validation

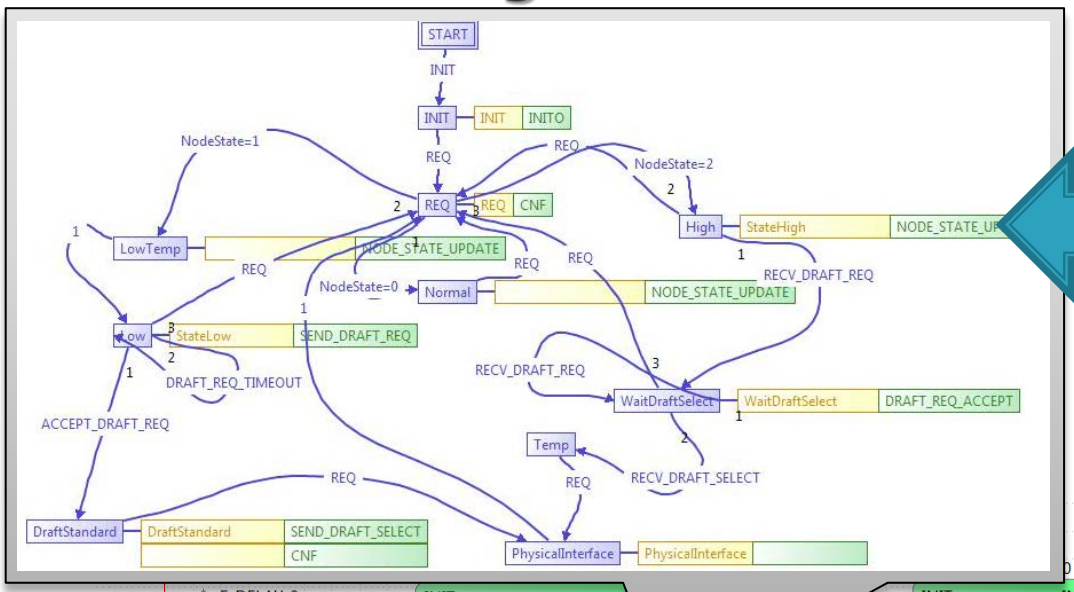


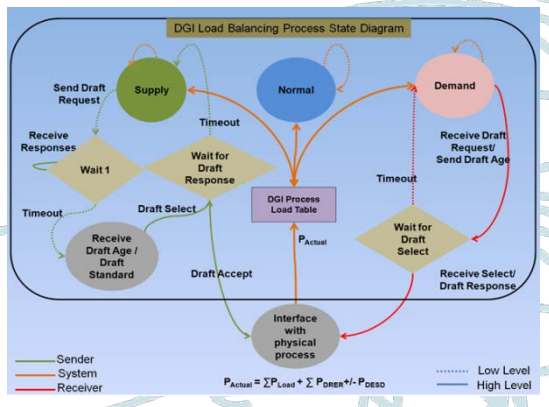


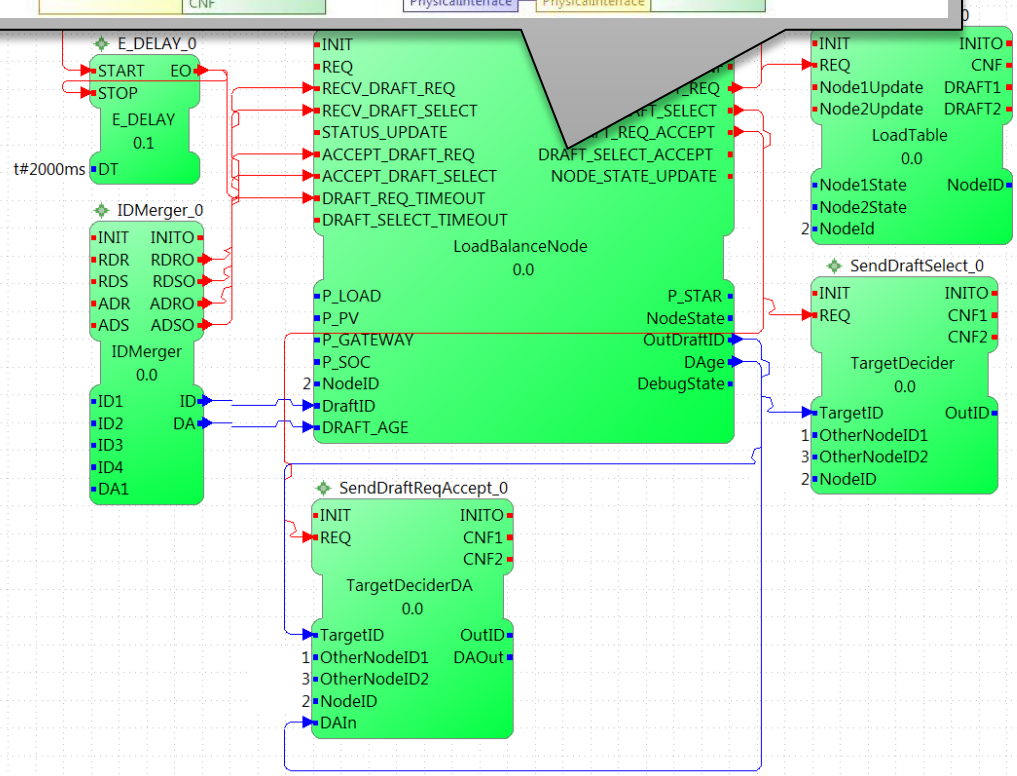
DGI: Load Balancing



Load Balancing: Model-based Software Engineering

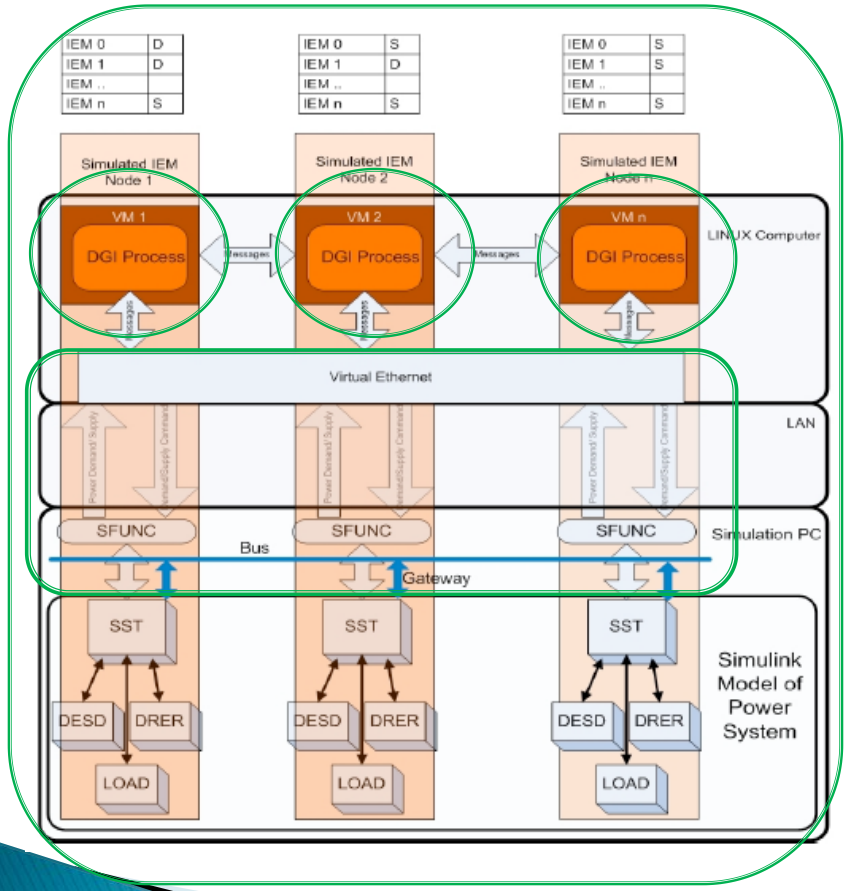


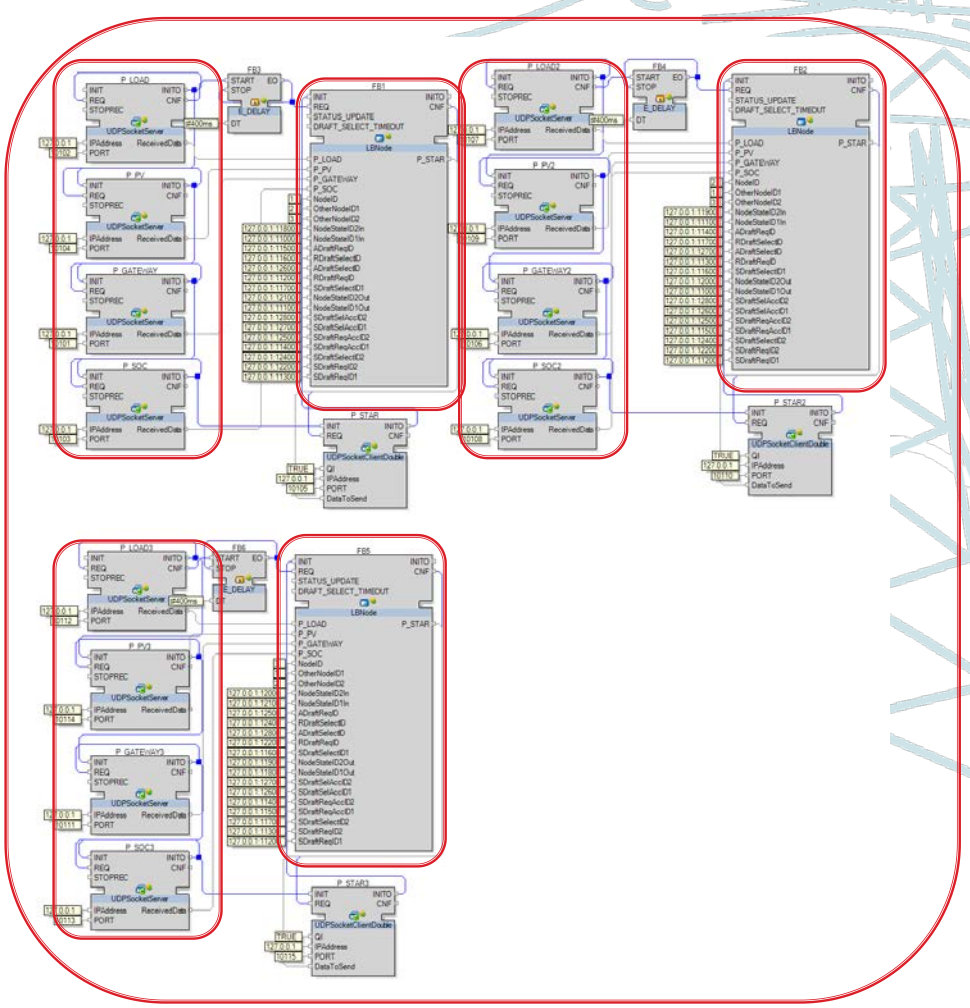




Load Balancing System model Initially in NxtStudio

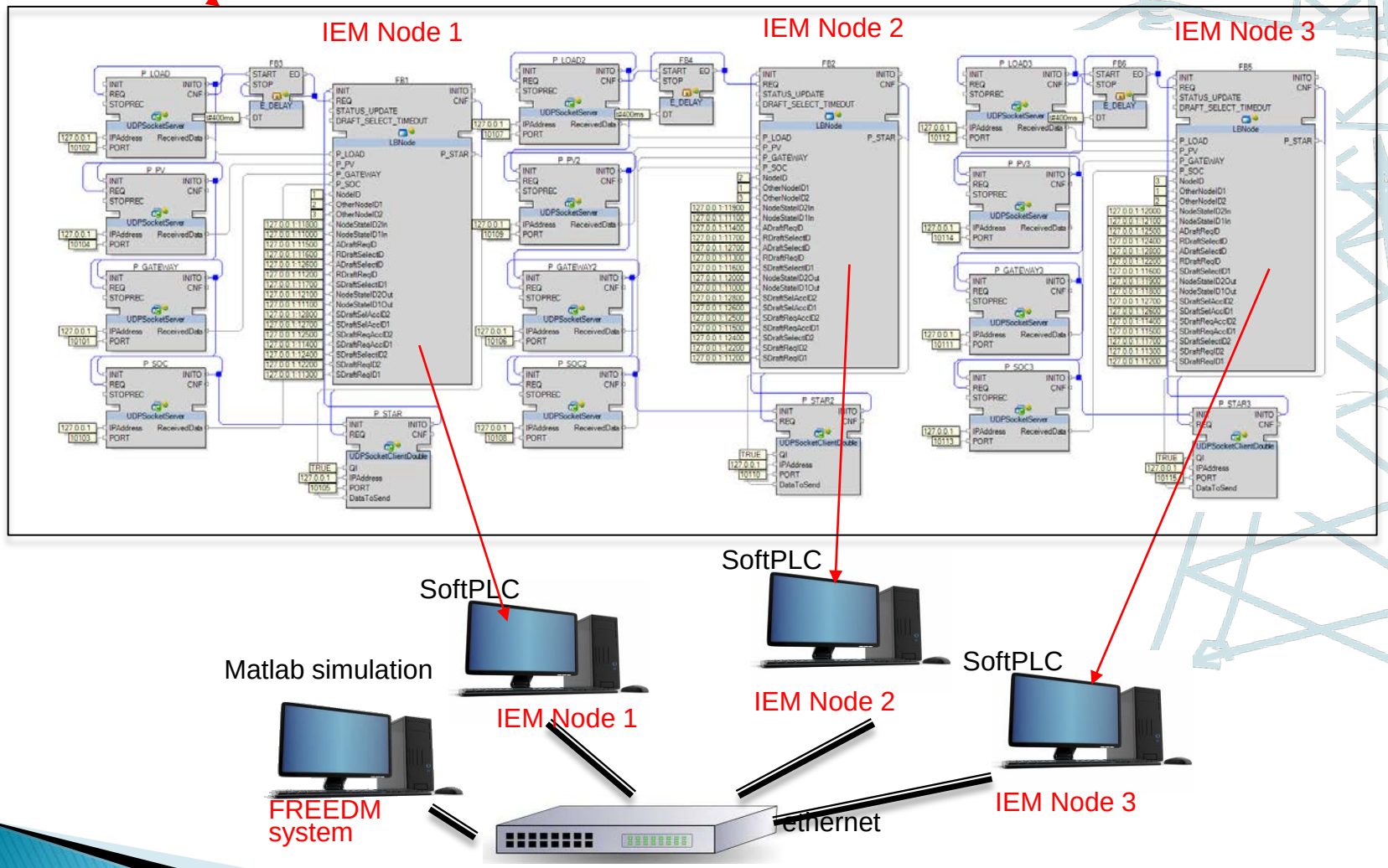
- Load balancing application system level model





Exploring Portability benefits of IEC 61499

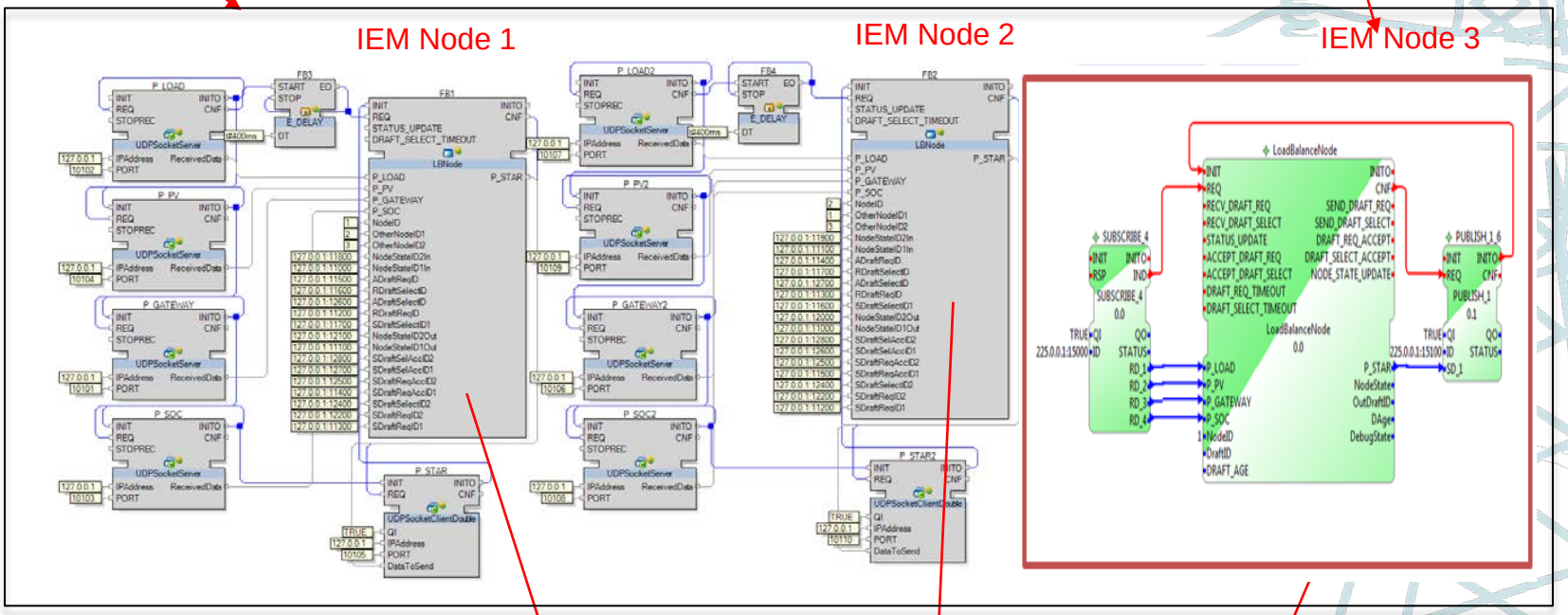
FB application designed in NxtStudio

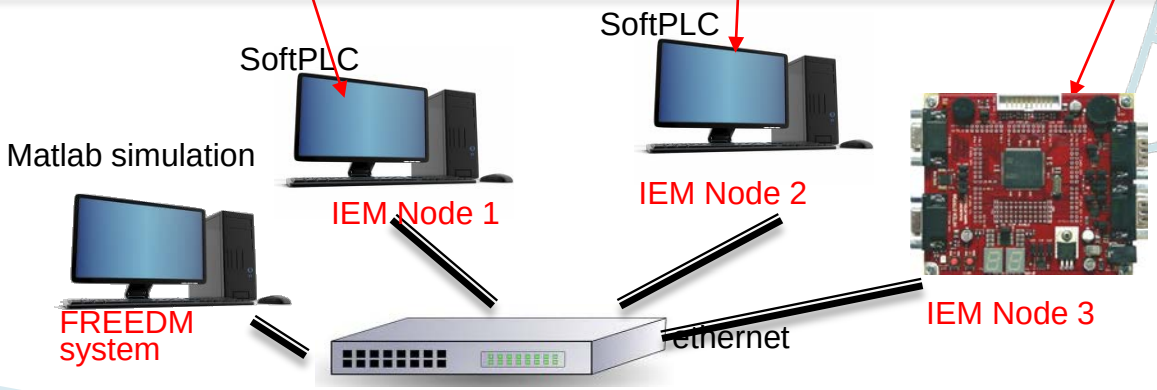


Exploring Portability benefits of IEC 61499

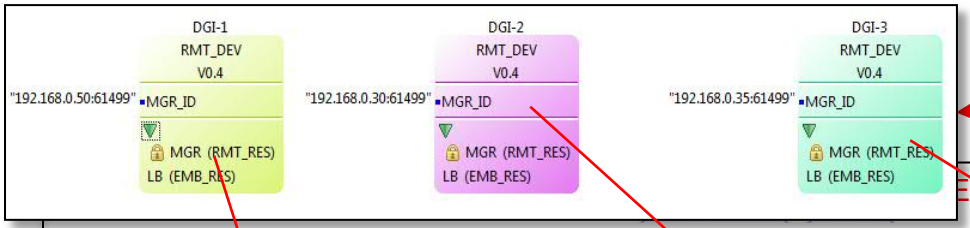
FB application designed in NxtStudio

Migrated to 4DIAC





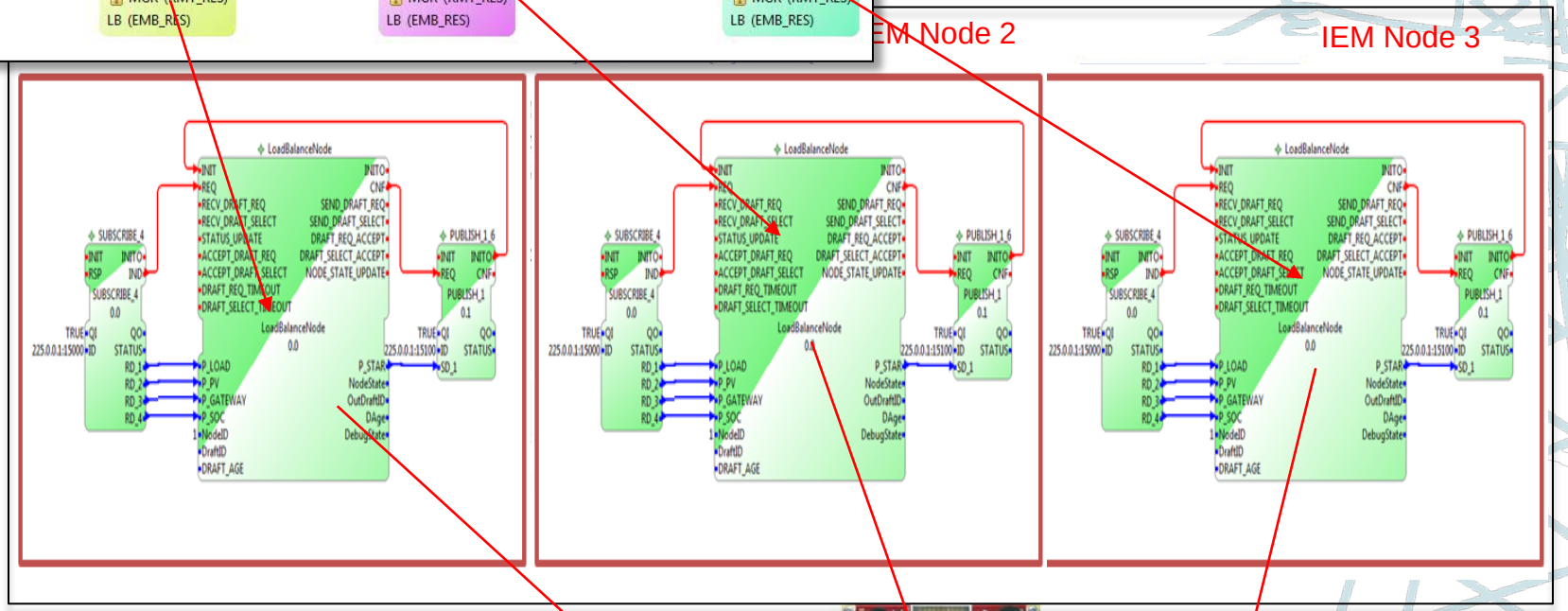
Exploring Portability benefits of IEC 61499



Migrated to 4DIAC

IEM Node 2

IEM Node 3



Matlab simulation

IEM Node 1

IEM Node 2

IEM Node 3

FREEDM system

ethernet

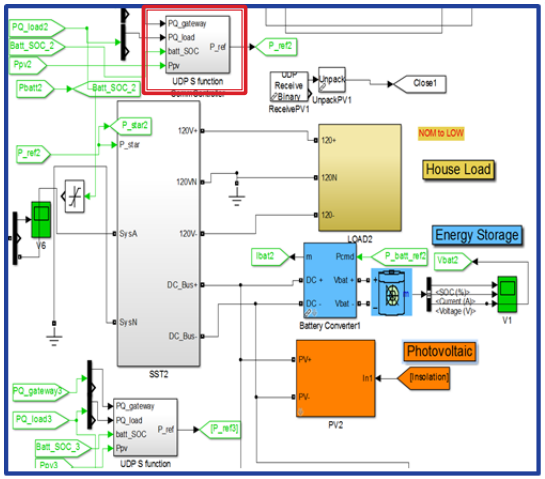
Why port to 4DIAC

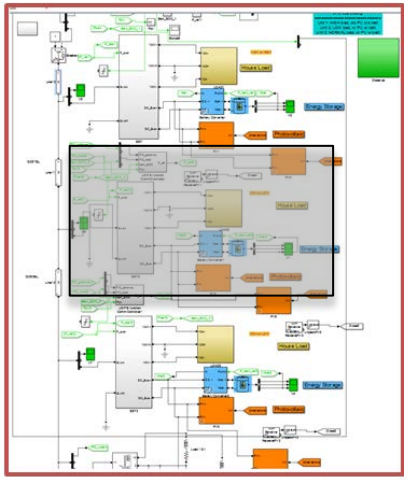
- Open source
- Very easy to cross compile the run time to target hardware.
  - Uses CMake
  - Hence it is just a two step procedure (to get your build environment set)
    - Generate the build environment by specifying your cmake configuration file
      - -DCMAKE_TOOLCHAIN_FILE
    - Build it.

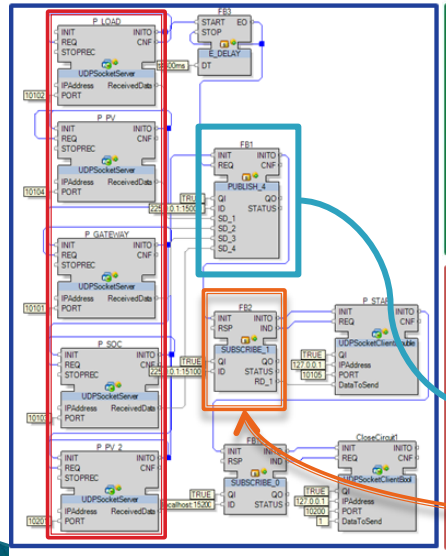
Any issues with semantic differences?

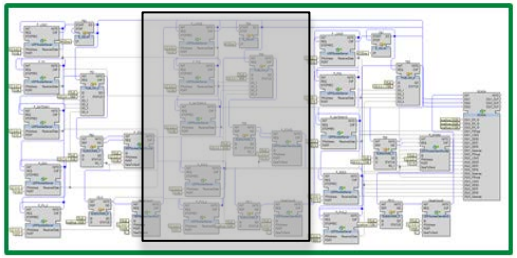
- None for this application

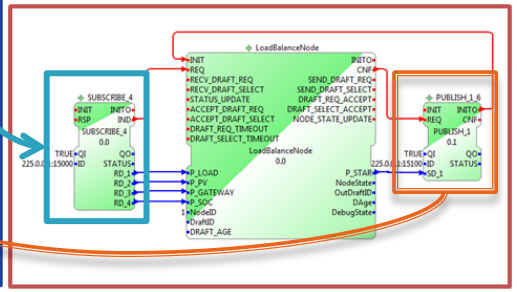
Load Balancing Co-Simulation Setup

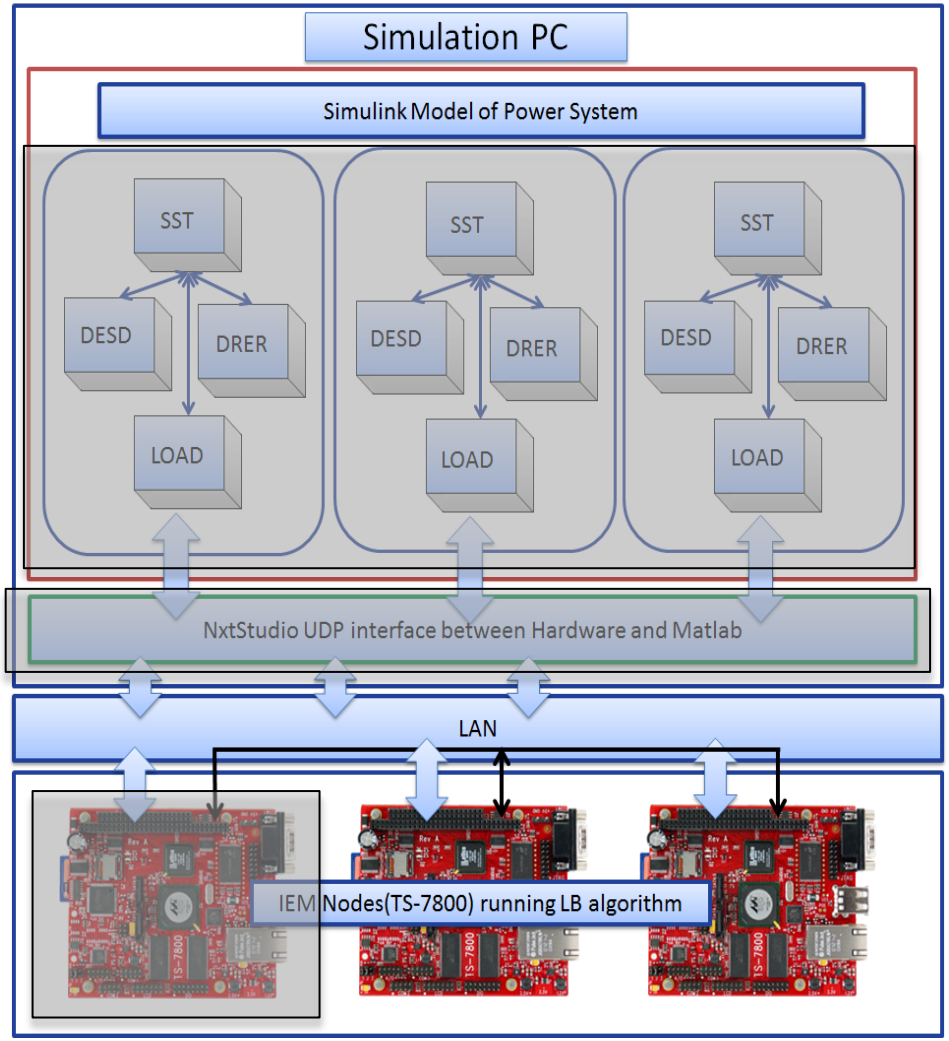










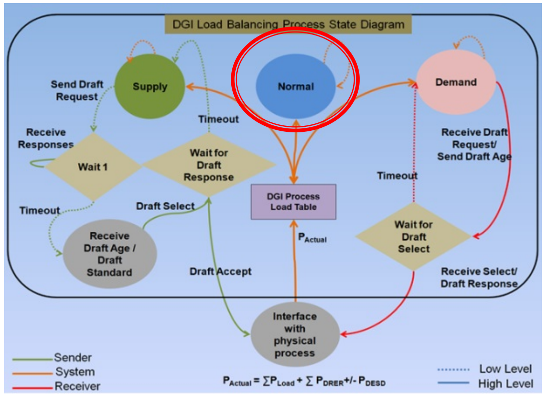


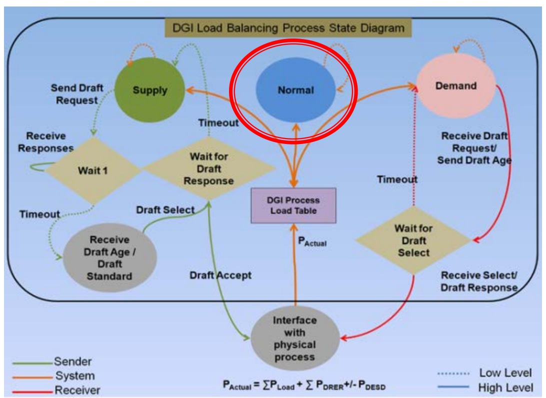
Communication between Matlab and NxtStduio Interface

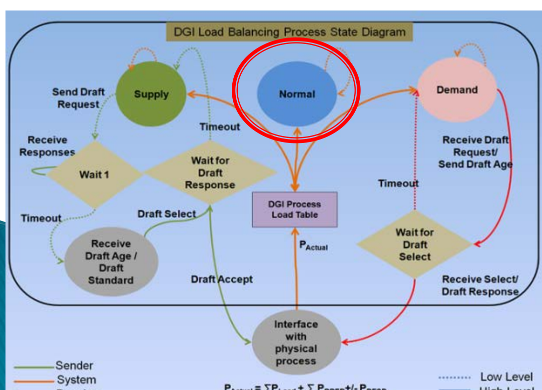
Communication between NxtStduio Interface and ARM Boards (4DIAC)

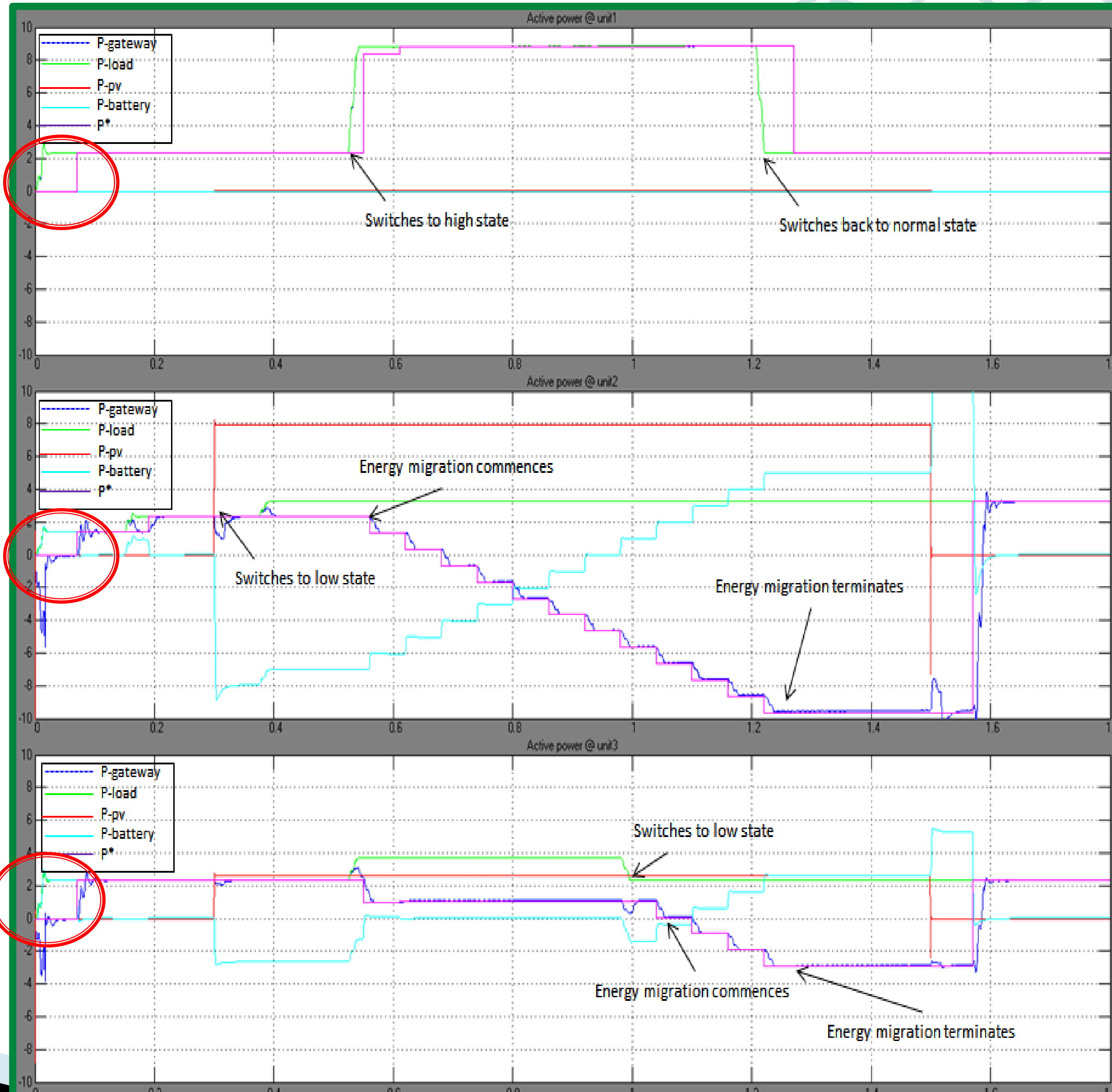
Results – 3 Node without additional DESD

At t = 0



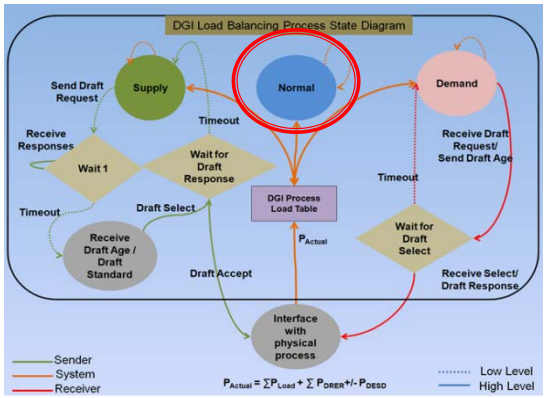


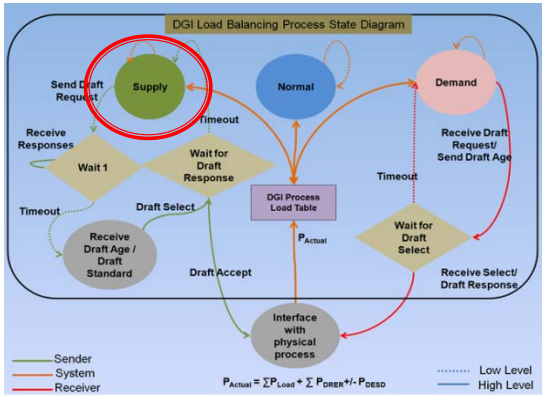


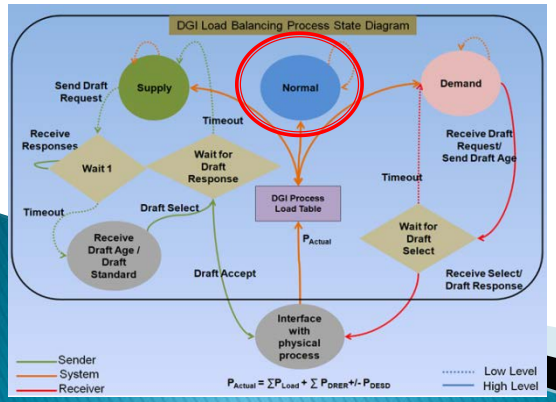


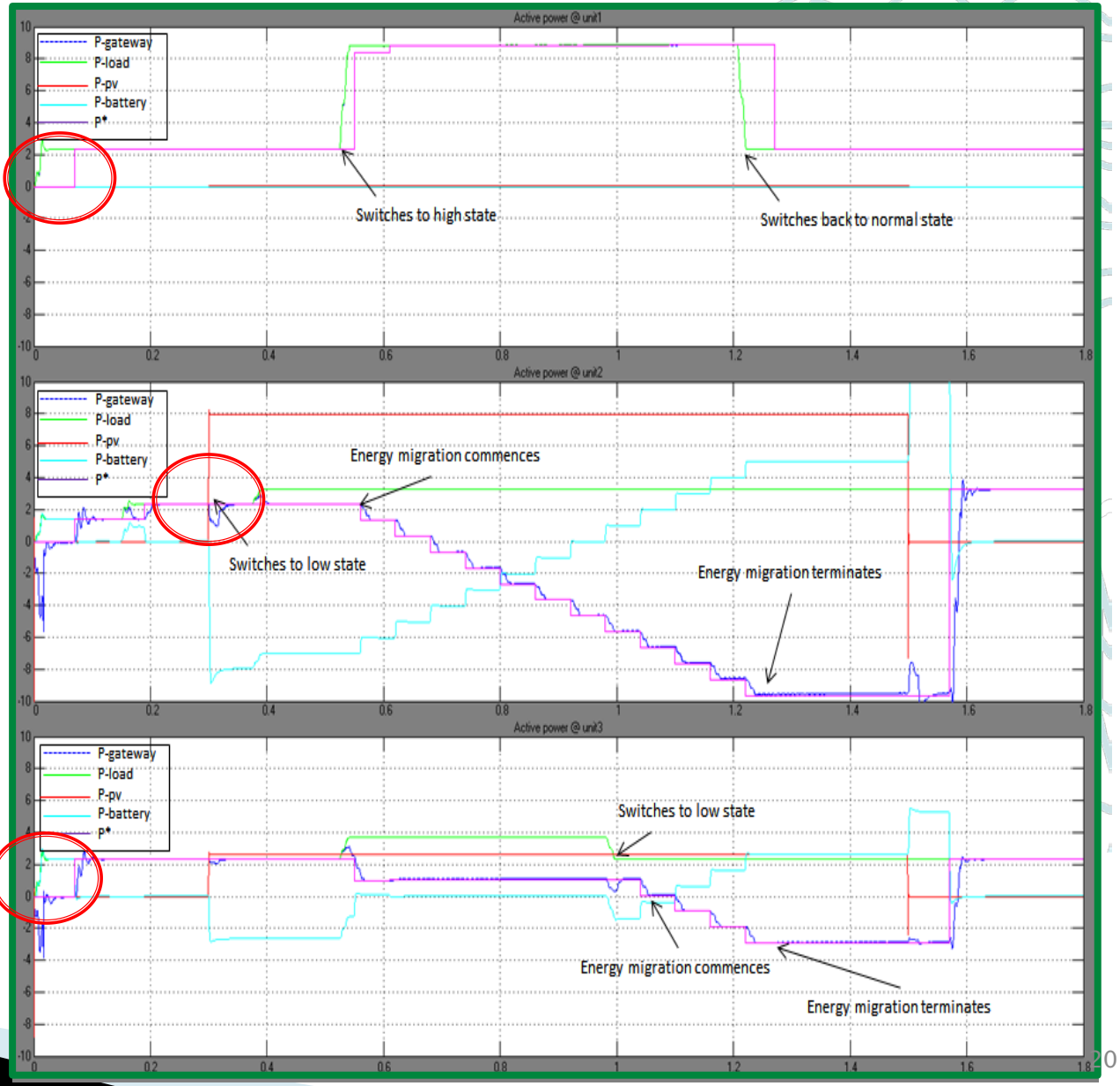
Results – 3 Node without additional DESD

At t = 0.3



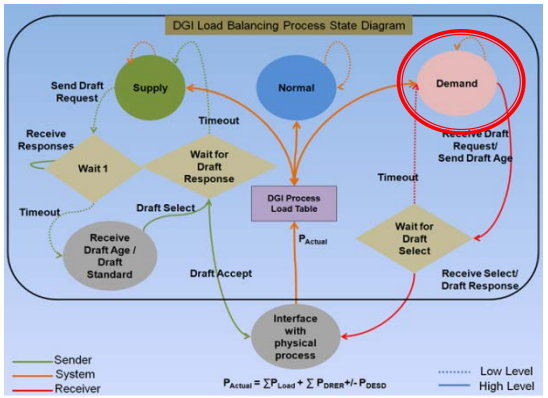


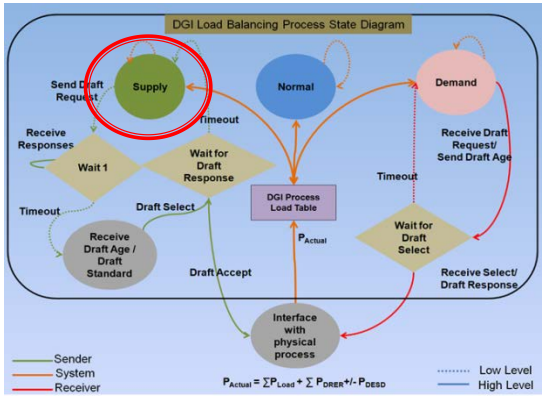


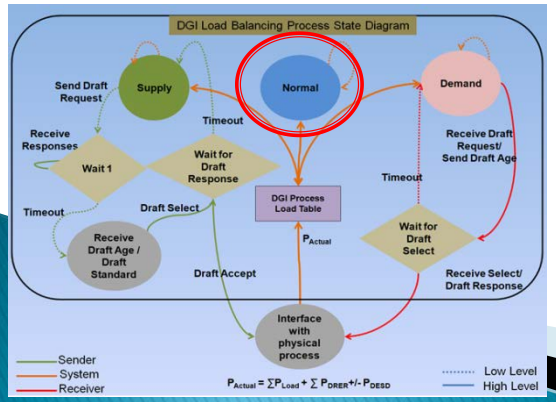


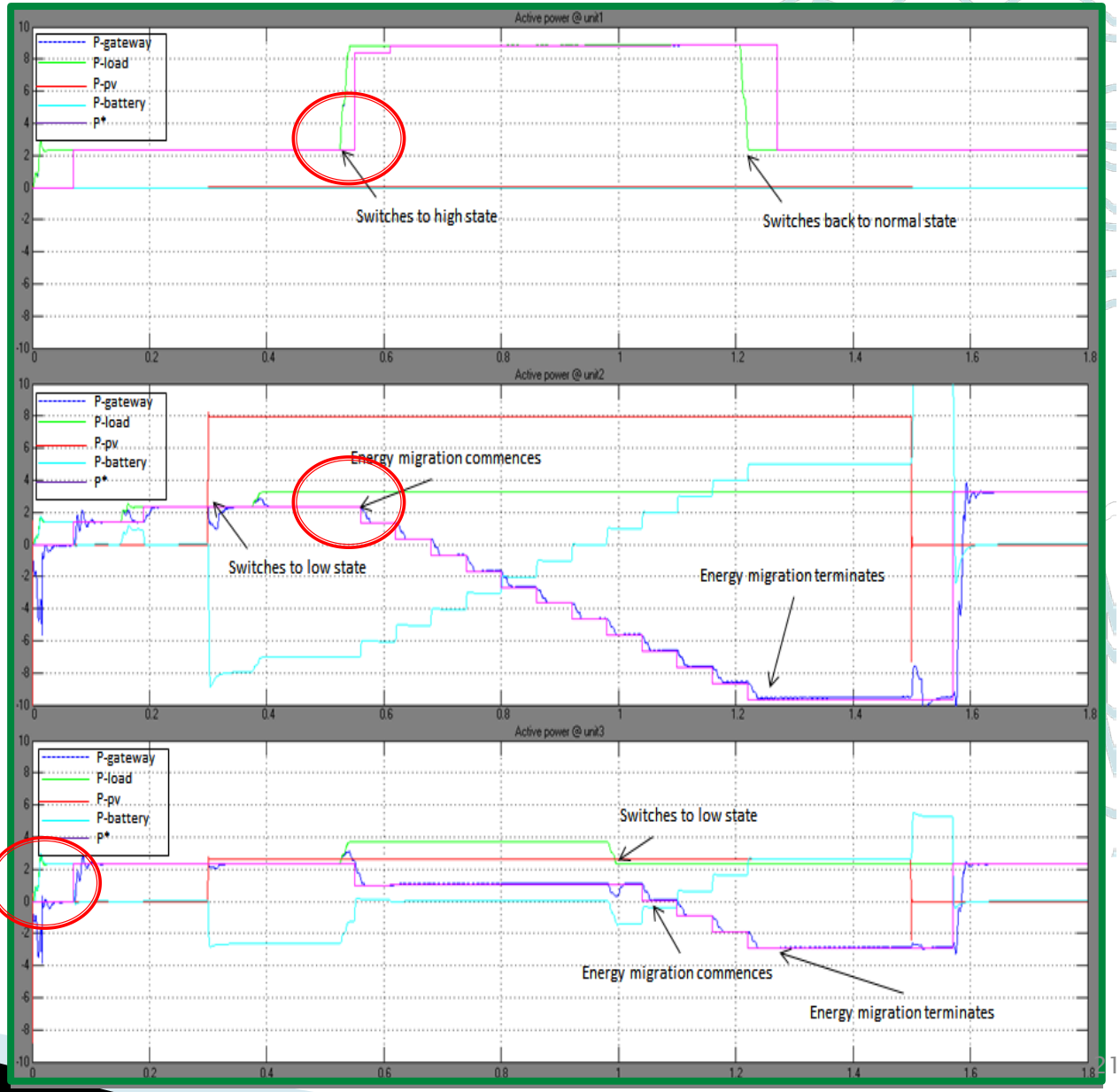
Results – 3 Node without additional DESD

At t = 0.525



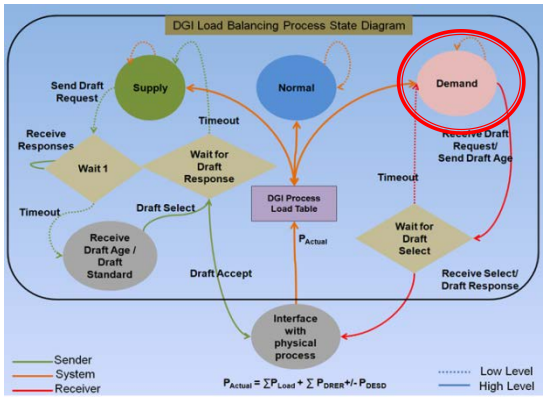


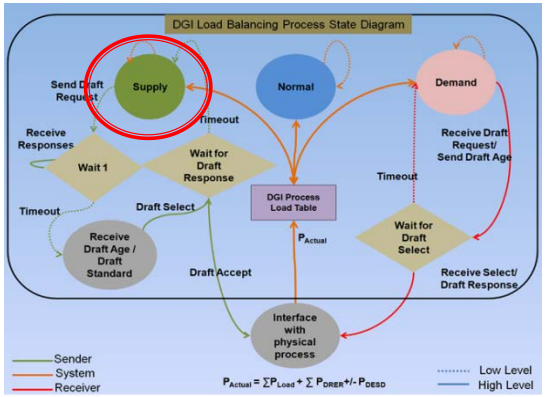


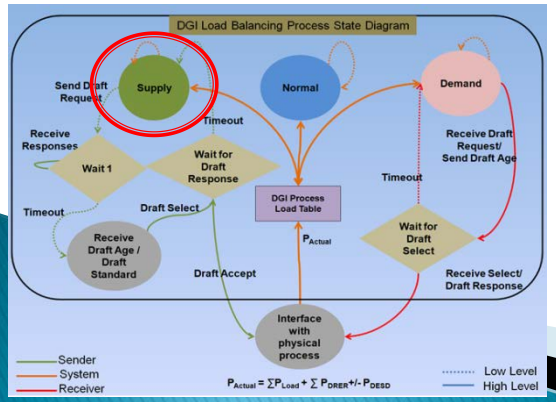


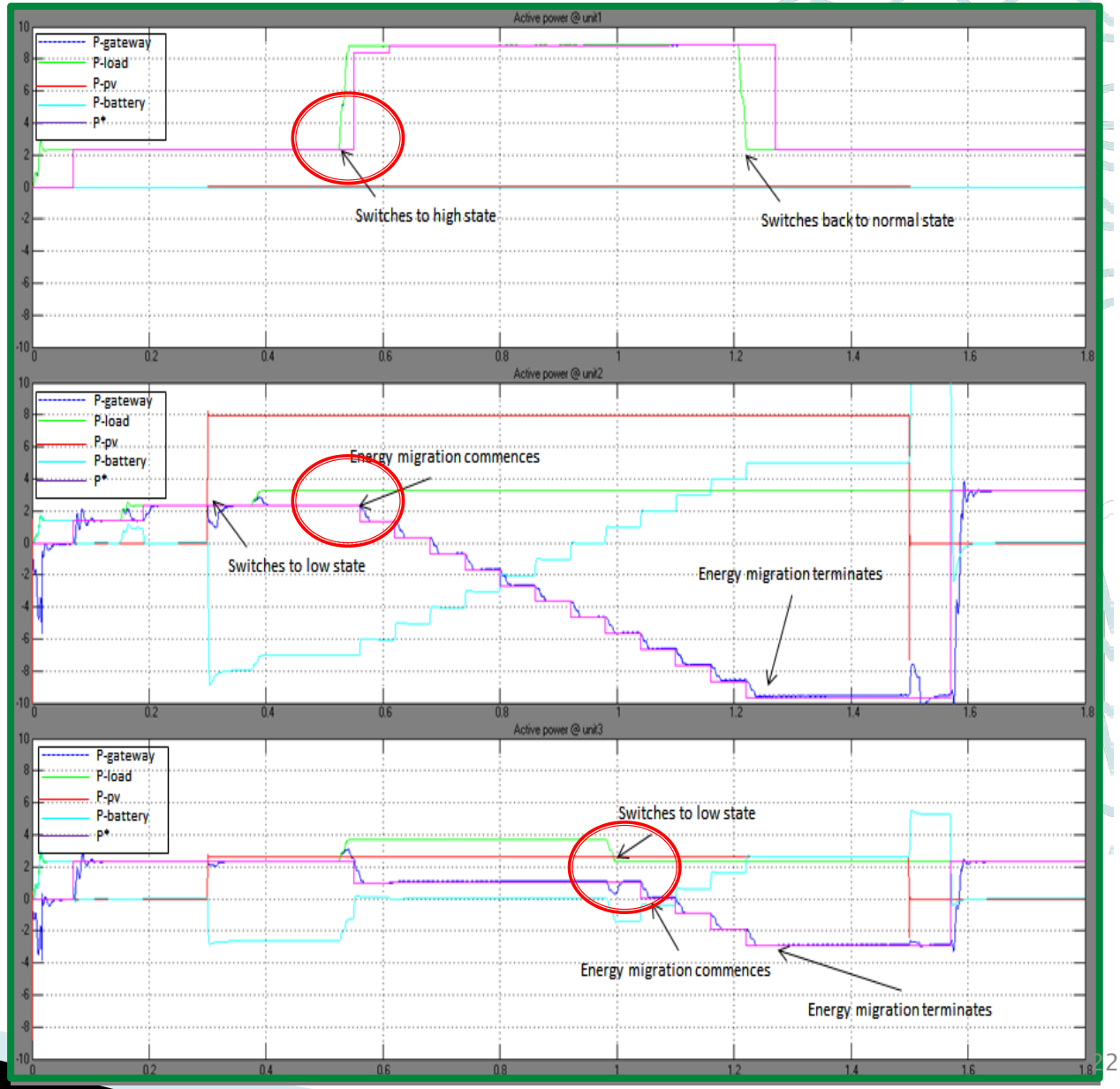
Results – 3 Node without additional DESD

At t = 1.0



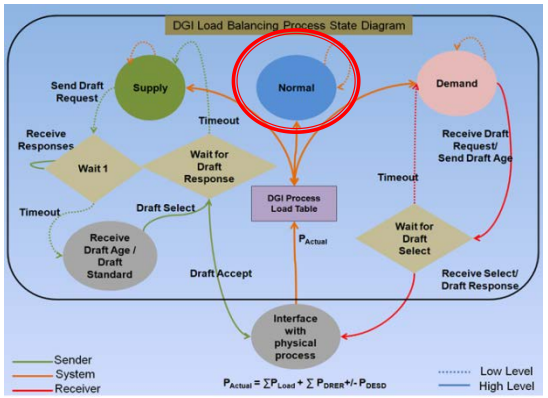


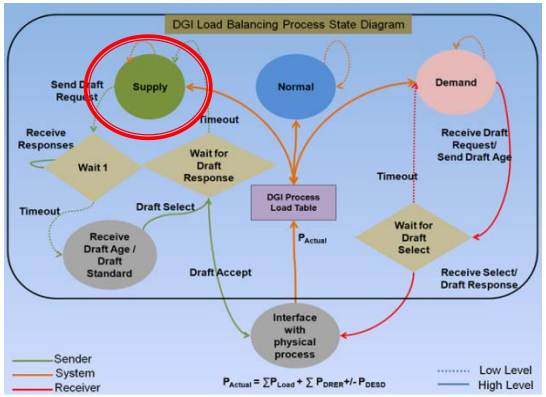


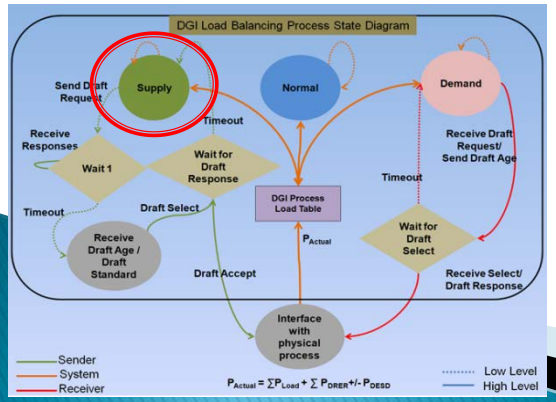


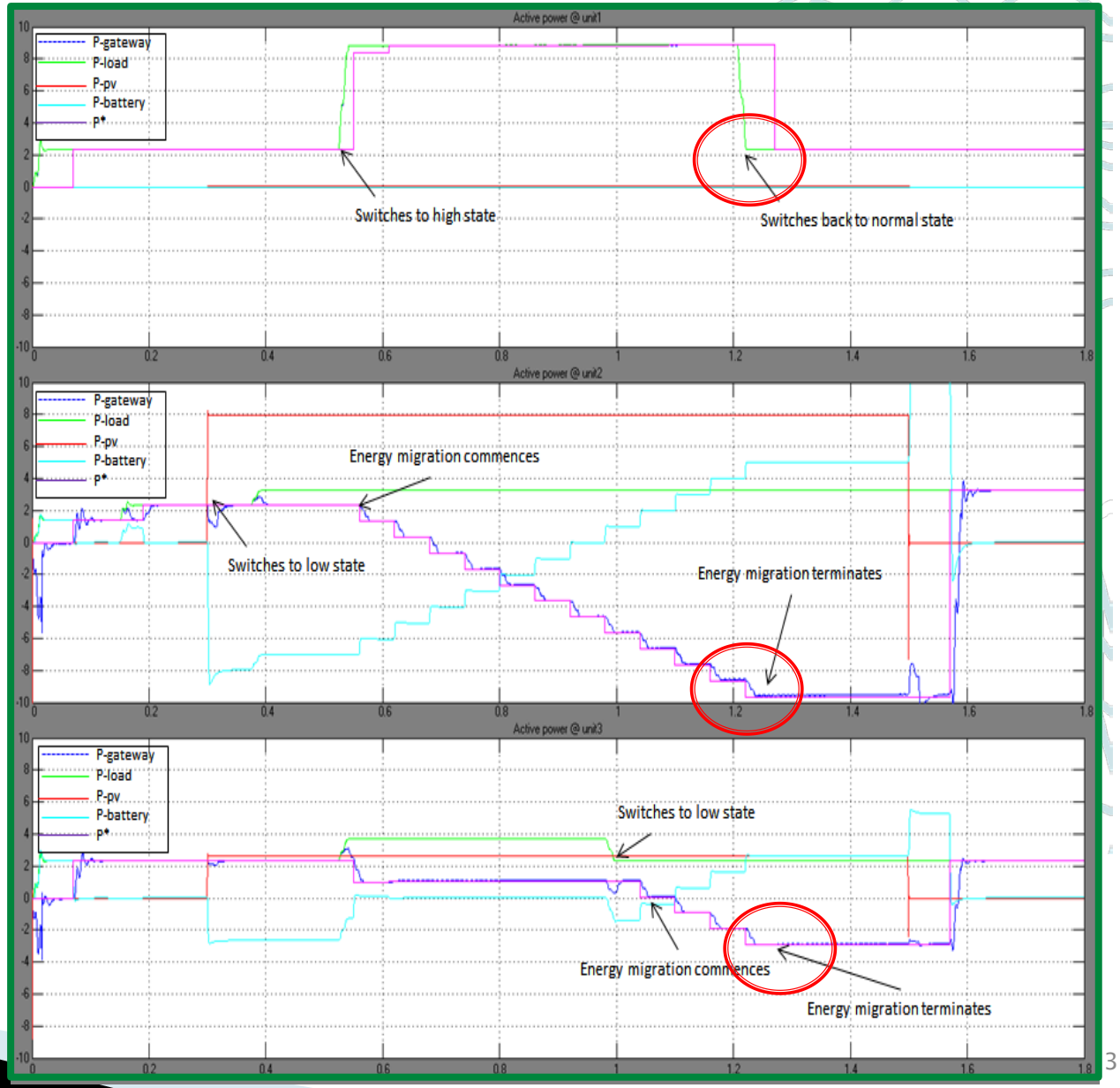
Results – 3 Node without additional DESD

At t = 1.225

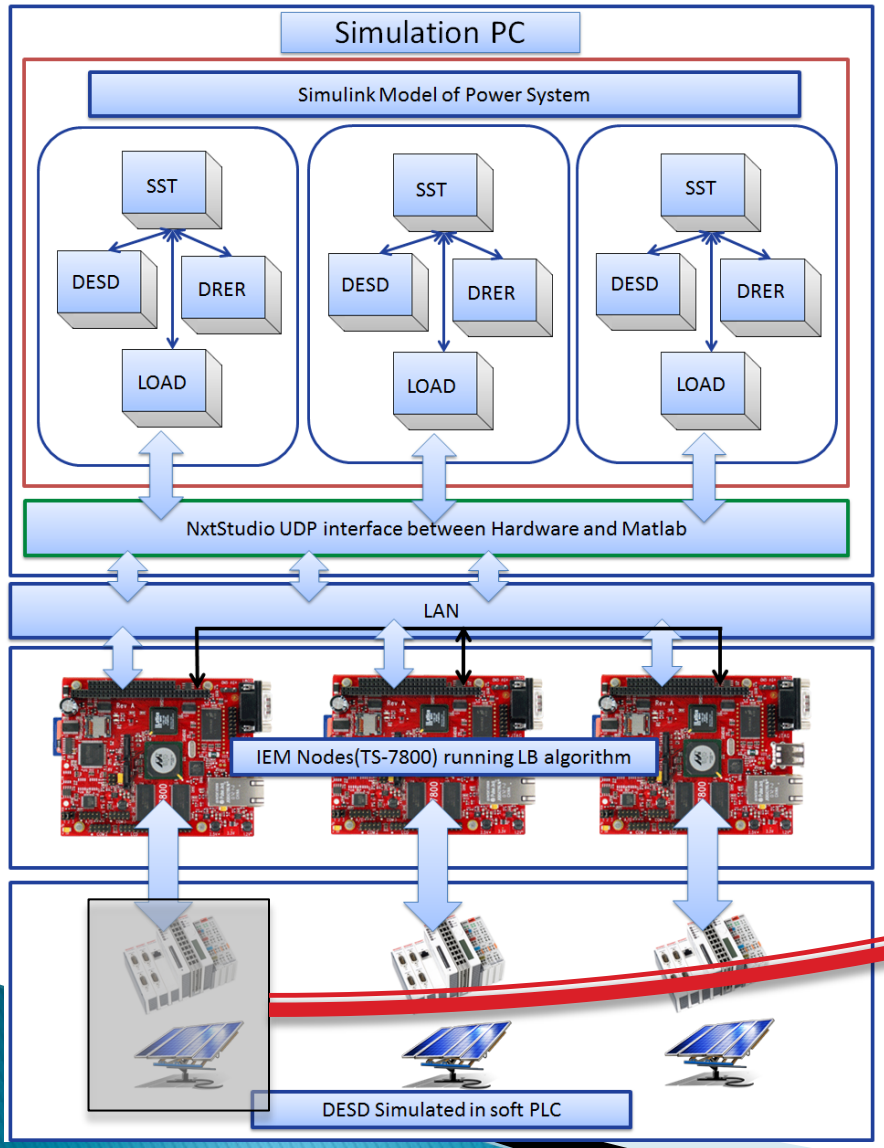


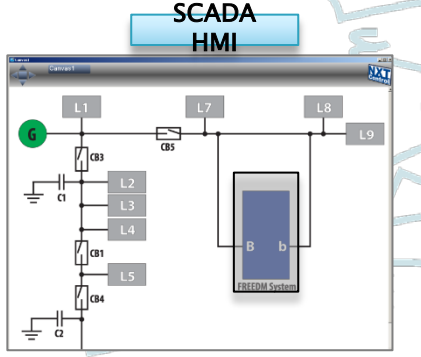


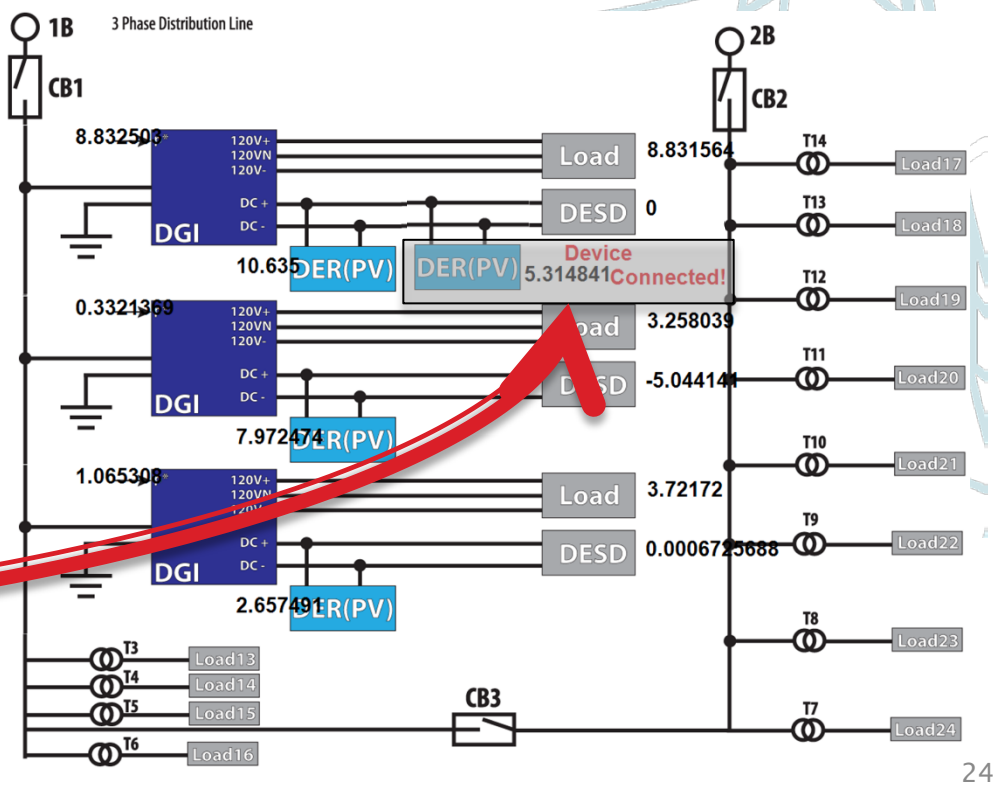




Distributed SCADA concept with PnP support

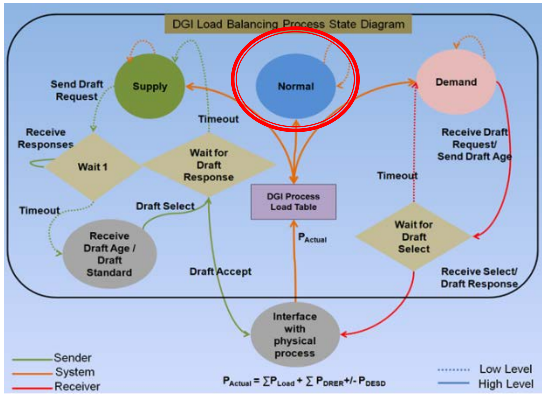


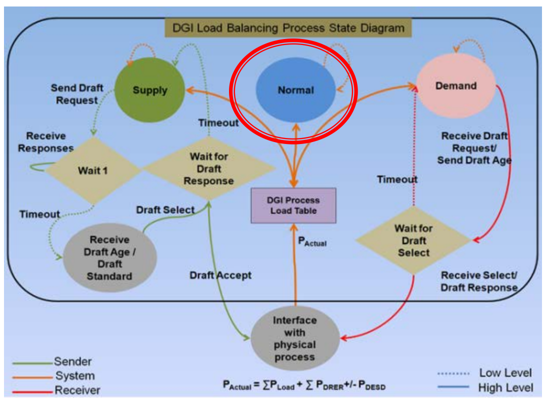


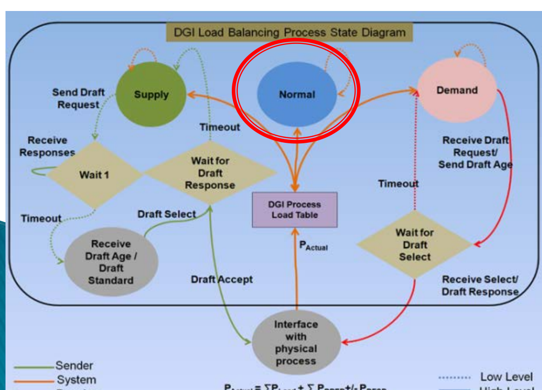


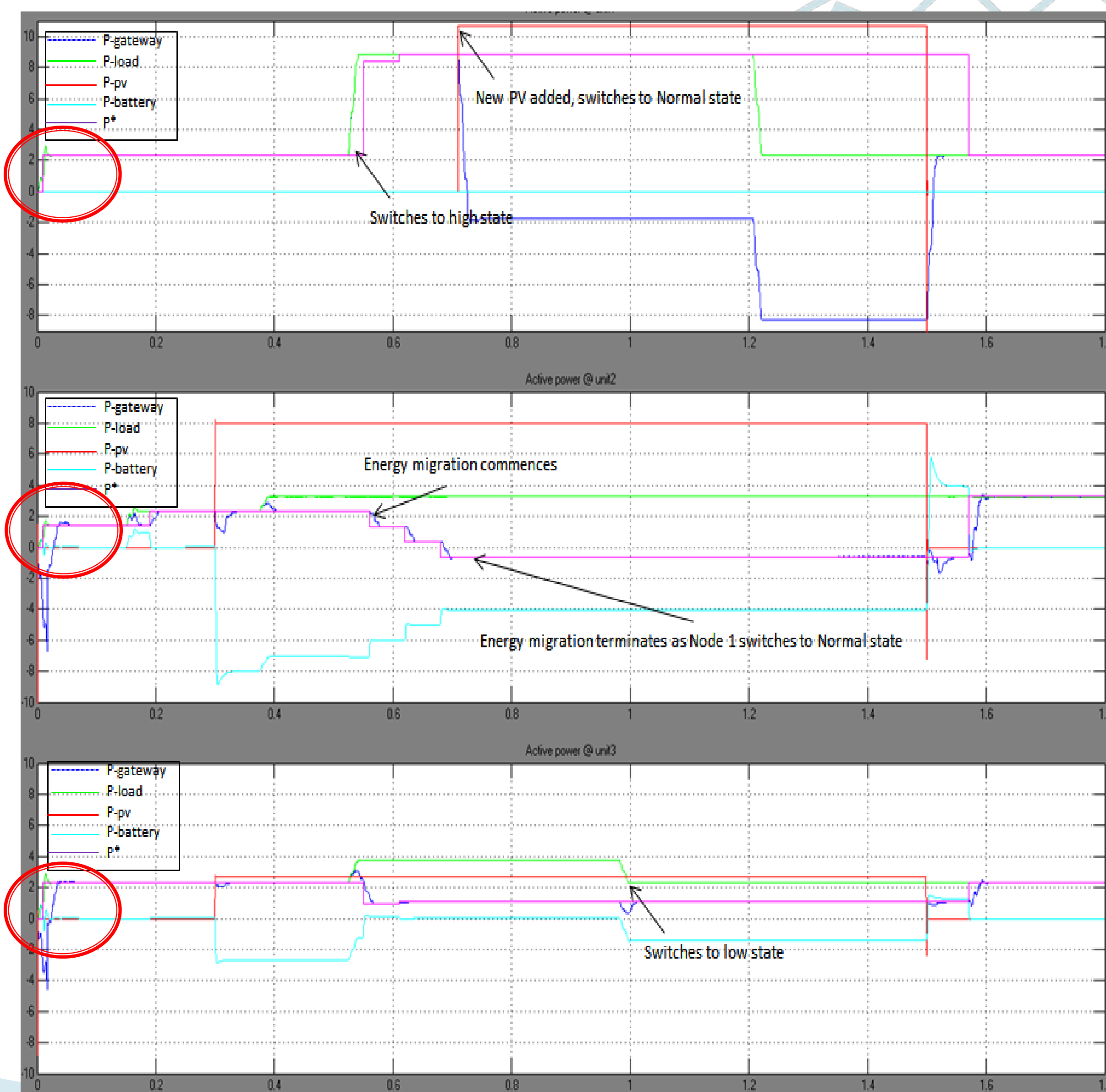
Results – 3 Node with additional DESD

At t = 0



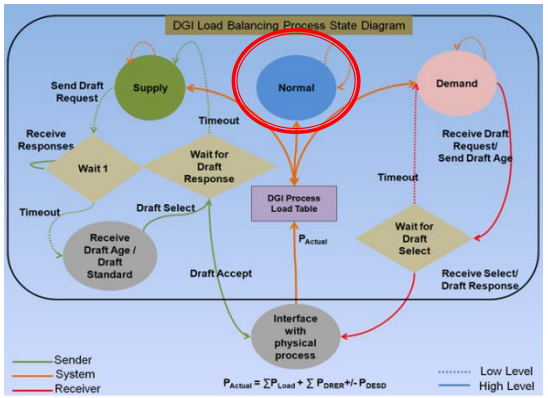


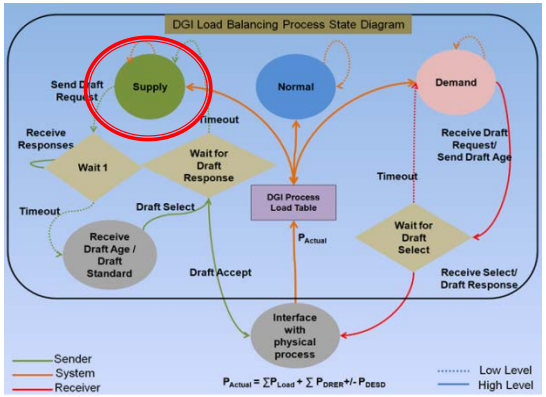


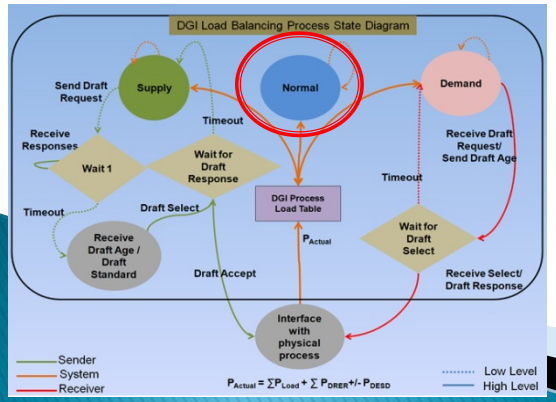


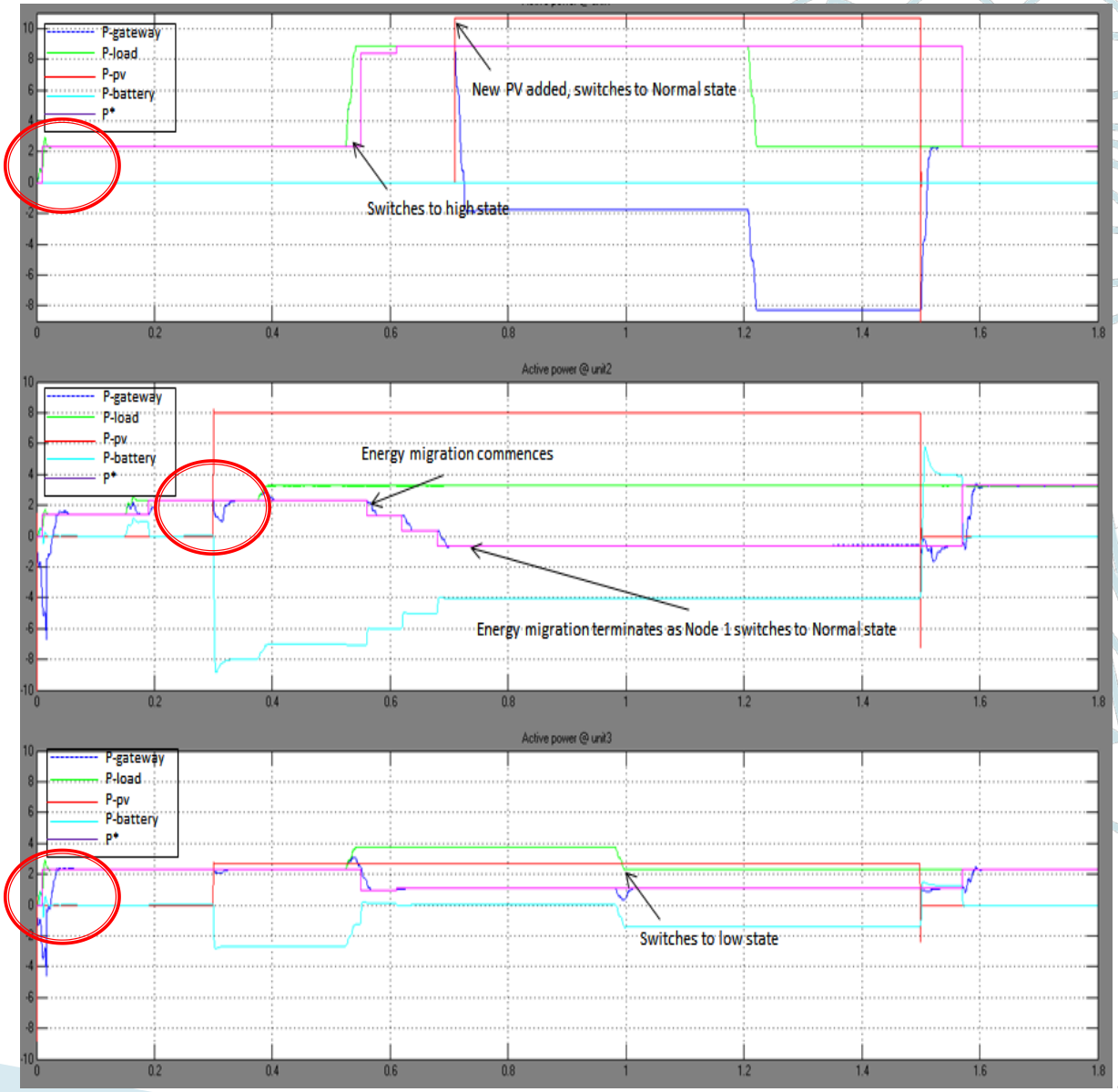
Results – 3 Node with additional DESD

At t = 0.3









Results – 3 Node with additional DESD

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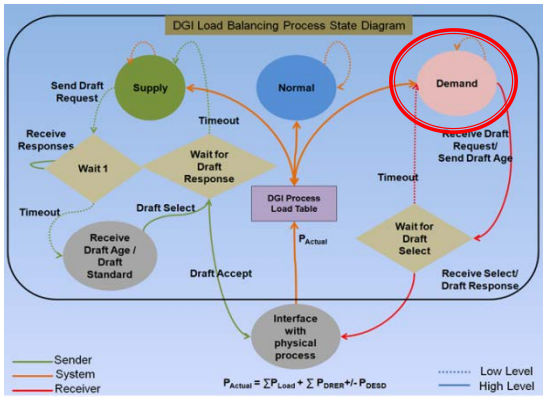
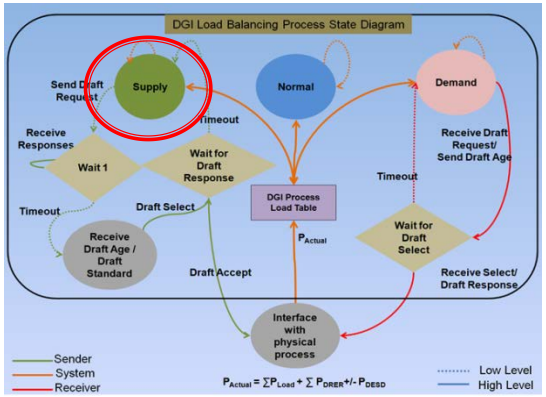
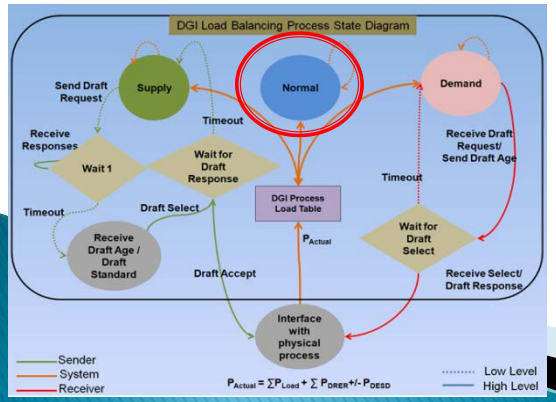
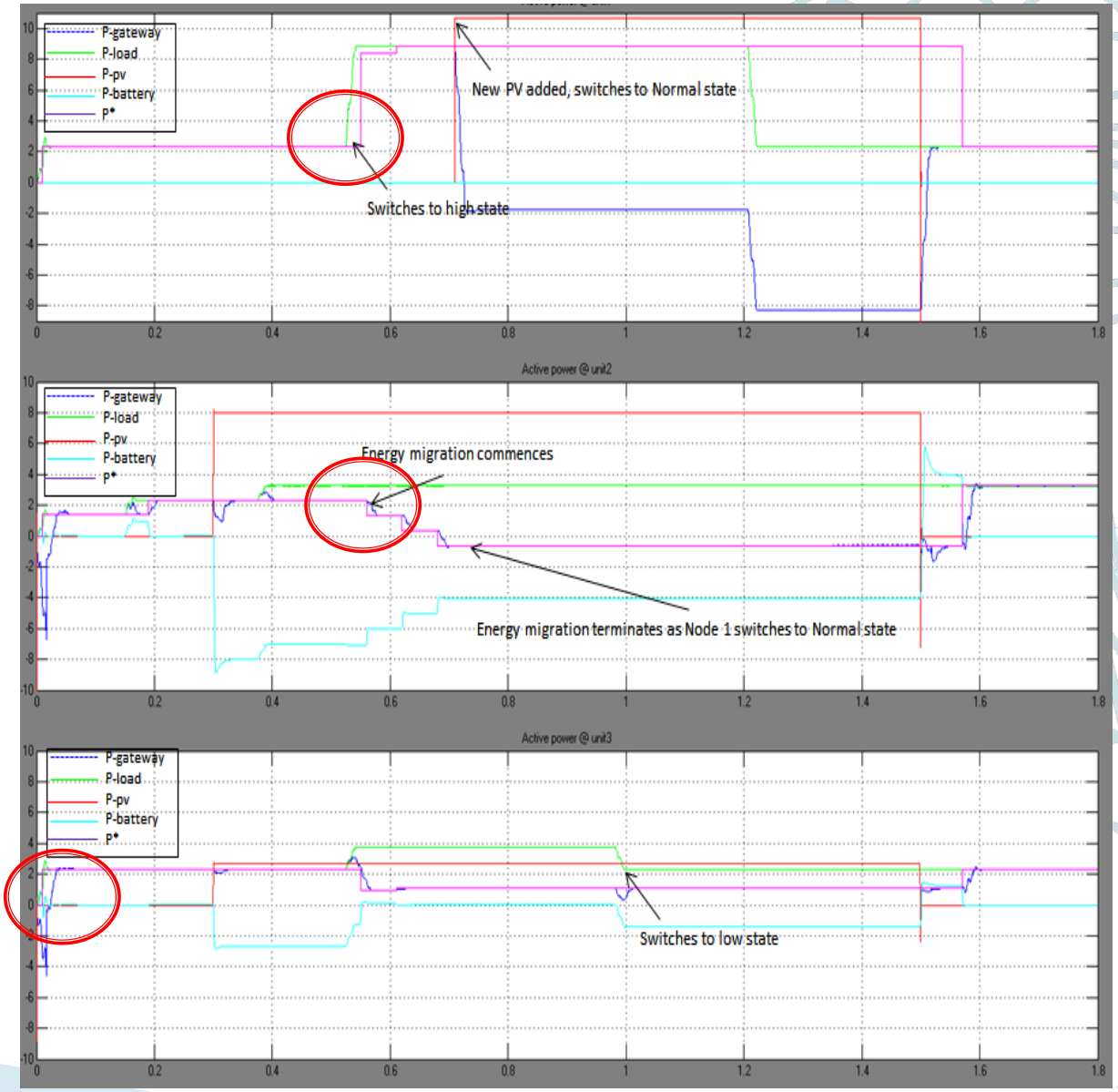


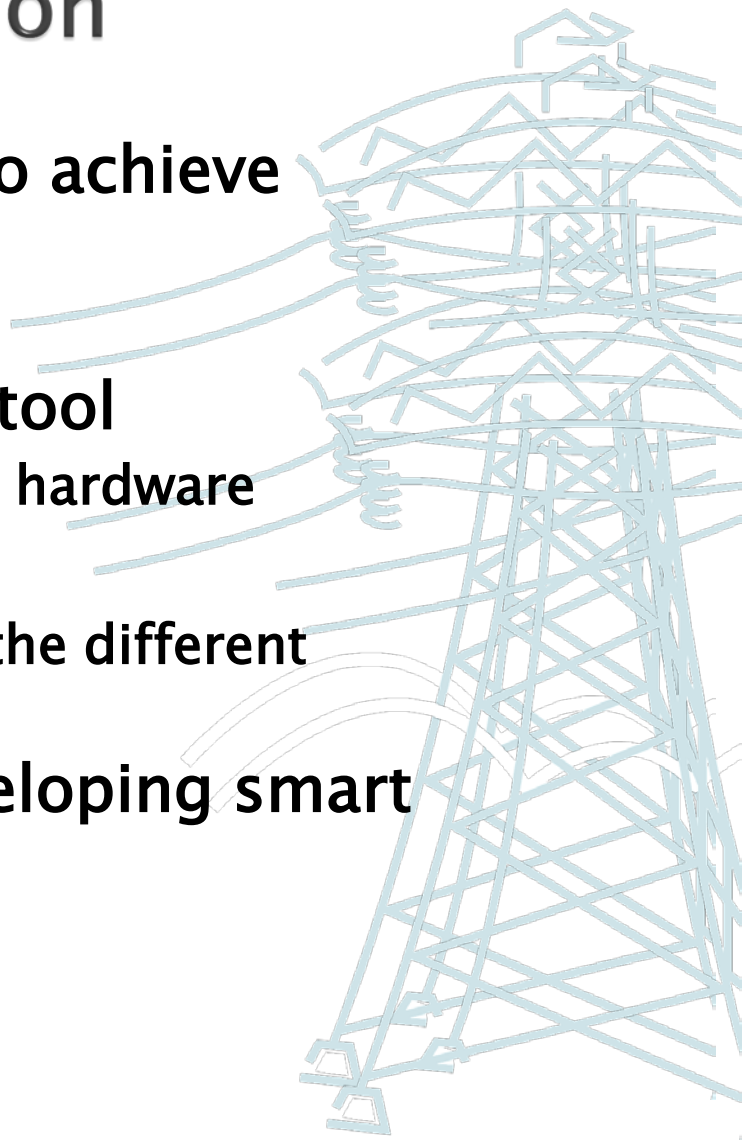






Conclusion

- Use of different IEC61499 tools to achieve interoperability.
  - Use of 4DIAC and NxtStudio
- Multi-platform use of the 4DIAC tool
  - Cross compiled the run time to target hardware
- Some important learning's
  - Difference in execution semantics of the different IEC61499 tool vendors.
- Use of 4DIAC (IEC61499) for developing smart grid applications.



Future Work

- We are porting all our smart grid applications to 4DIAC
- SIFB's for ARM board peripherals and communication blocks for MATLAB

Thank you

Questions?