

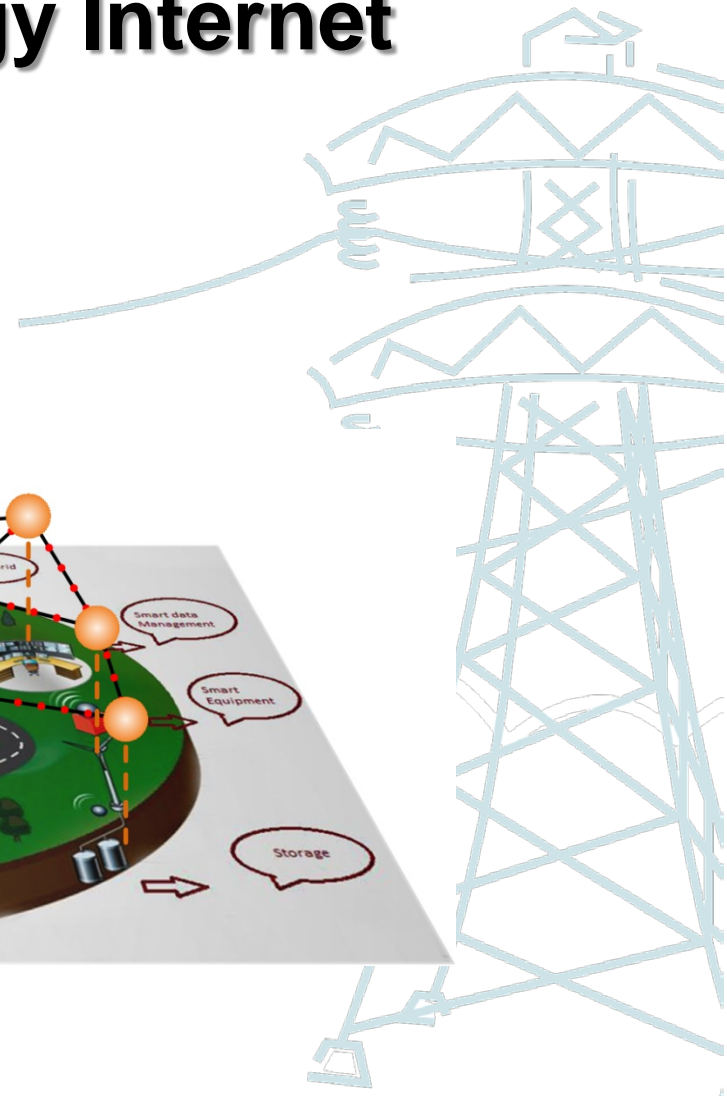
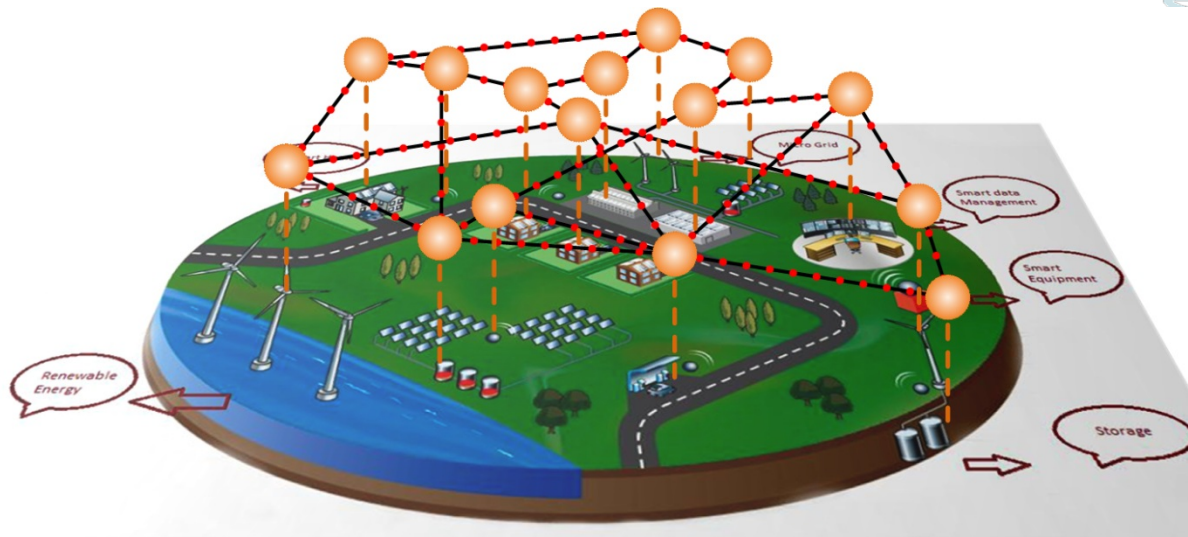


IEC61499 Function Block implementation of distributed Load Balancing for FREEDM System

Sandeep Patil
Valeriy Vyatkin
Chen-Wei Yang
Gulnara Zhabelova



Smart Grid as Energy Internet

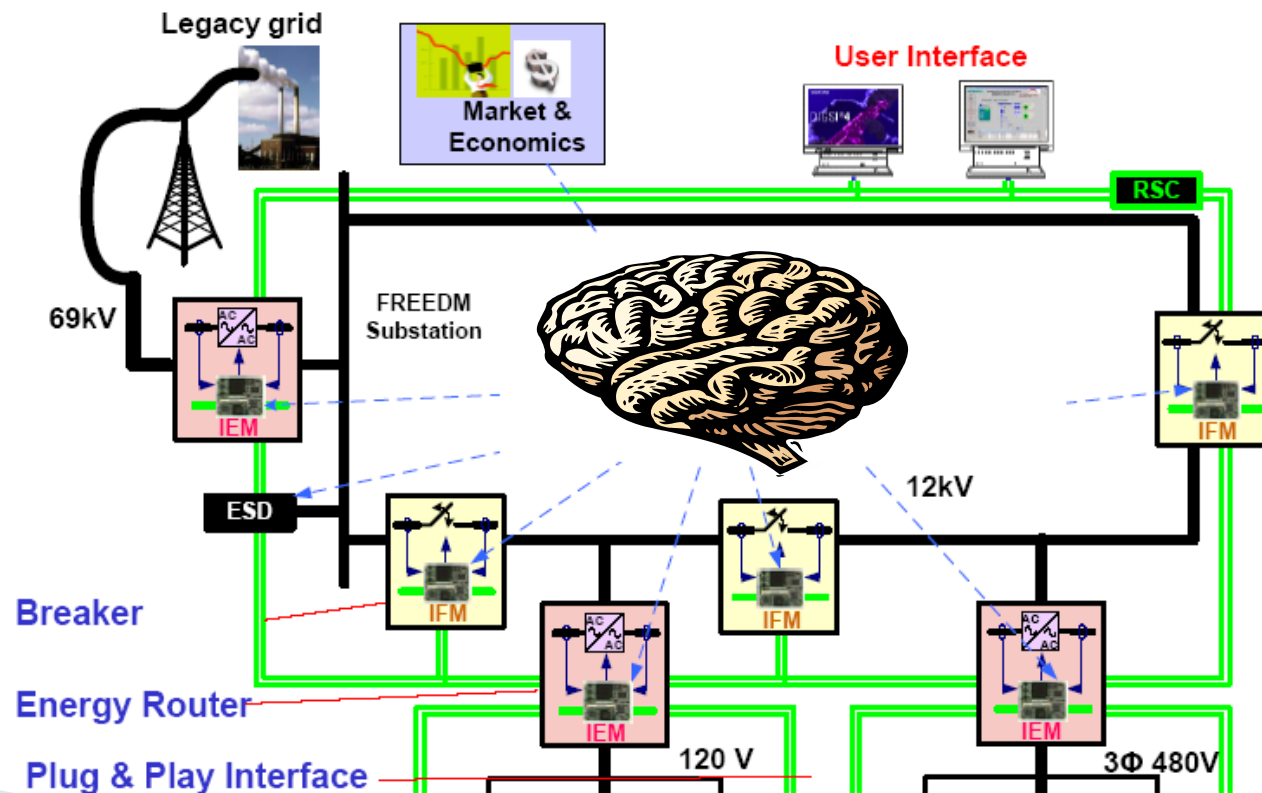


FREEDM NSF Project

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”

TR10 - Technology Review
www.technologyreview.com/tr10/

technology review
Published by MIT

English | en Español | auf Deutsch | in Italiano | 中文 | in India

HOME COMPUTING WEB COMMUNICATIONS ENERGY MATERIALS BIOMEDICINE BUSINESS

10 EMERGING TECHNOLOGIES 2011

Every year, Technology Review looks at the advances that have happened over the previous year and chooses 10 emerging technologies that we think will have the greatest impact. The ultimate criterion is straightforward: is the technology likely to change the world? This year's group includes high-energy batteries that could make cheaper hybrid and electric vehicles possible and a new class of electrical transformers that could stabilize power grids. Some of our choices will alter how you use technology: you'll be tapping into computationally intensive applications on mobile devices, or using gestures to command computers that are embedded in televisions and cars. Other choices could improve your health; for instance, doctors will craft more effective cancer treatments by understanding the genetics of individual tumors. But no matter the category, all 10 promise to make our lives better.

Watch the TR10 Video Introduction

View by: Show All

- Social Indexing**
Facebook remaps the Web to personalize online services
- Homomorphic Encryption**
Making cloud computing more secure
- Smart Transformers**
Controlling the flow of electricity to stabilize the grid
- Cloud Streaming**
Bringing high-performance software to mobile devices
- Gestural Interfaces**
Controlling computers with our bodies
- Crash-Proof Code**
Making critical software safer
- Cancer Genomics**
- Separating**

MAGAZINE: TR 10
Smart Transformers
Controlling the flow of electricity to stabilize the grid
MAY/JUNE 2011 | BY DAVID H. FREEDMAN

In a lab wired up to simulate a residential neighborhood, Alex Huang is working to revamp aging power grids into something more like the Internet—a network that might direct energy not just from centralized power stations to consumers but from any source to any destination, by whatever route makes the most sense. To that end, Huang, a professor of electrical engineering at North Carolina State University, is reinventing the transformers that currently reduce the voltage of the electricity distributed to neighborhoods so that it's suitable for use in homes and offices.

His new transformer will make it easier for the grid to cope with things it was never designed for, like charging large numbers of electric vehicles and tapping surplus

Powerful electronics: The smart transformer can handle AC and DC power and, thanks to semiconductors capable of handling high voltages, be programmed to redirect the flow of electricity in response to fluctuations in supply and demand.
A. High-voltage semiconductor-based AC rectifier.
B. High-voltage semiconductor-based DC converter.
C. High-frequency transformers.
D. Control circuitry. Credit: Bryan Regan

Alex Huang
(North Carolina State University) Directing the flow of energy more precisely could mean more resilient and efficient grids.

Others working on Smart Transformers
Amantys, Cambridge, U.K.
Cree, Durham, North Carolina
Electric Power Research Institute, Palo Alto, California

To build such a transformer, Huang started developing transistors and other semiconductor-based devices that can handle thousands of volts, founding the Future Renewable Electric Energy Delivery and Management Systems Center at NC State in 2008. His first transformer had silicon-based components, but silicon is too unreliable for large-scale use at high voltages. So Huang has pioneered the development of transformers with semiconductors based on compounds of silicon and carbon or gallium and nitrogen, which are more reliable in high-power applications. He expects to have a test version of the silicon-carbon transformer ready in two years and to have a device that utilities can test in five years.

Distributed Grid Intelligence

Legacy grid



User Interface



Intelligent Energy Managing (IEM) Node

Distributed System Management (Broker Architecture)

Group Management (Election Algorithm)

Power Balancing Algorithm

Incremental Cost Consensus Algorithm

Distributed State Collection Algorithm

Fault Management

DGI Process

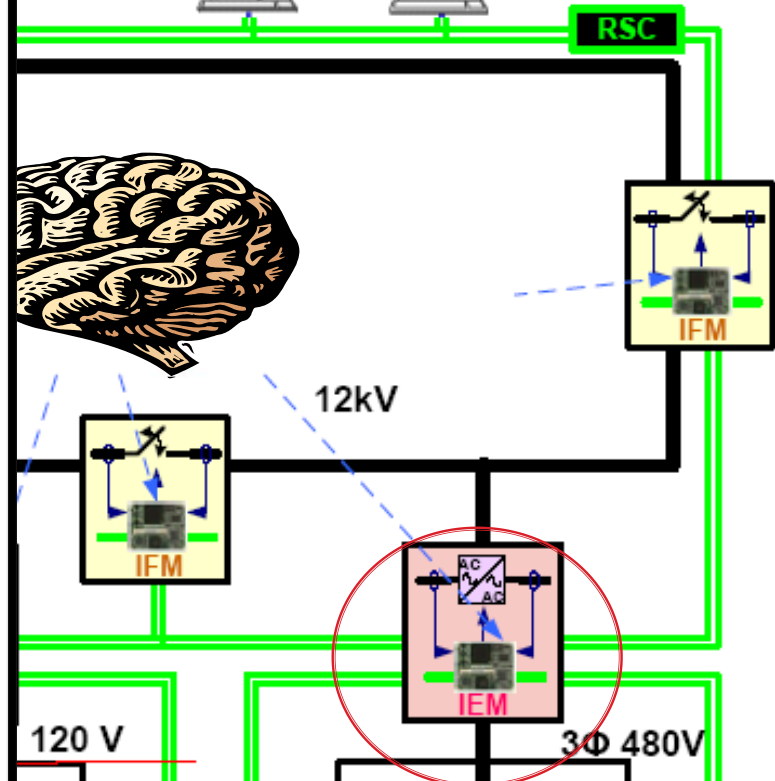
Micro Controller

SST

DESD

DRER

LOAD

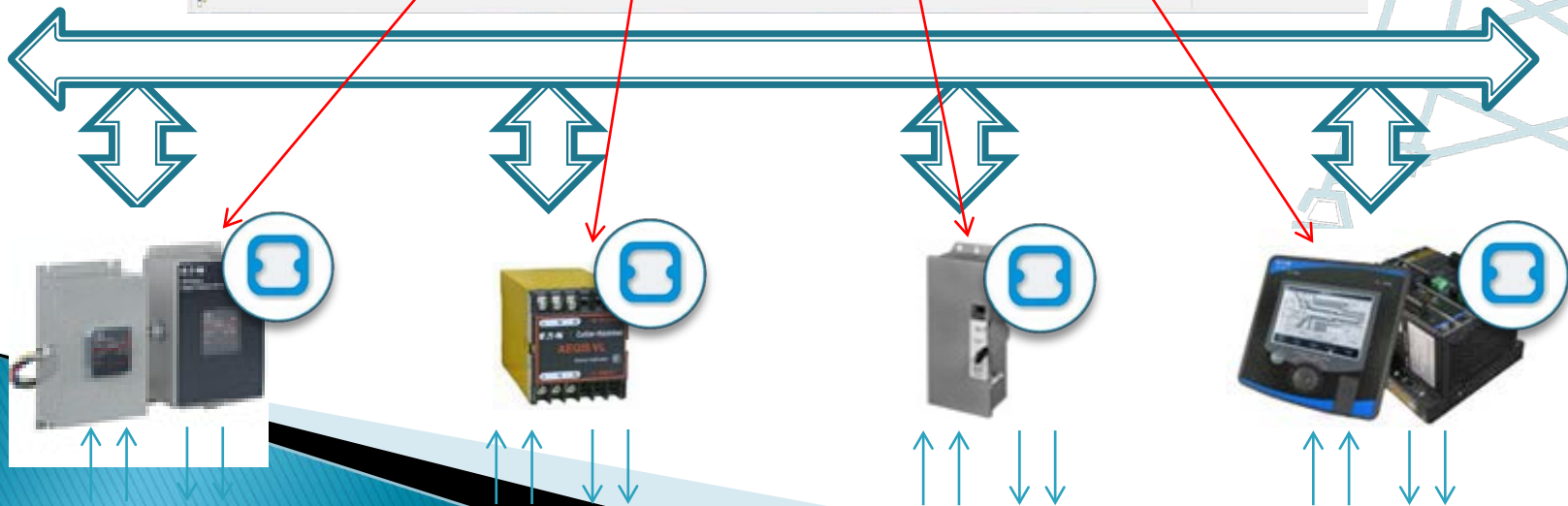
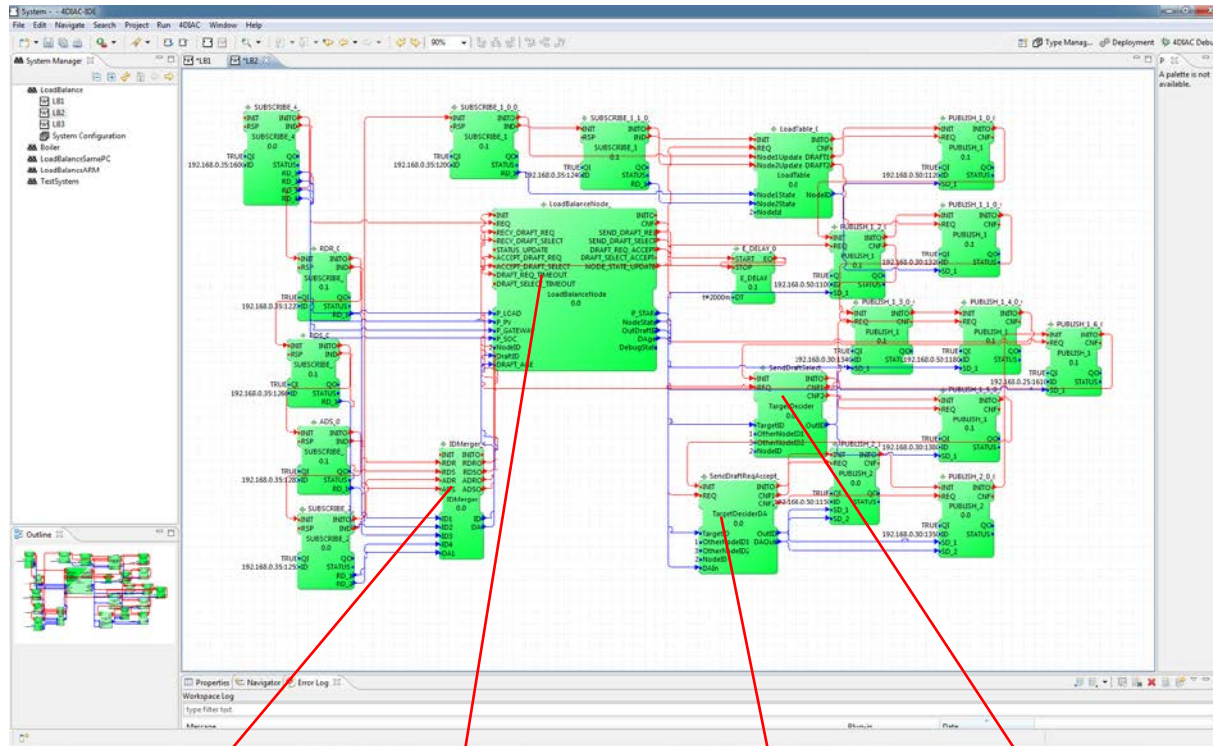


A. Q. Huang, M. L. Crow, G. T. Heydt, J. P. Zheng, and S. J. Dale, "The Future Renewable Electric Energy Delivery and Management (FREEDM) System: The Energy Internet," *Proceedings of the IEEE*, vol. 99, pp. 133-148, 2011

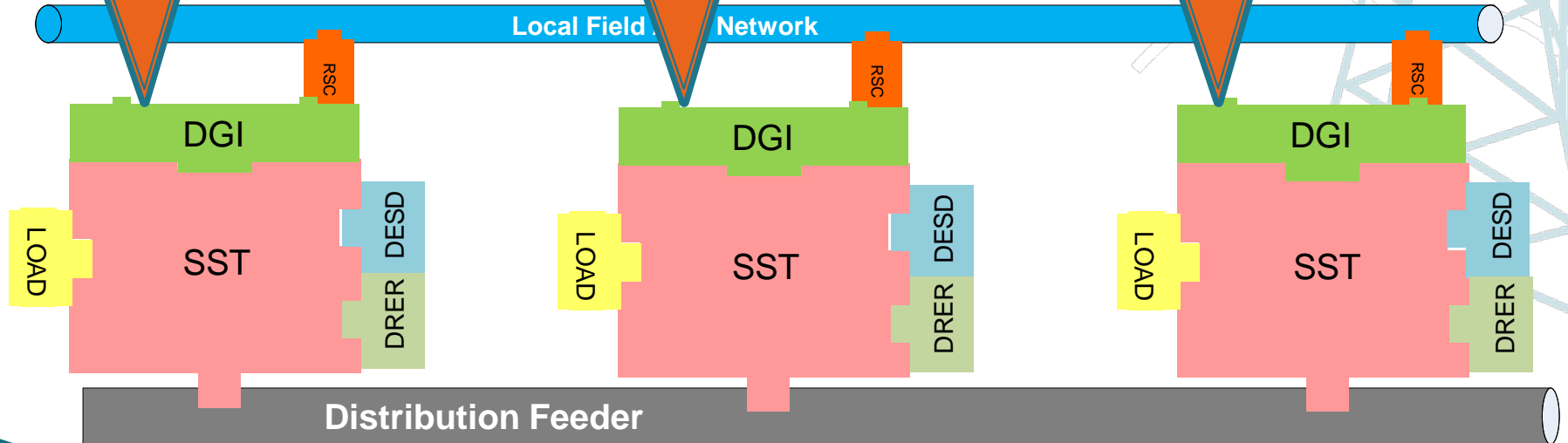
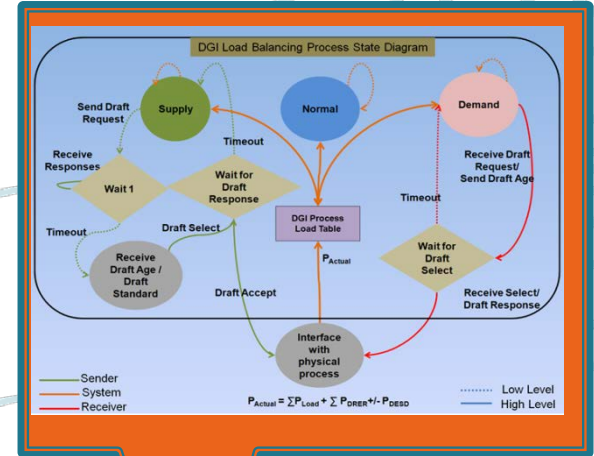
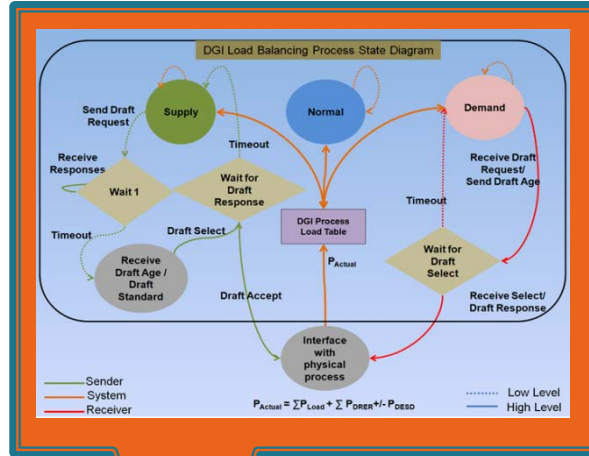
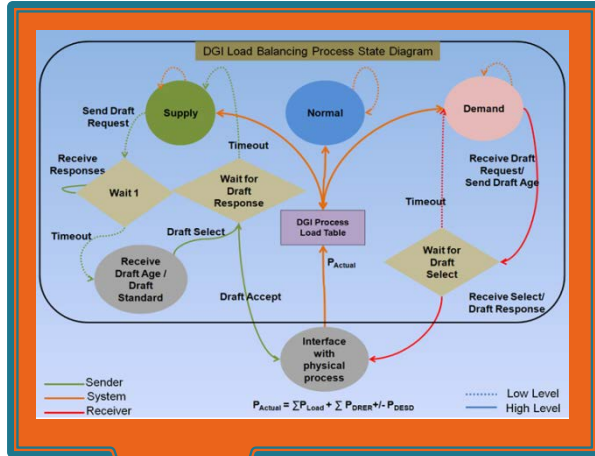
Why IEC 61499 ?

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

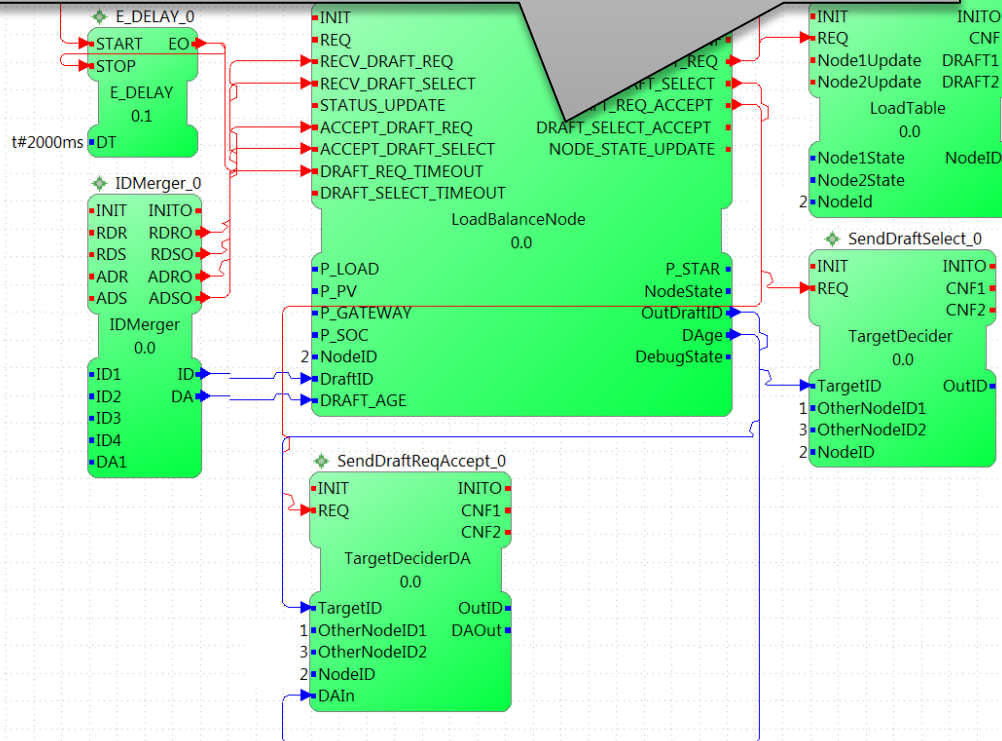
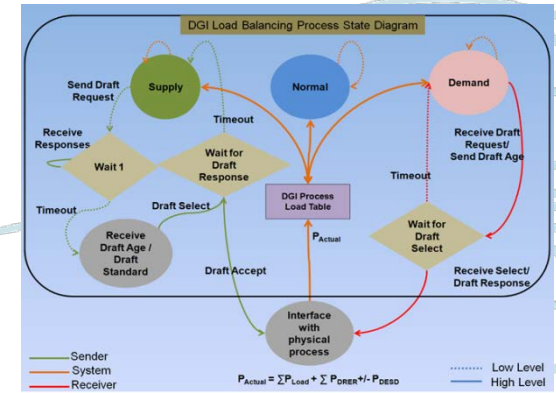
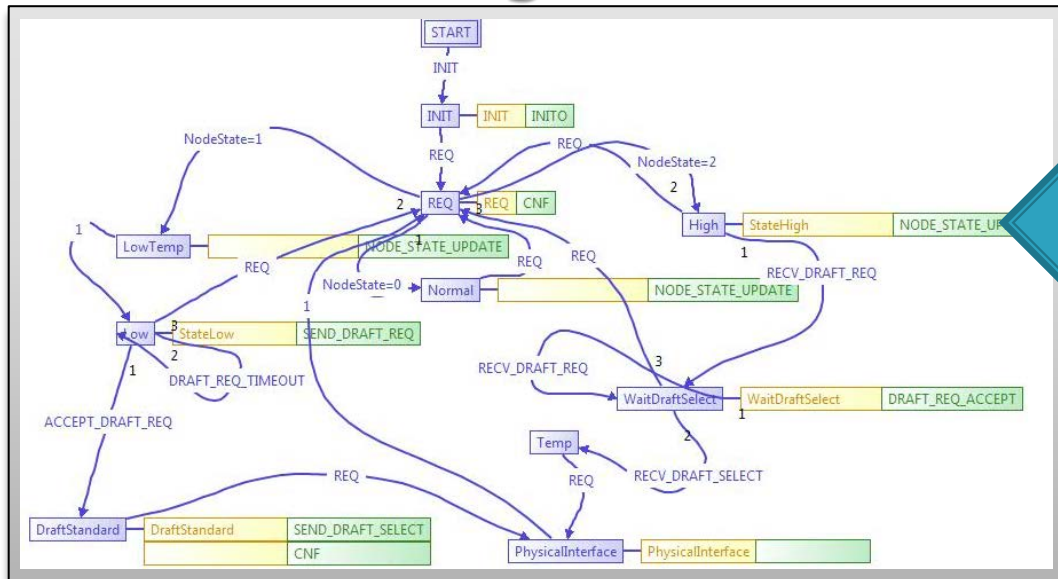
Direct Distributed System Programming + System-level Validation



DGI: Load Balancing

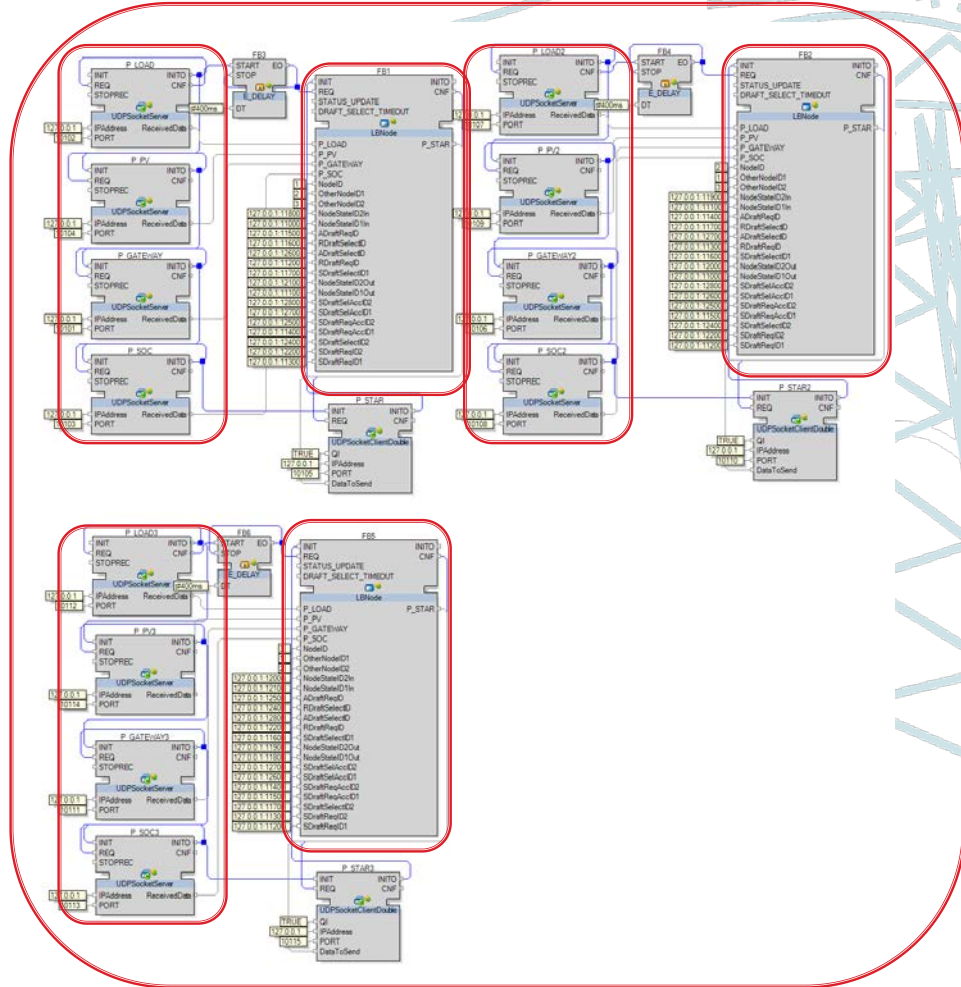
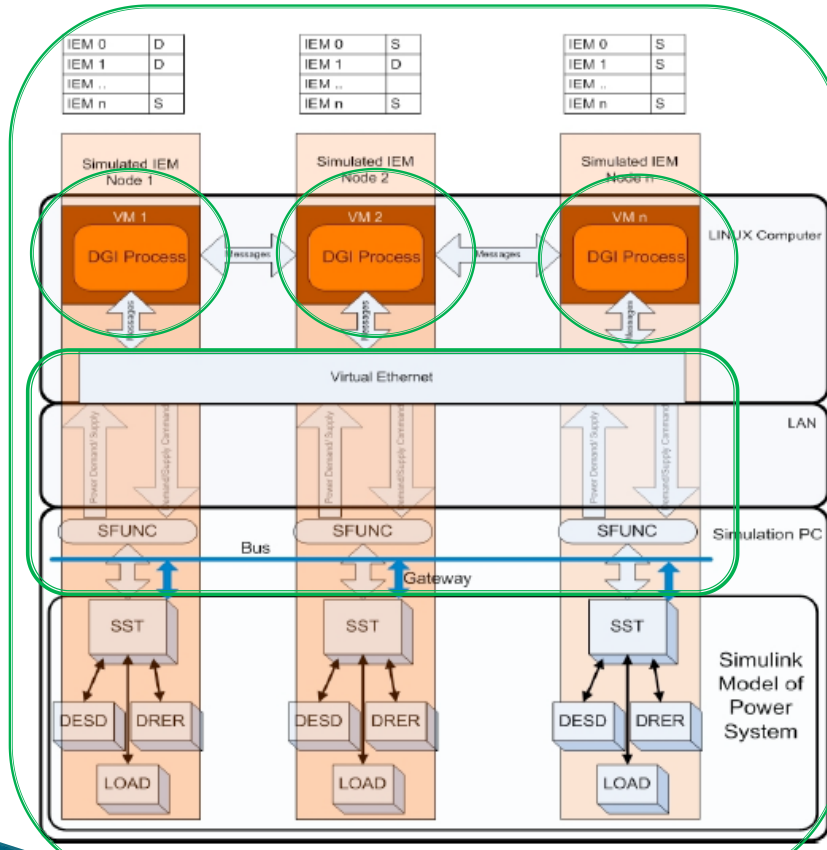


Load Balancing: Model-based Software Engineering



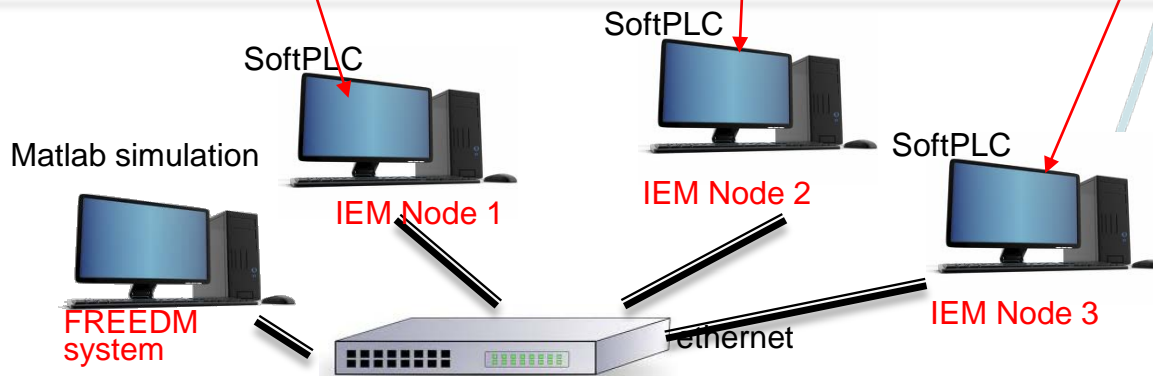
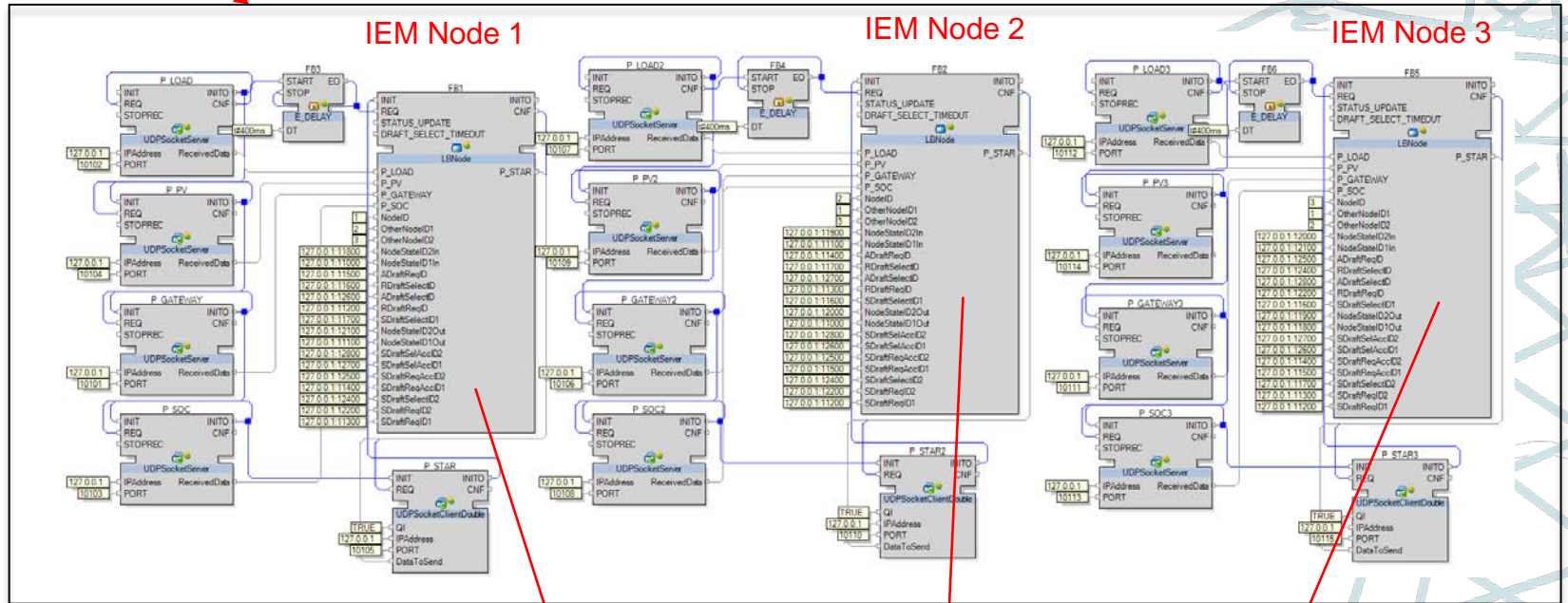
Load Balancing System model Initially in NxtStudio

- ▶ Load balancing application system level model



Exploring Portability benefits of IEC 61499

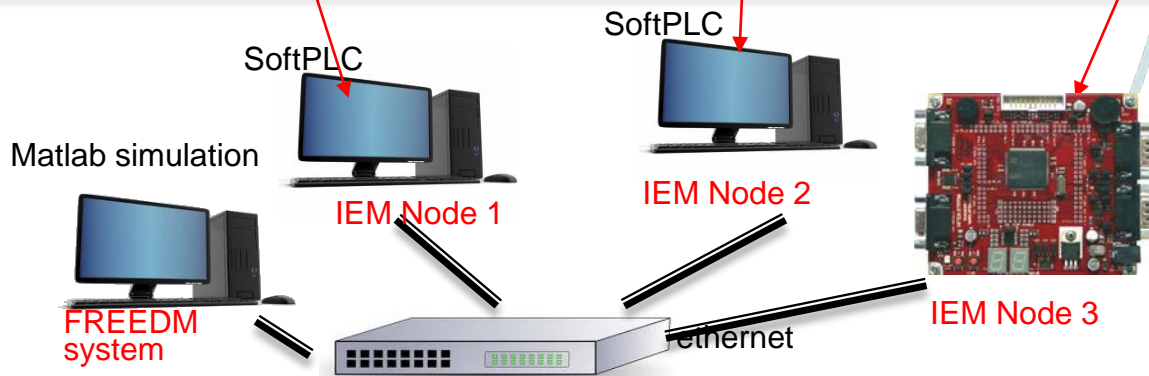
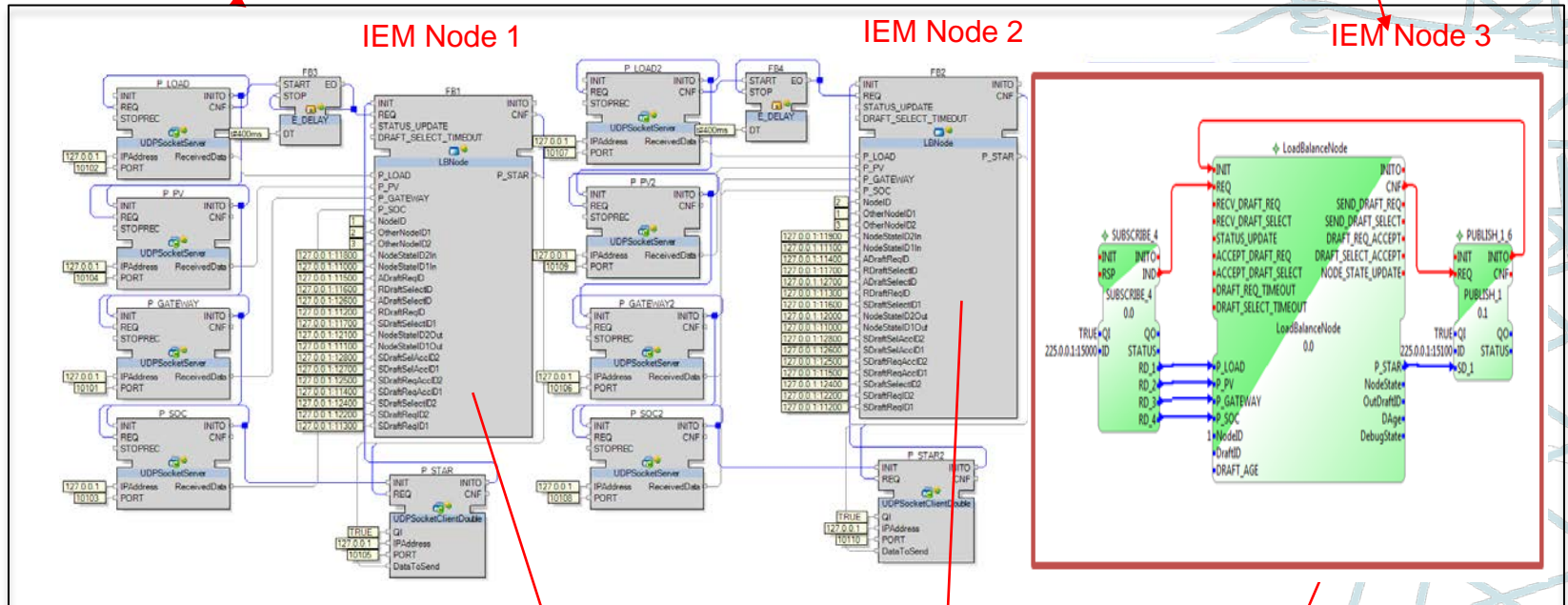
FB application designed in NxtStudio



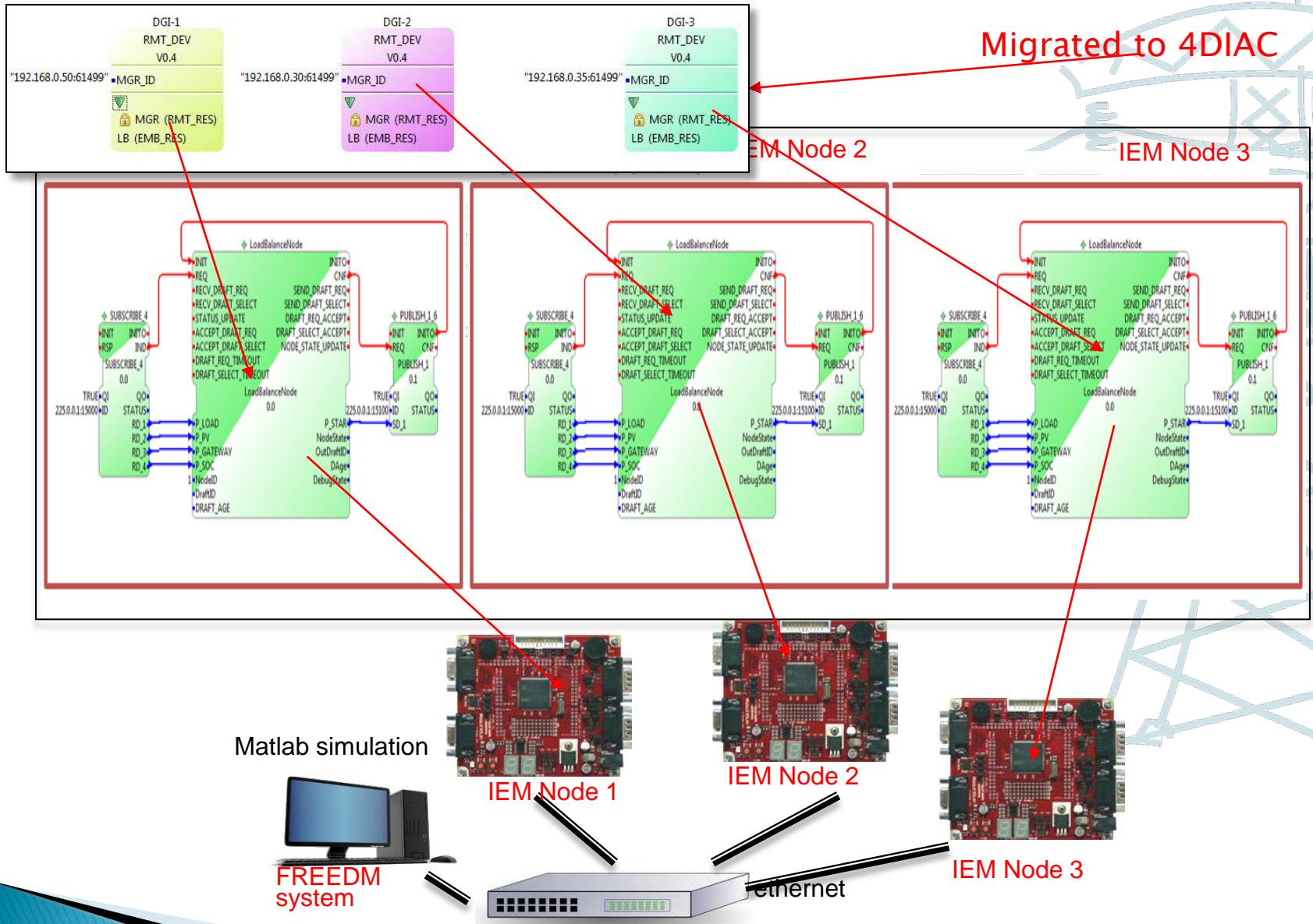
Exploring Portability benefits of IEC 61499

FB application designed in NxtStudio

Migrated to 4DIAC



Exploring Portability benefits of IEC 61499



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.

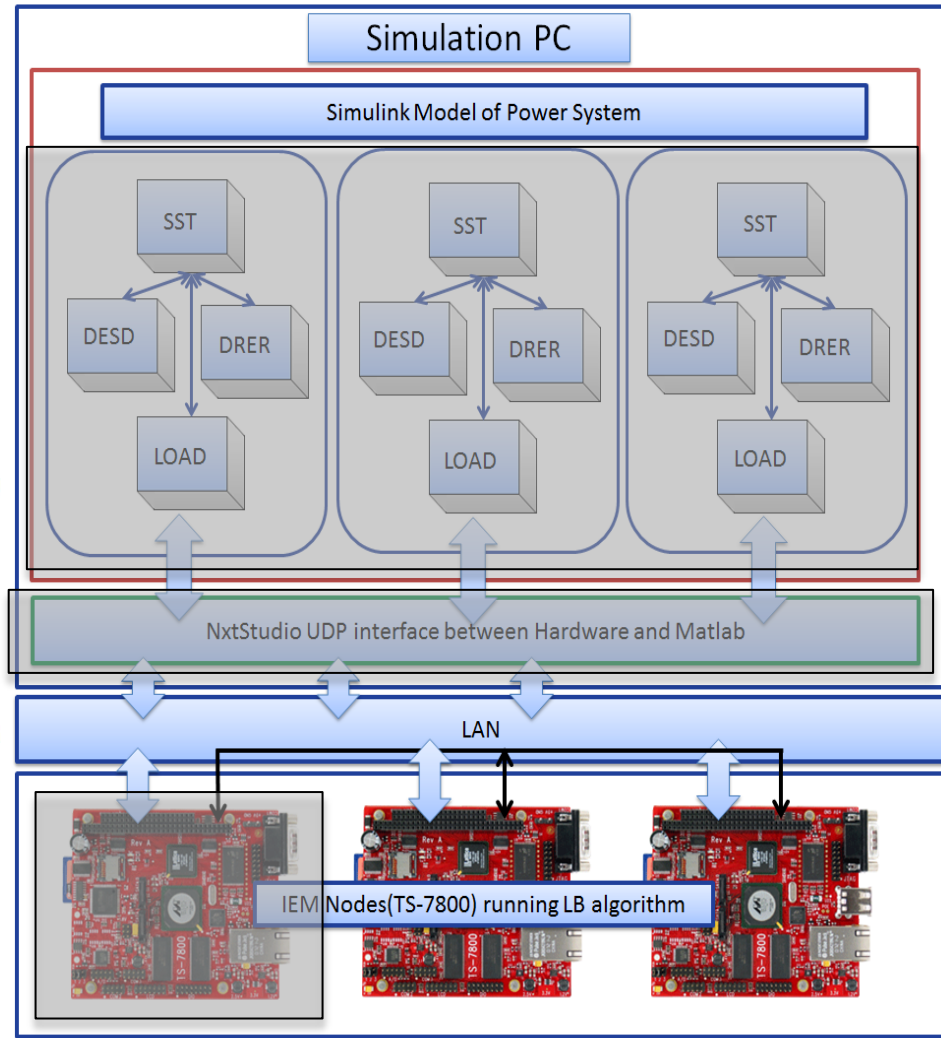
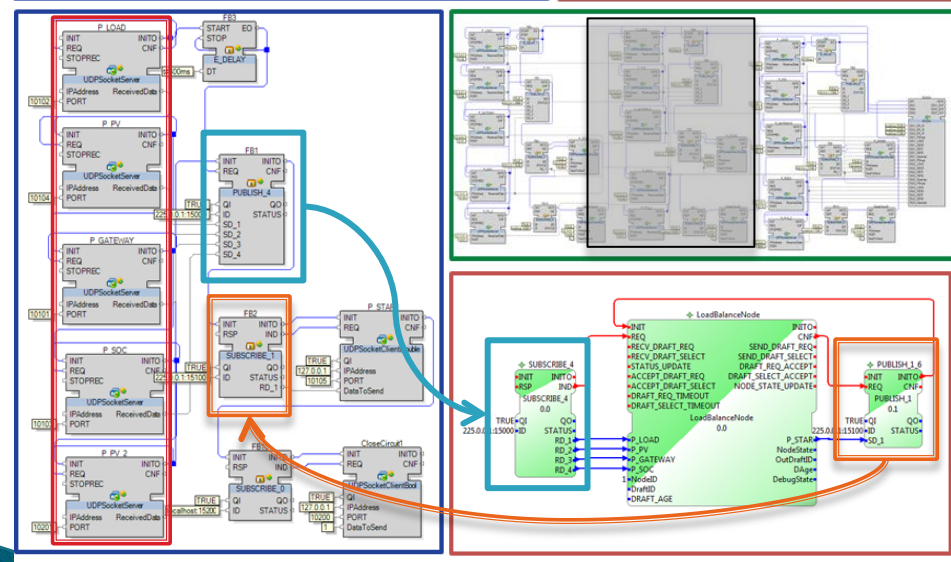
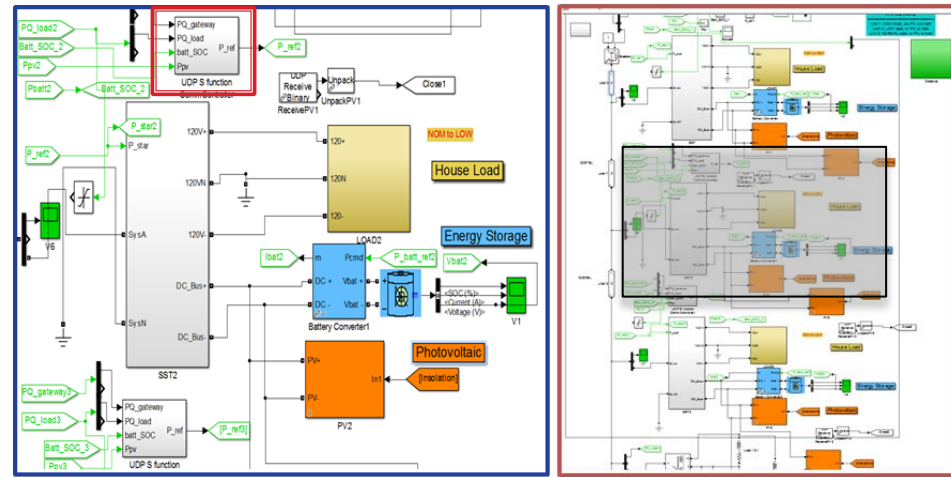


Any issues with semantic differences?

- ▶ None for this application



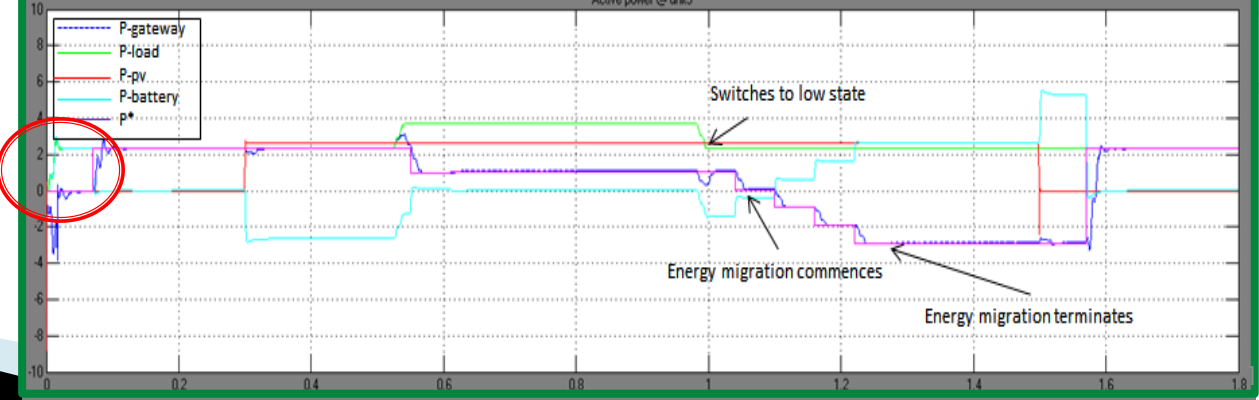
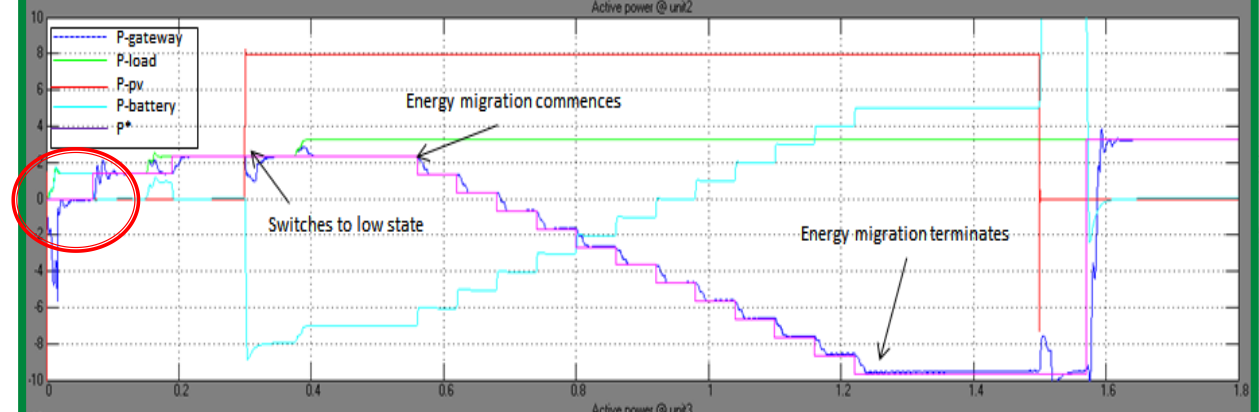
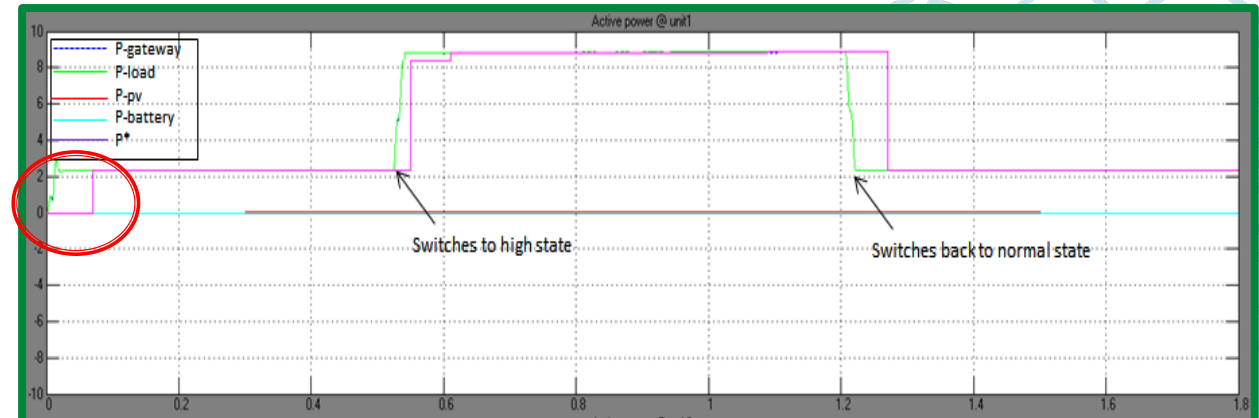
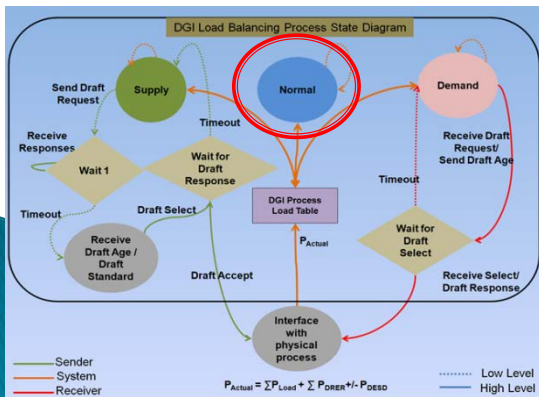
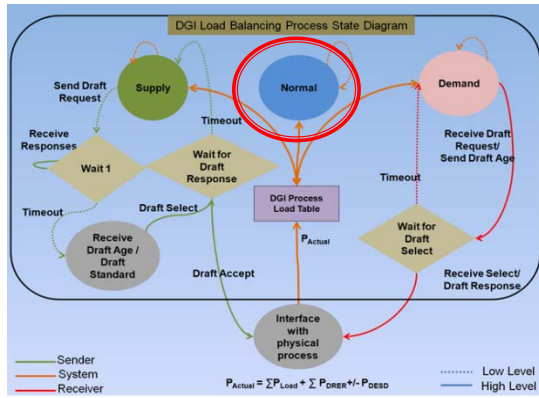
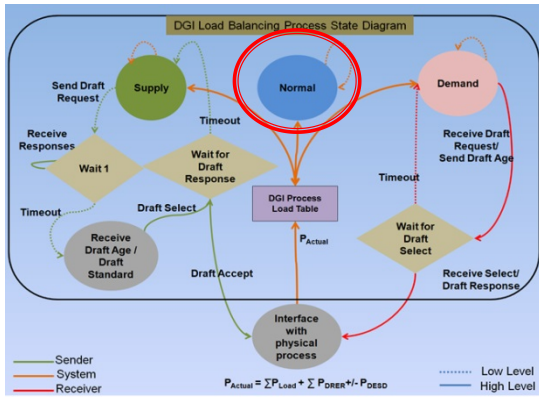
Load Balancing Co-Simulation Setup



Communication between Matlab and NxtStudio Interface
Communication between NxtStudio Interface and ARM Boards (4DIAC)

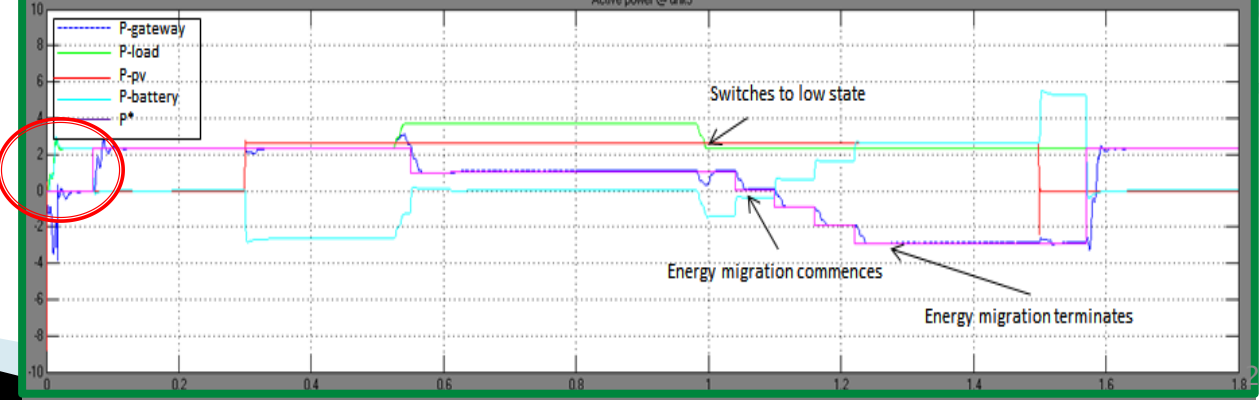
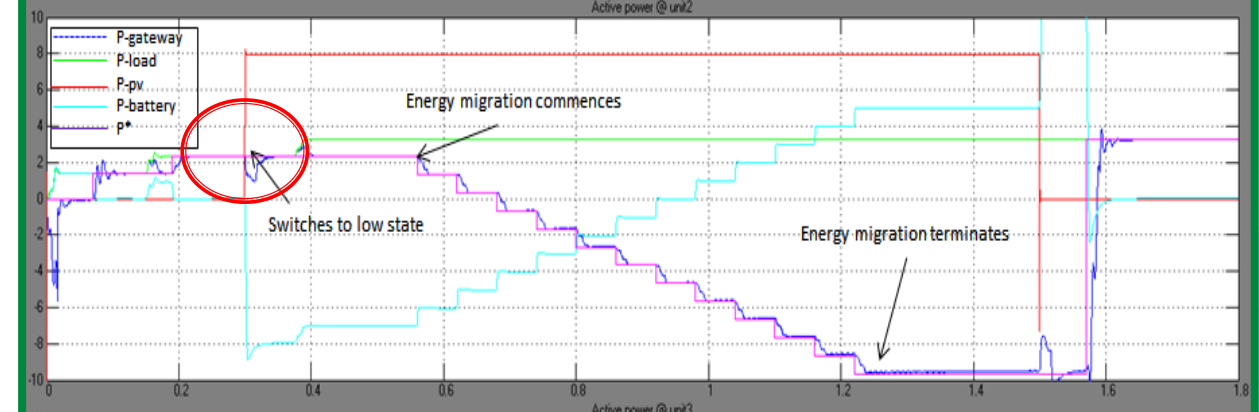
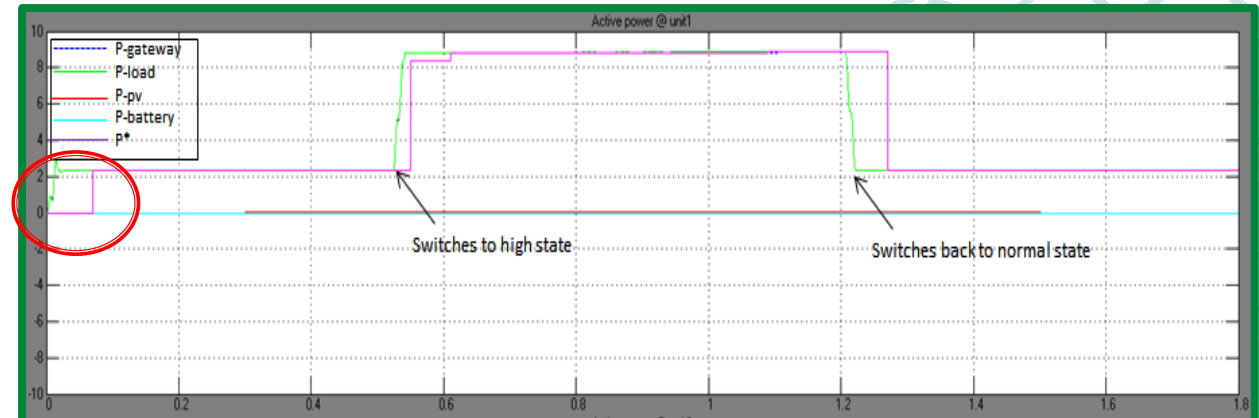
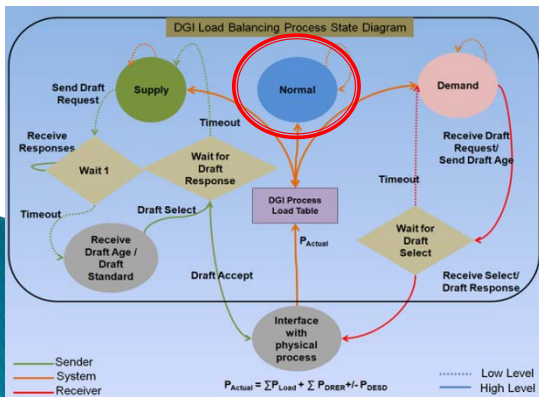
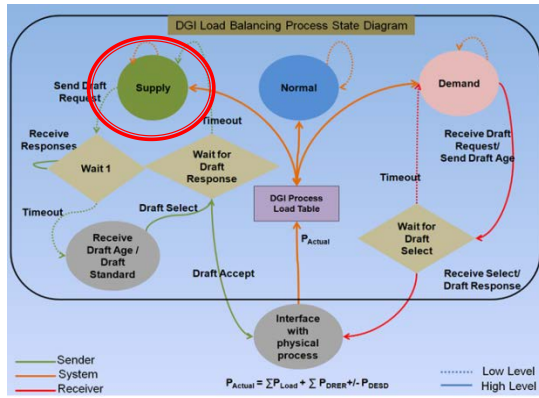
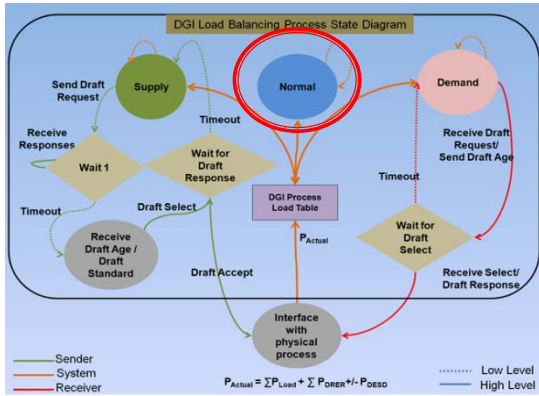
Results - 3 Node without additional DESD

At t = 0



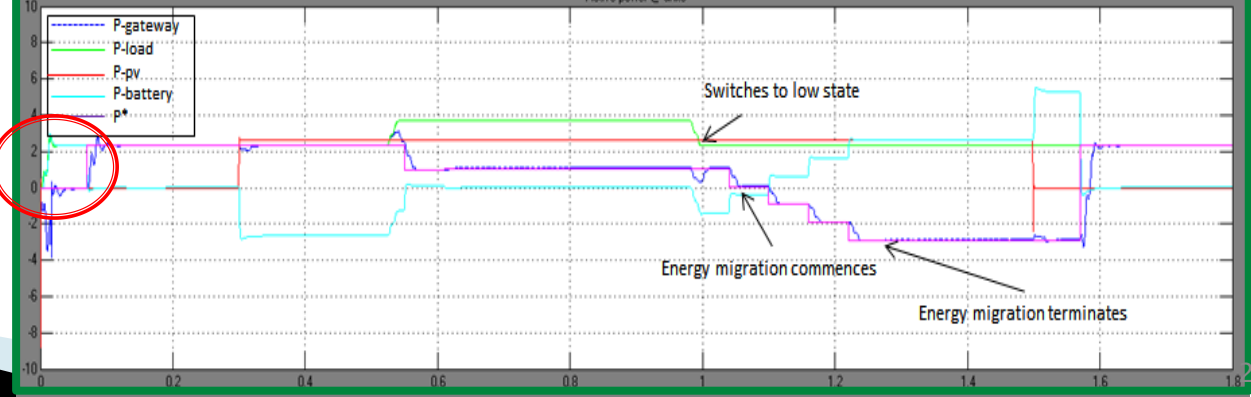
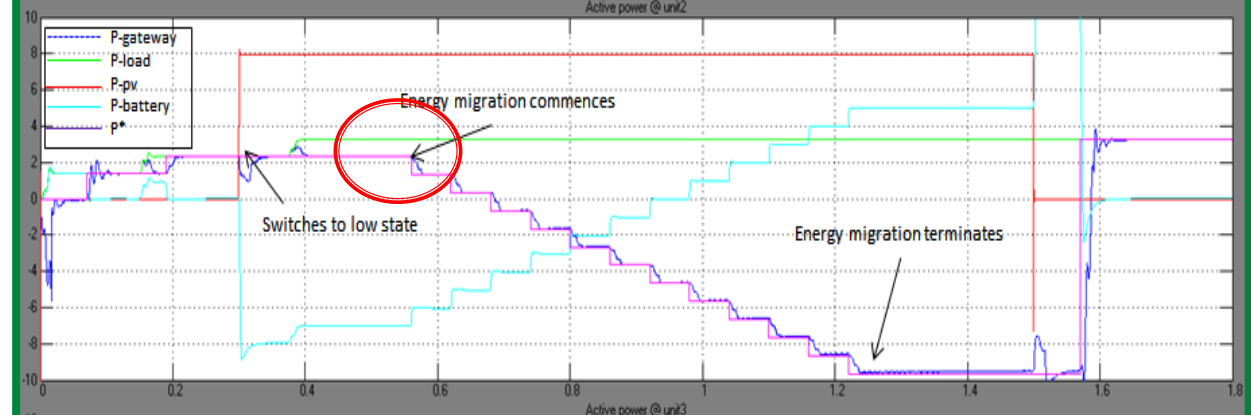
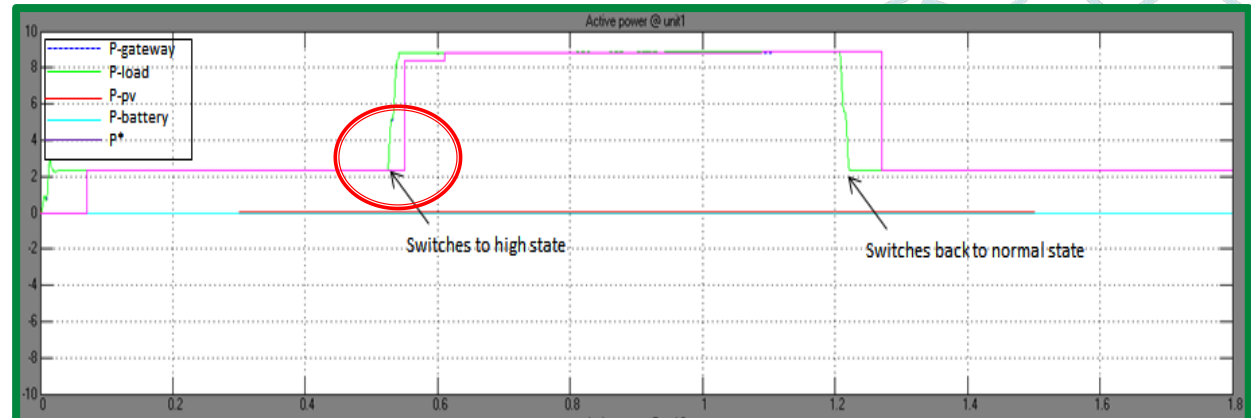
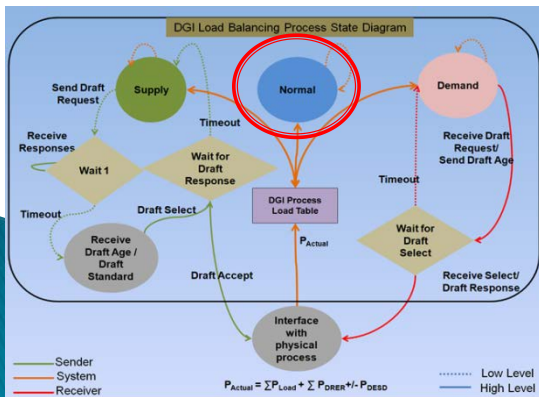
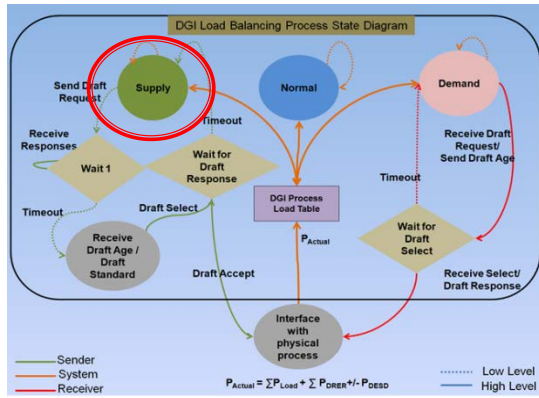
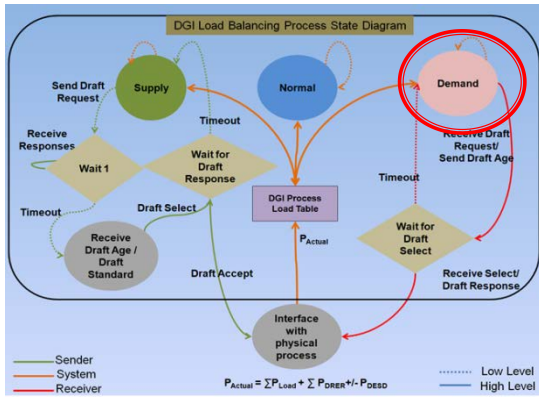
Results - 3 Node without additional DESD

At $t = 0.3$



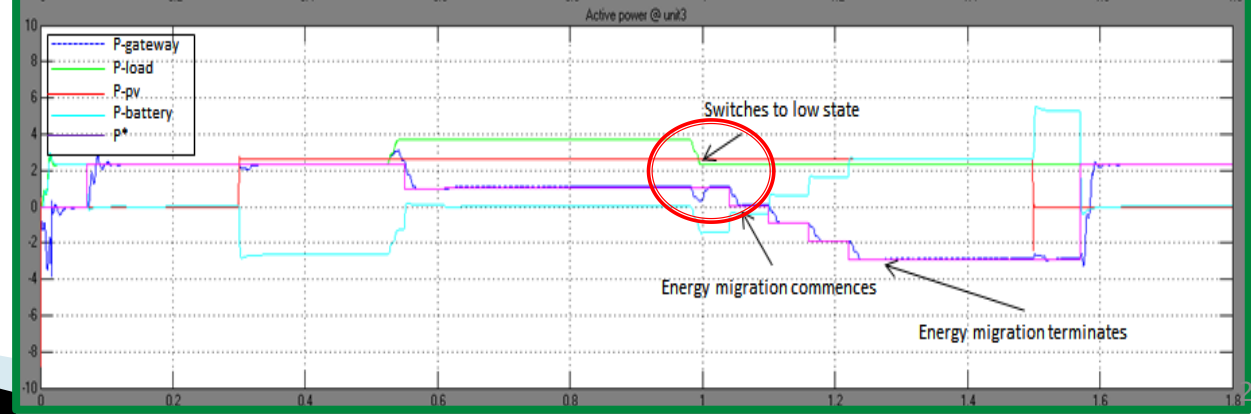
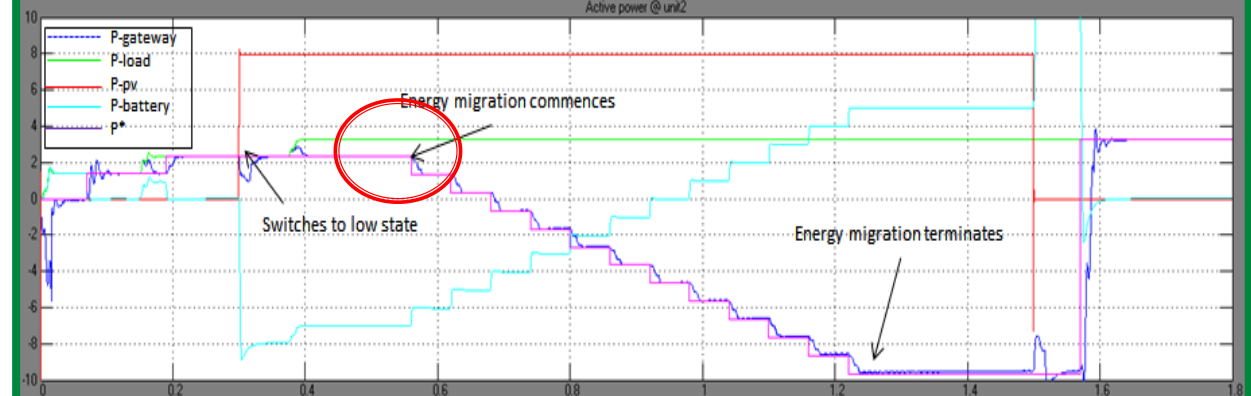
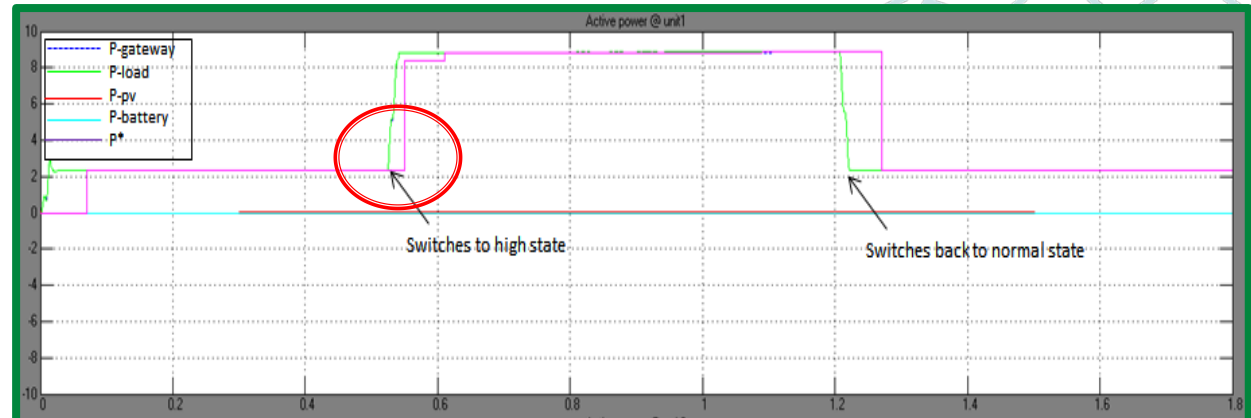
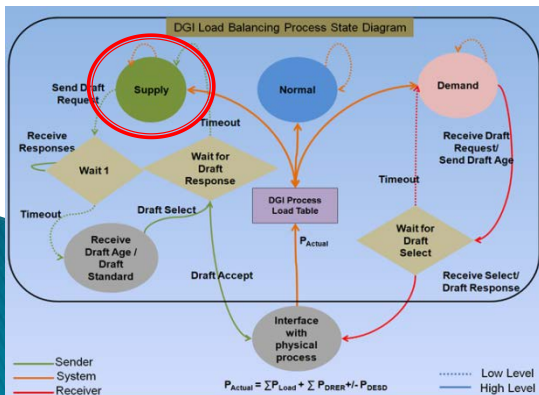
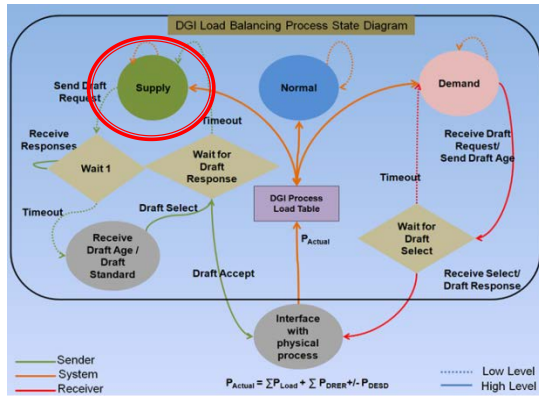
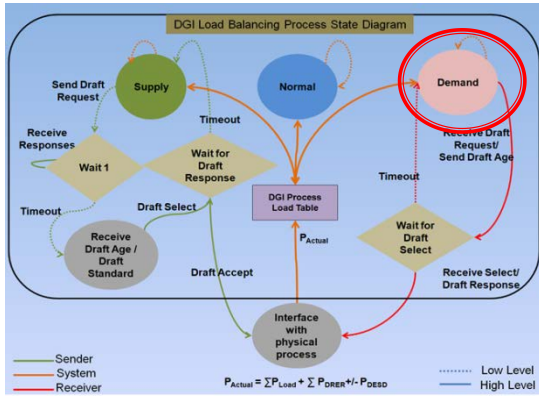
Results - 3 Node without additional DESD

At $t = 0.525$



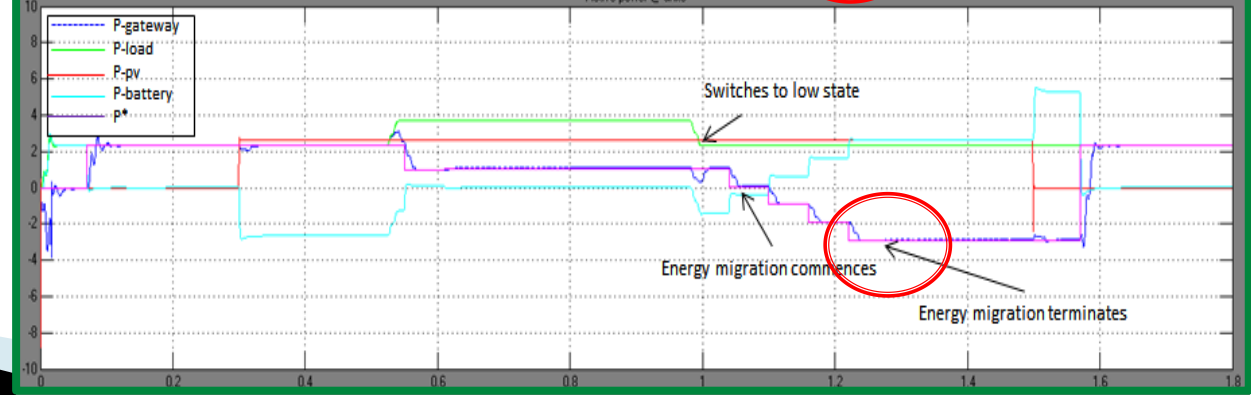
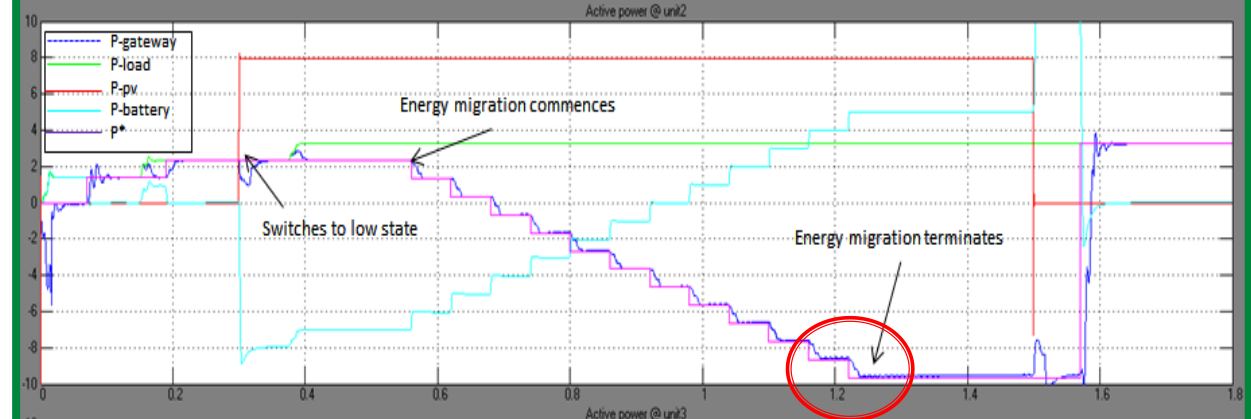
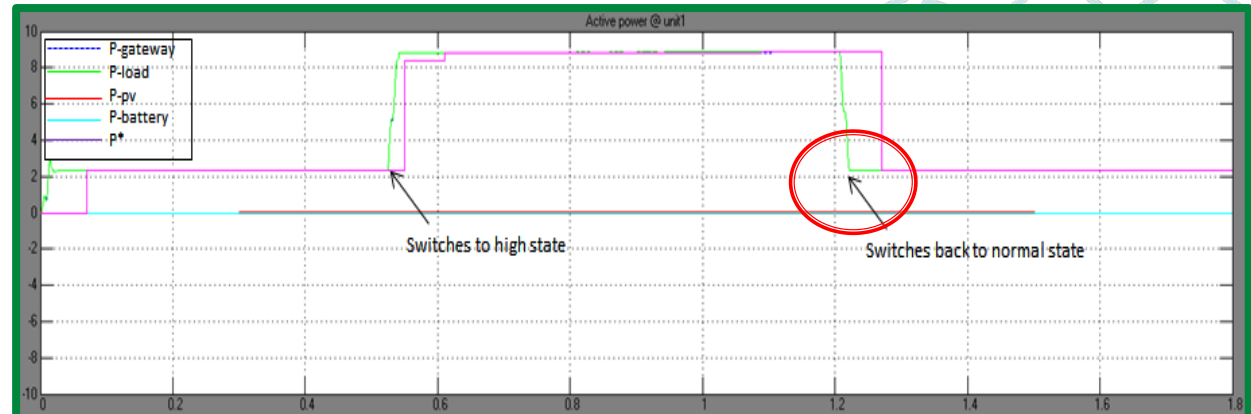
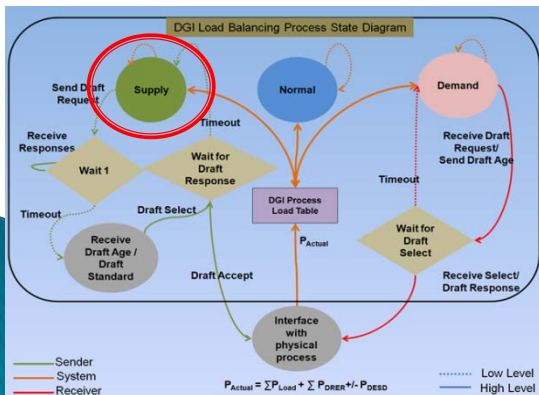
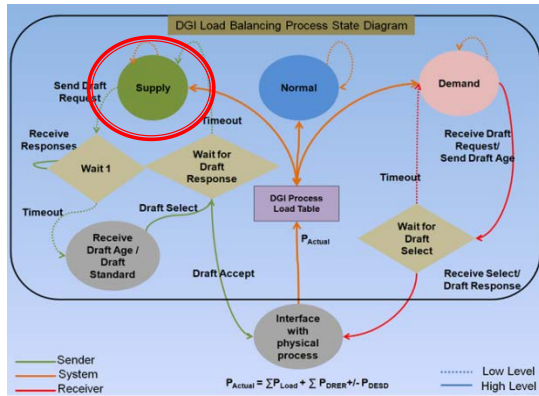
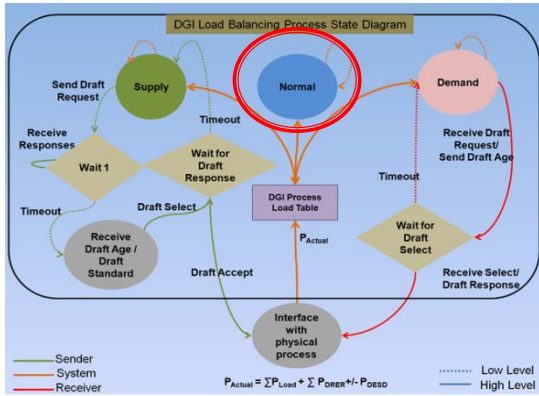
Results - 3 Node without additional DESD

At t = 1.0

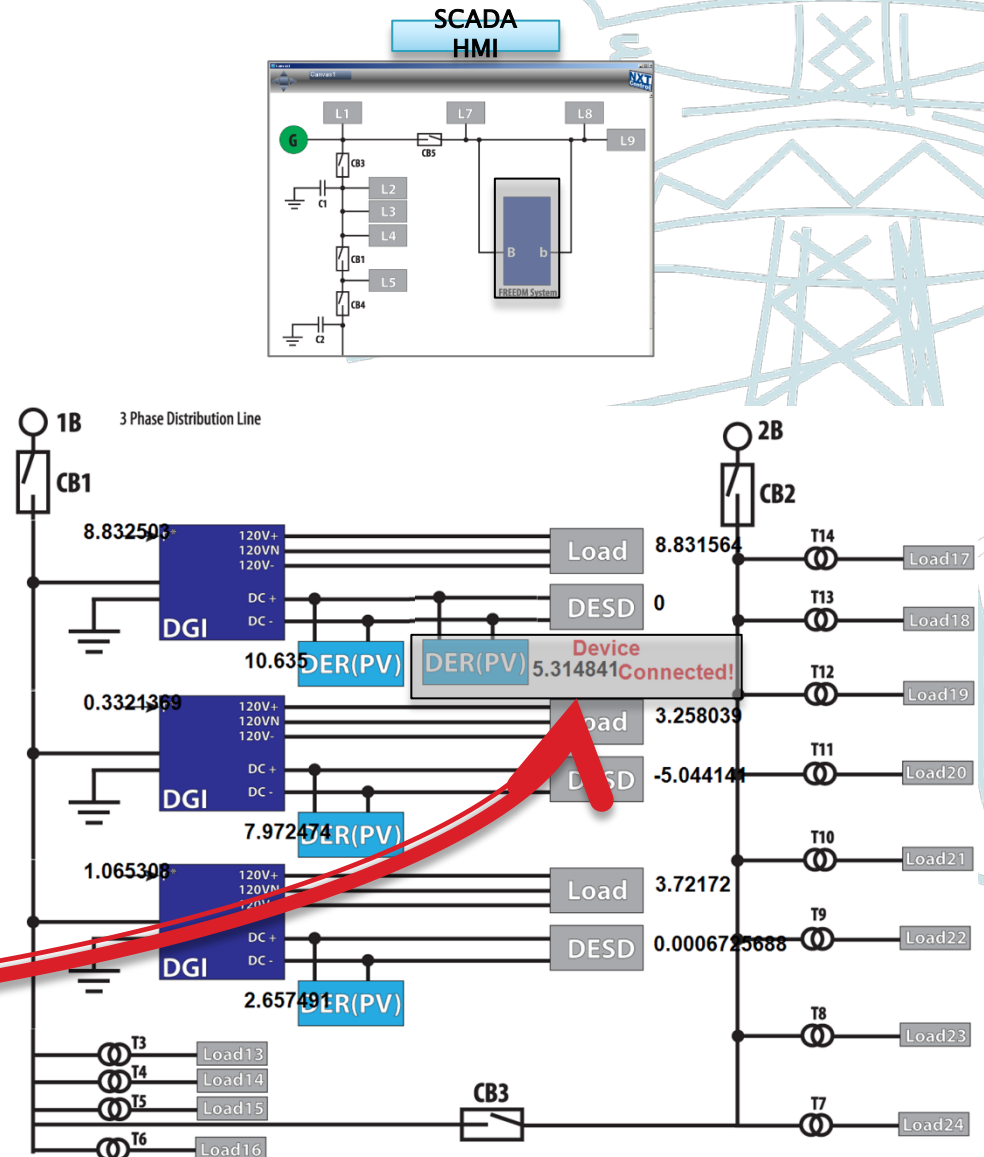
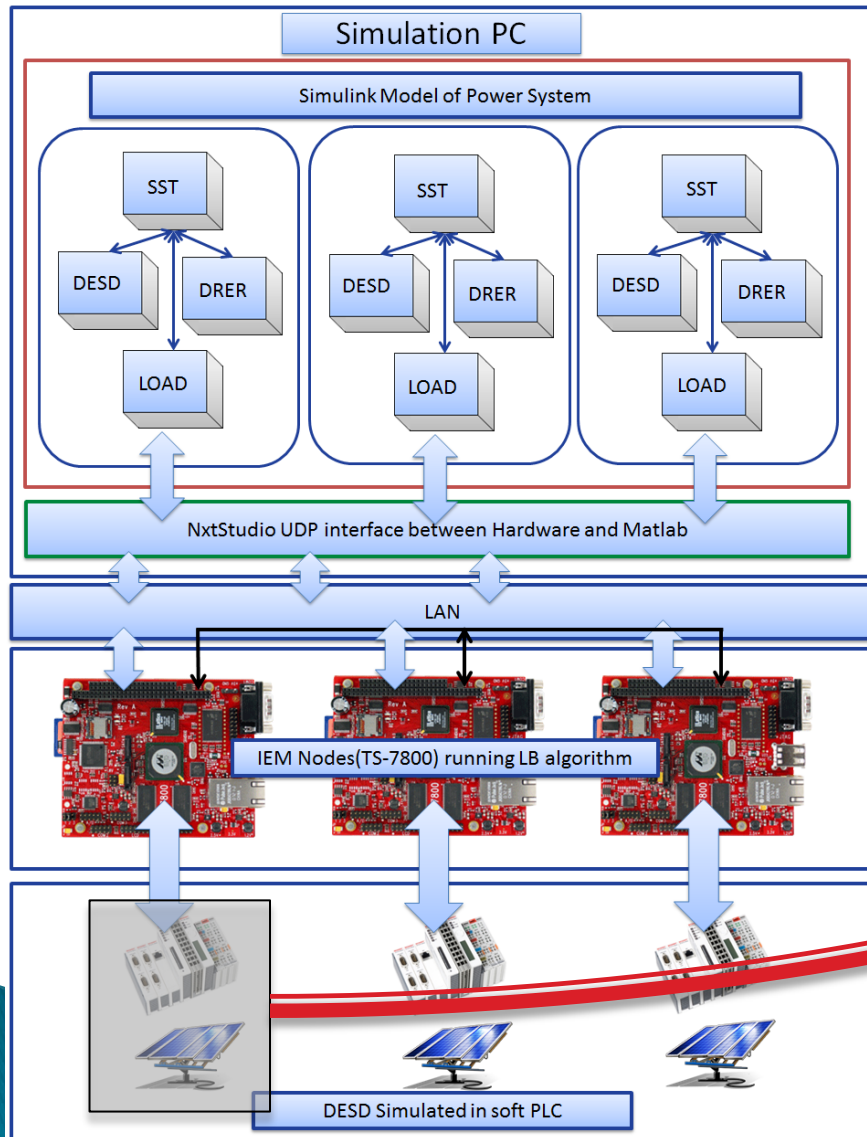


Results - 3 Node without additional DESD

At t = 1.225

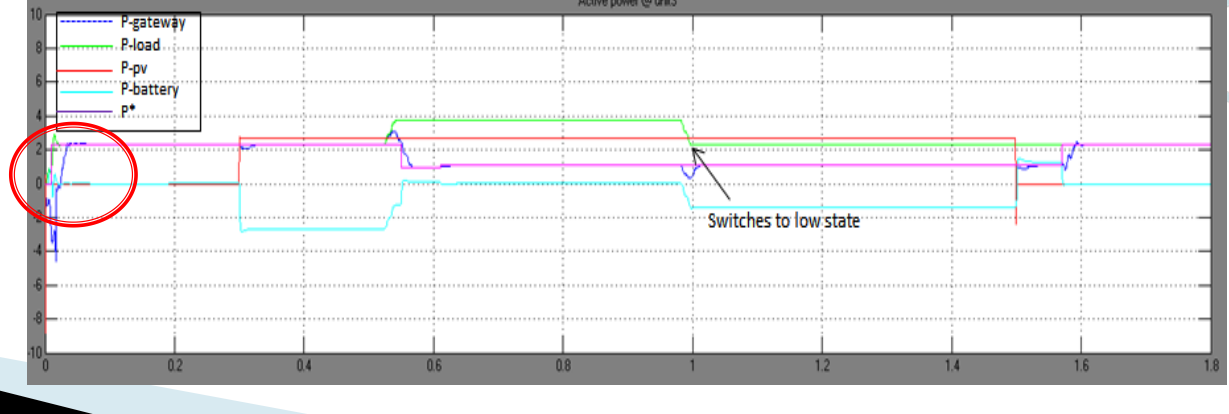
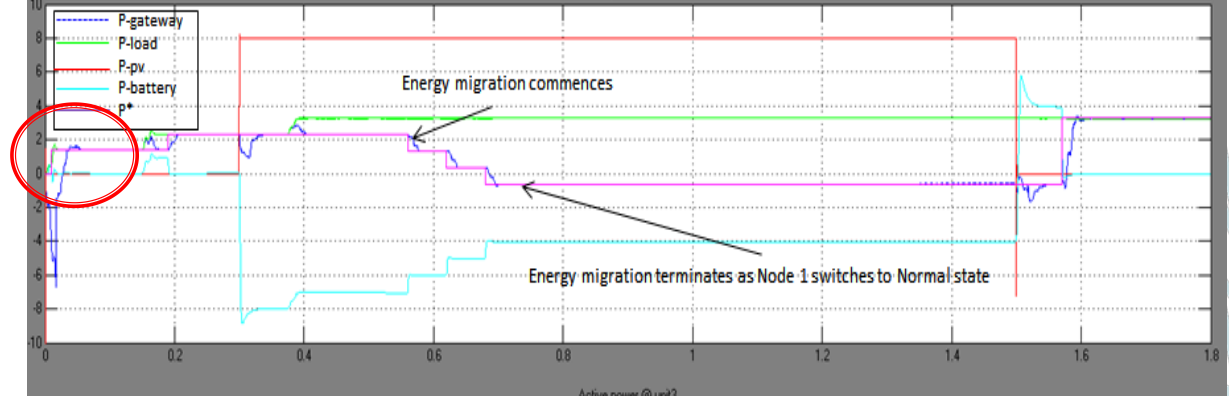
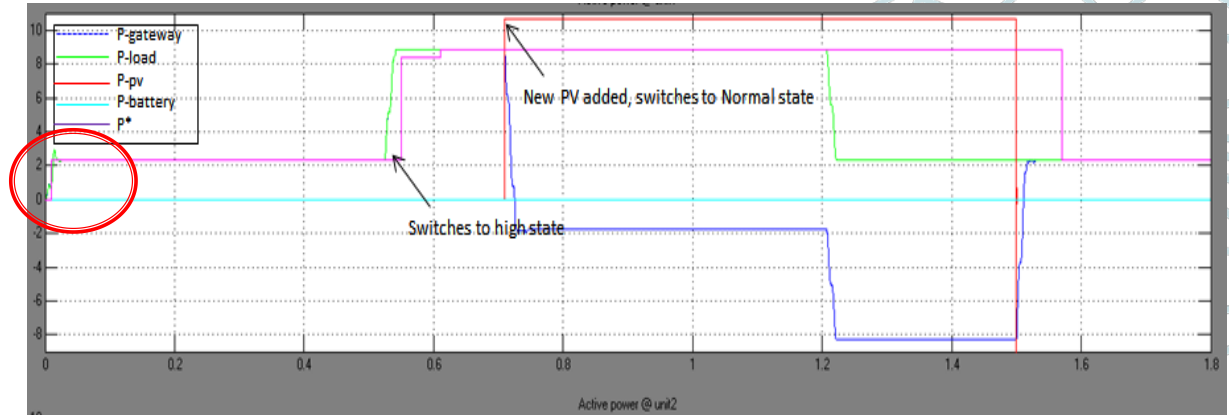
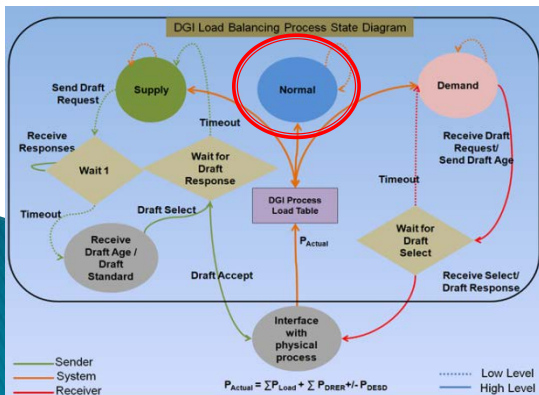
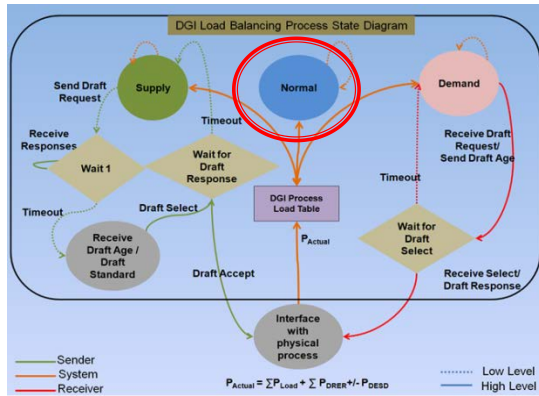
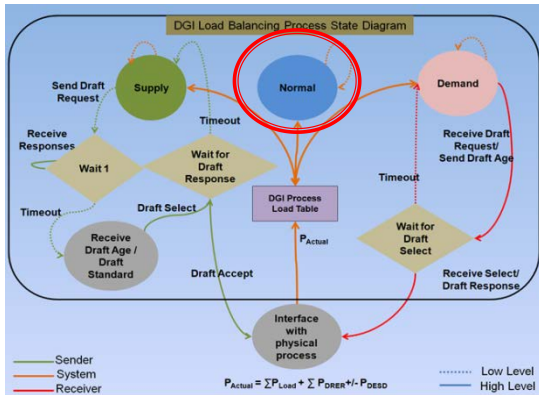


Distributed SCADA concept with PnP support



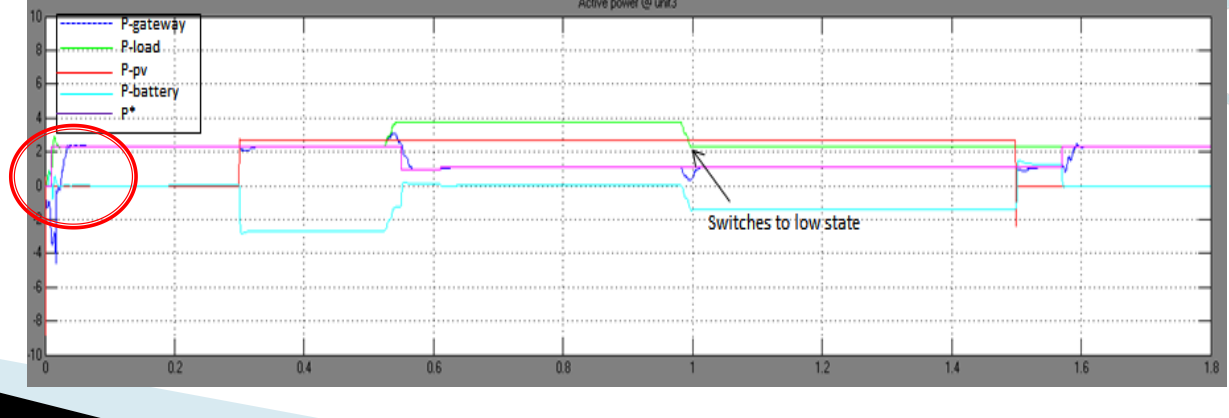
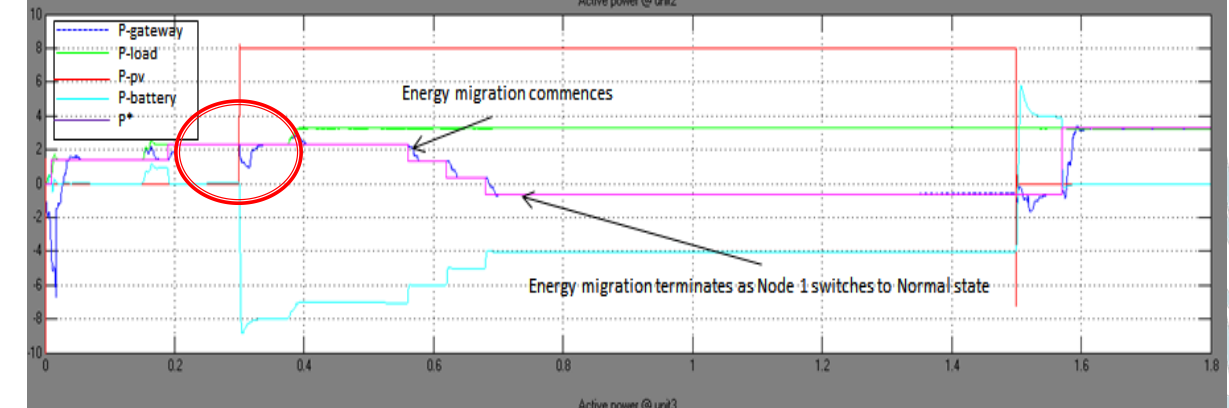
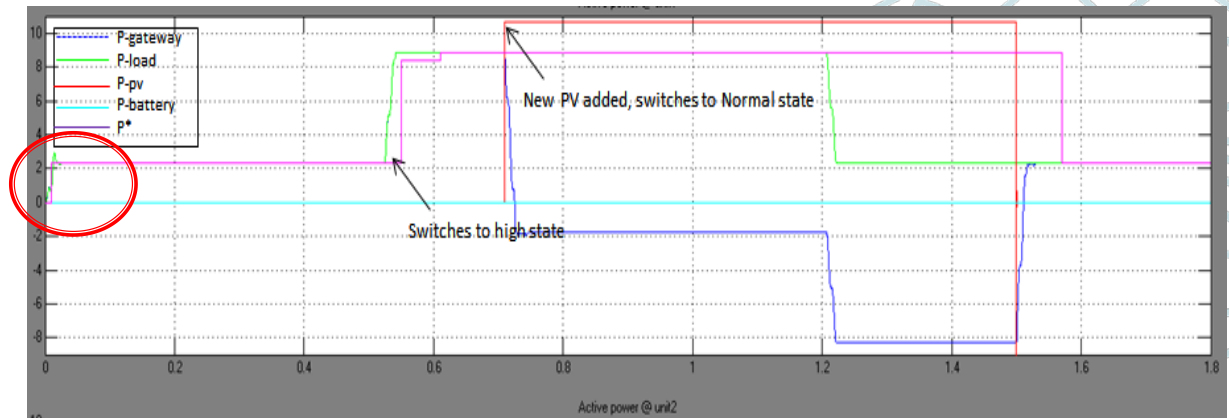
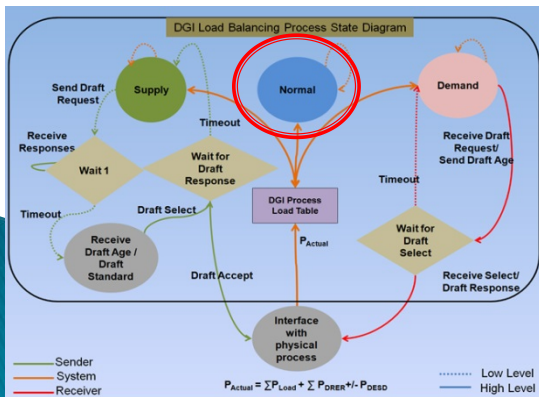
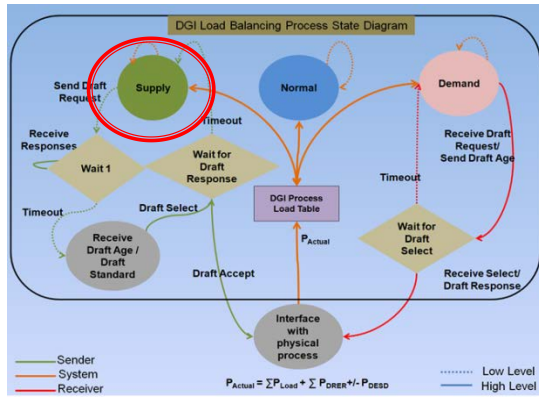
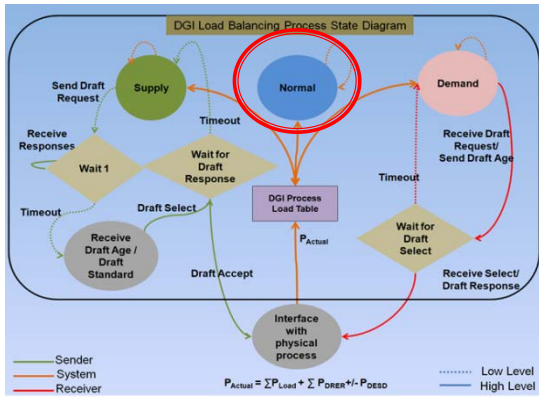
Results - 3 Node with additional DESD

At t = 0



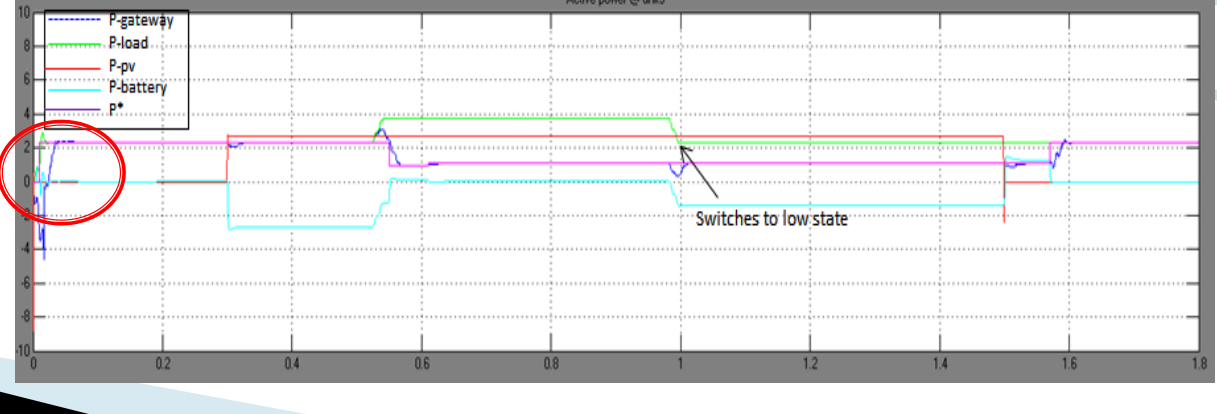
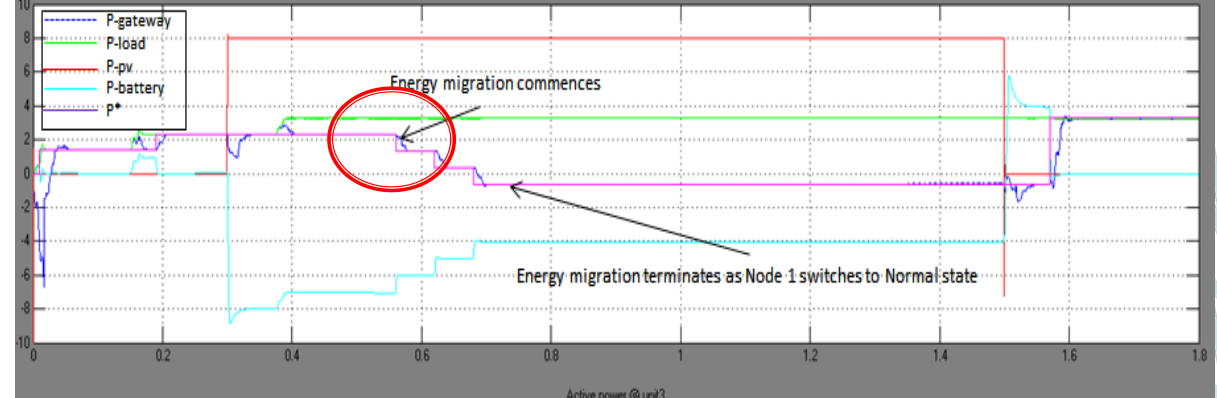
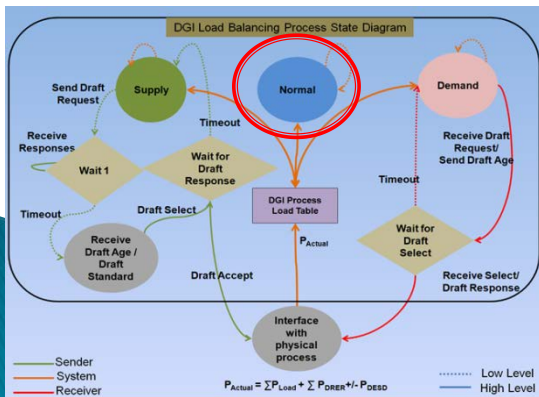
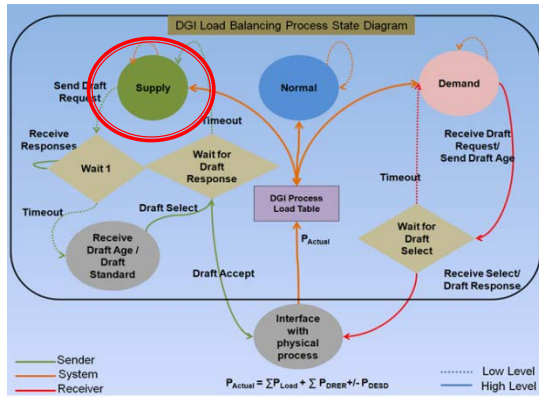
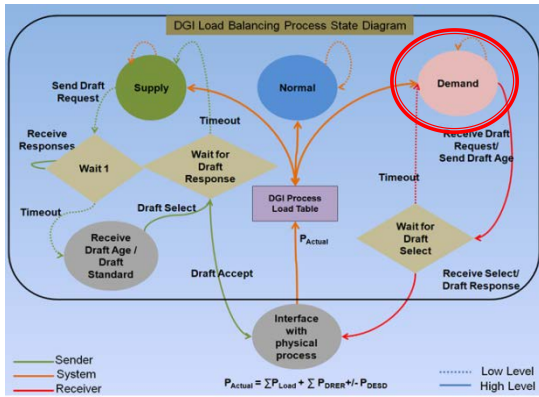
Results - 3 Node with additional DESD

At $t = 0.3$



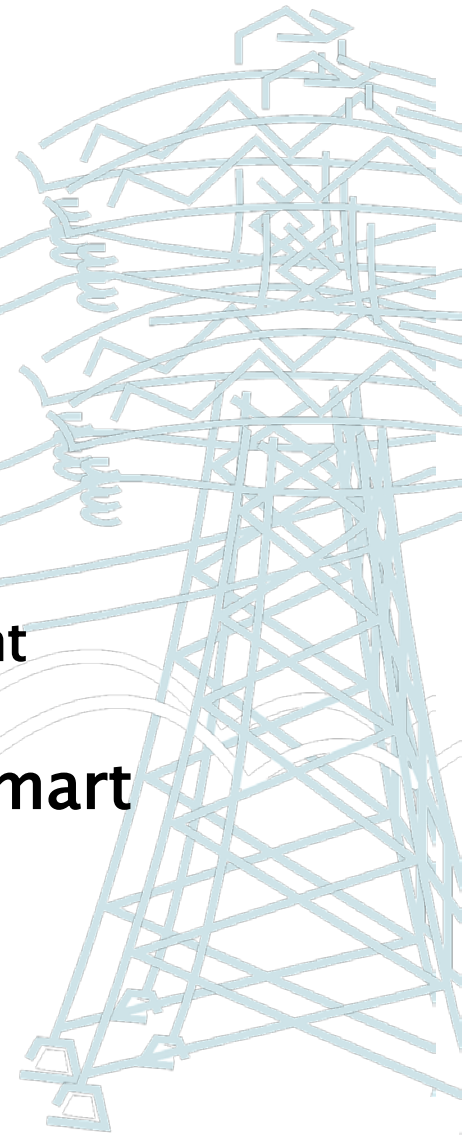
Results - 3 Node with additional DESD

At $t = 0.525$



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?

