Distribution System of the Future

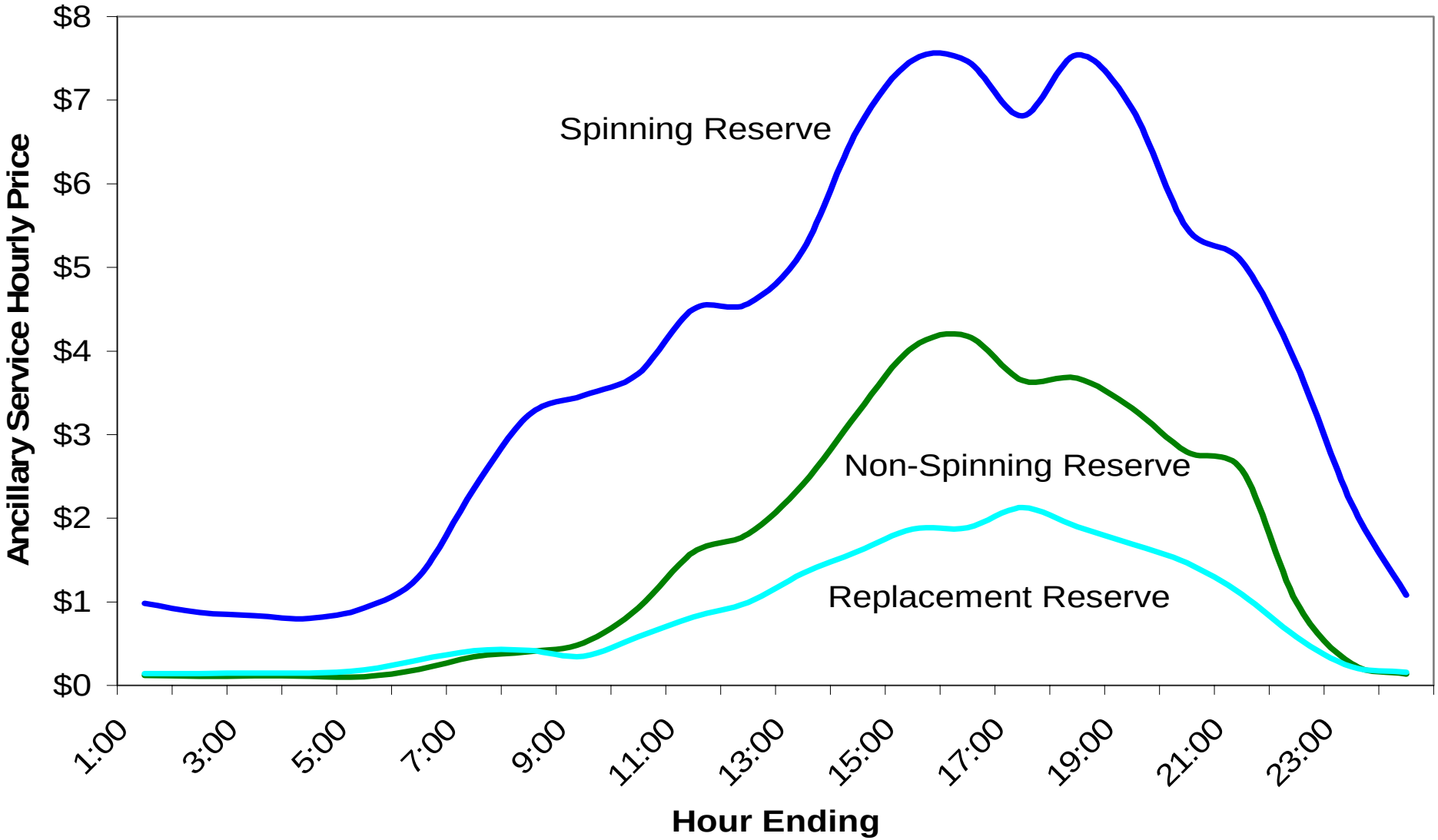
John Kueck 865-574-5178

Overview

- **Increased Level of Safety**
- **Reduced Electrical Losses and Minimized Damage Due to Faults**
- **Advantages in Operation and Maintenance**
- **System Automation and Autonomy**
- **Local Provision of Reliability Services**

Distribution System of Future

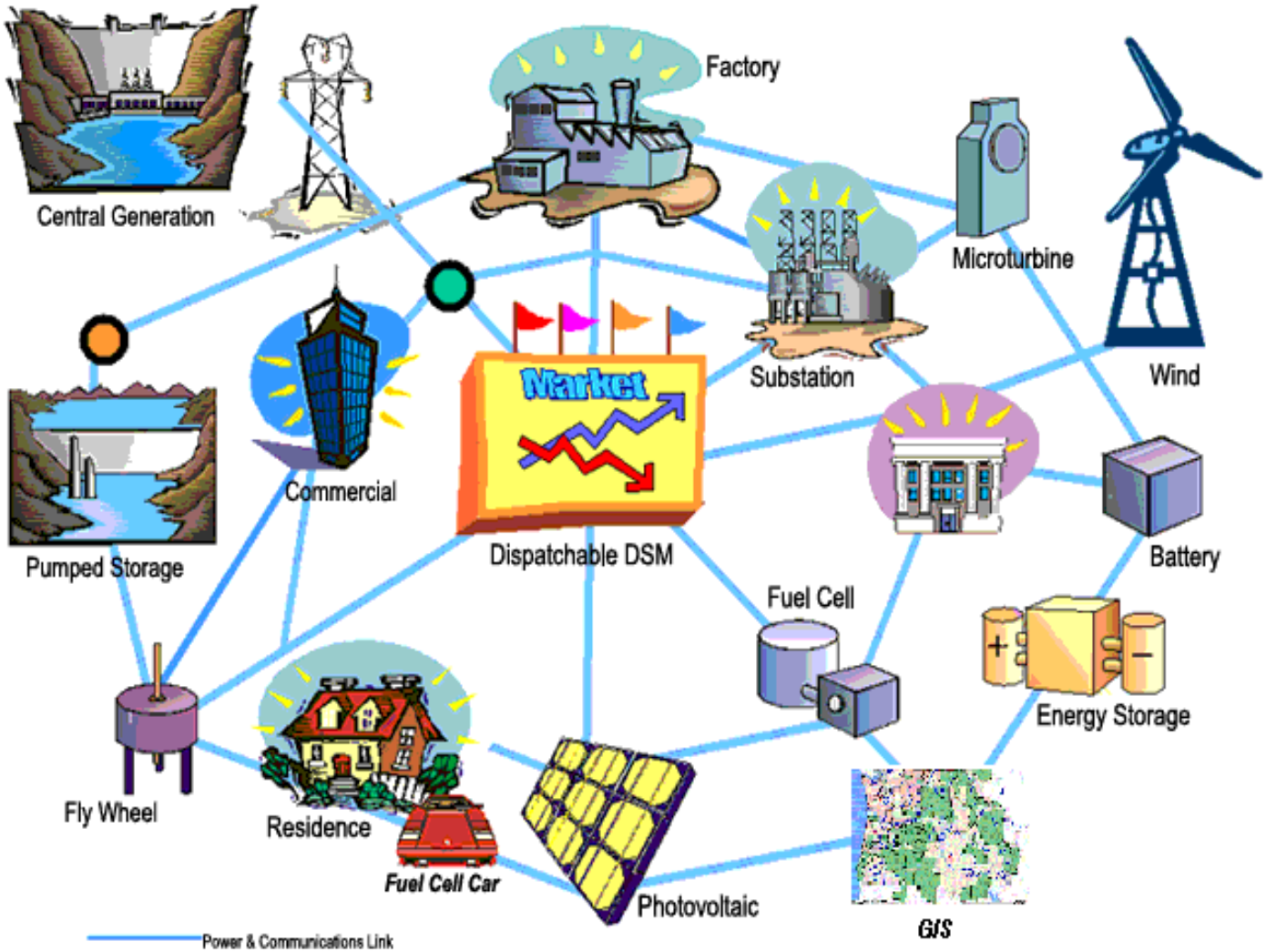
- **Present day distribution systems are in a sense, unintelligent; there is no autonomous response to contingencies.**
- **Presently, there is very little control of load, or demand response, and Distributed Energy Resources (DER) located in the distribution system are prohibited from even regulating voltage.**
- **There is a pressing need to evolve the distribution system model to one that can respond to contingencies sensed locally and has the local intelligence and autonomy to deal with contingencies such as unusual loading, transmission congestion, and line outages, and can enable the customer to participate in the energy and reliability services market.**



The market for reliability services is established and functioning in some areas but there is no local response.

Vision

- **Reduced cost, both capital and operations and maintenance**
- **Increased Safety**
- **Reduced Electrical Losses**
- **Market Interaction at Distribution Level**
- **Improved reliability**
- **Improved power quality**
- **Local supply of Ancillary Services**
- **Facilitate Future Advances**



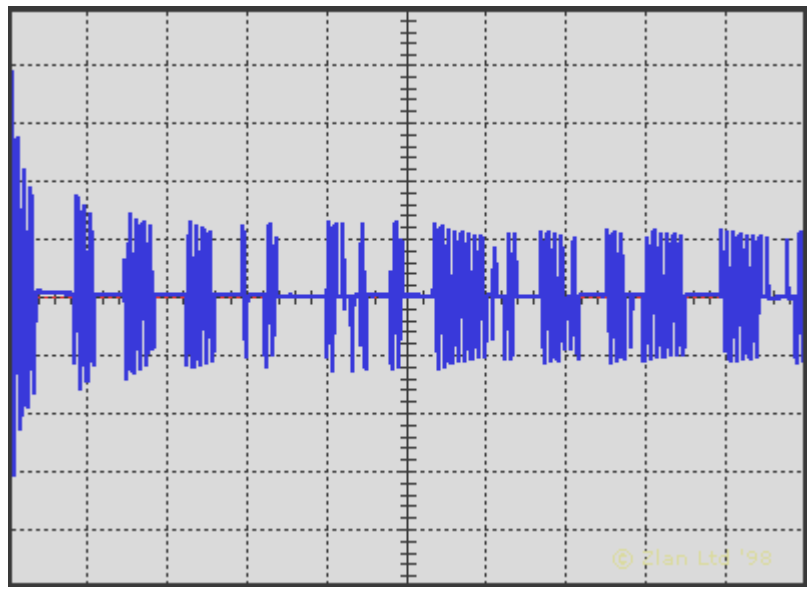
BPA Energy Web
Local Voltage Regulation is a Possibility

Increased Level of Safety

- **Presently linesmen rely on the central operator to clear circuits, and they also open disconnects and pull fuses.**
- **In the future, there will be a backup level of protection and monitoring from local agents.**
- **The local agents will ensure that DER is not connected or other switching is performed which could energize equipment.**
- **The local agent will also monitor equipment to ensure circuits are dead.**

Minimized Damage Due to Faults

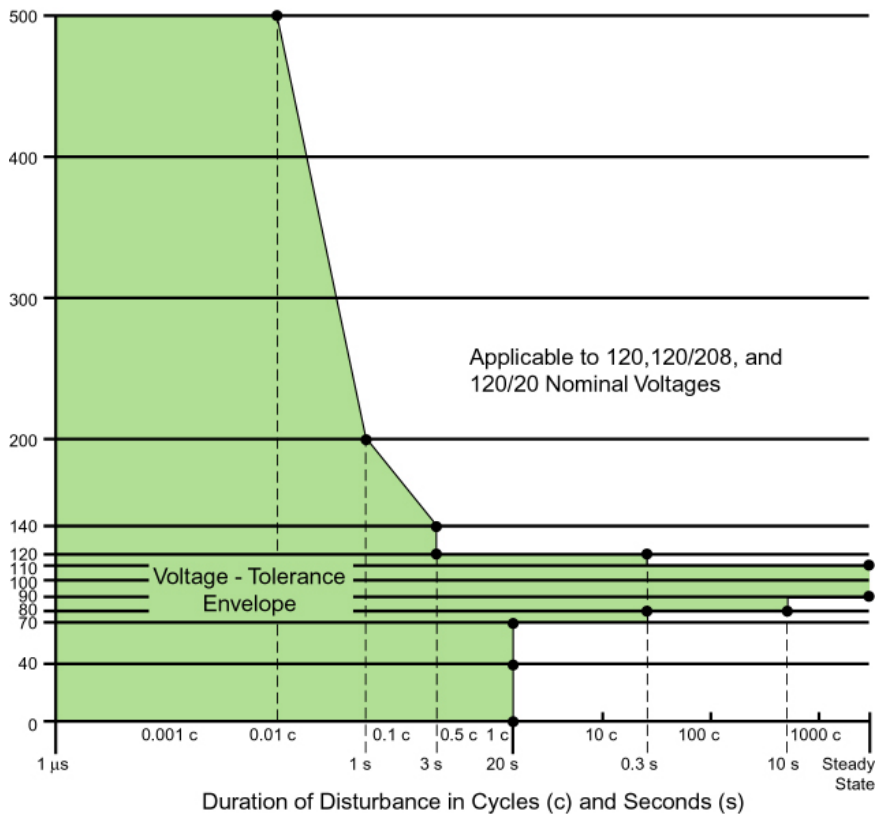
- **Presently, faults are detected by protective relaying and cleared by breakers or fuses.**
- **In the future, techniques will be used to detect arcing faults.**
- **Fault protection will act much more quickly.**
- **Static switches will clear faults much more quickly.**



Arcing Fault Signature

What Level of Power Quality Is Really Needed?

- **Some customers may need a level of power quality even better than the ITIC curve.**
- **Many customers may only need a nominal level of power quality.**
- **It may be wasteful to provide a premium power quality level to all customers.**
- **It may be best to design for a nominal level, and then use DER to make up the difference for those customers who actually require premium power quality.**



ITIC Curve

Reduced Electrical Losses

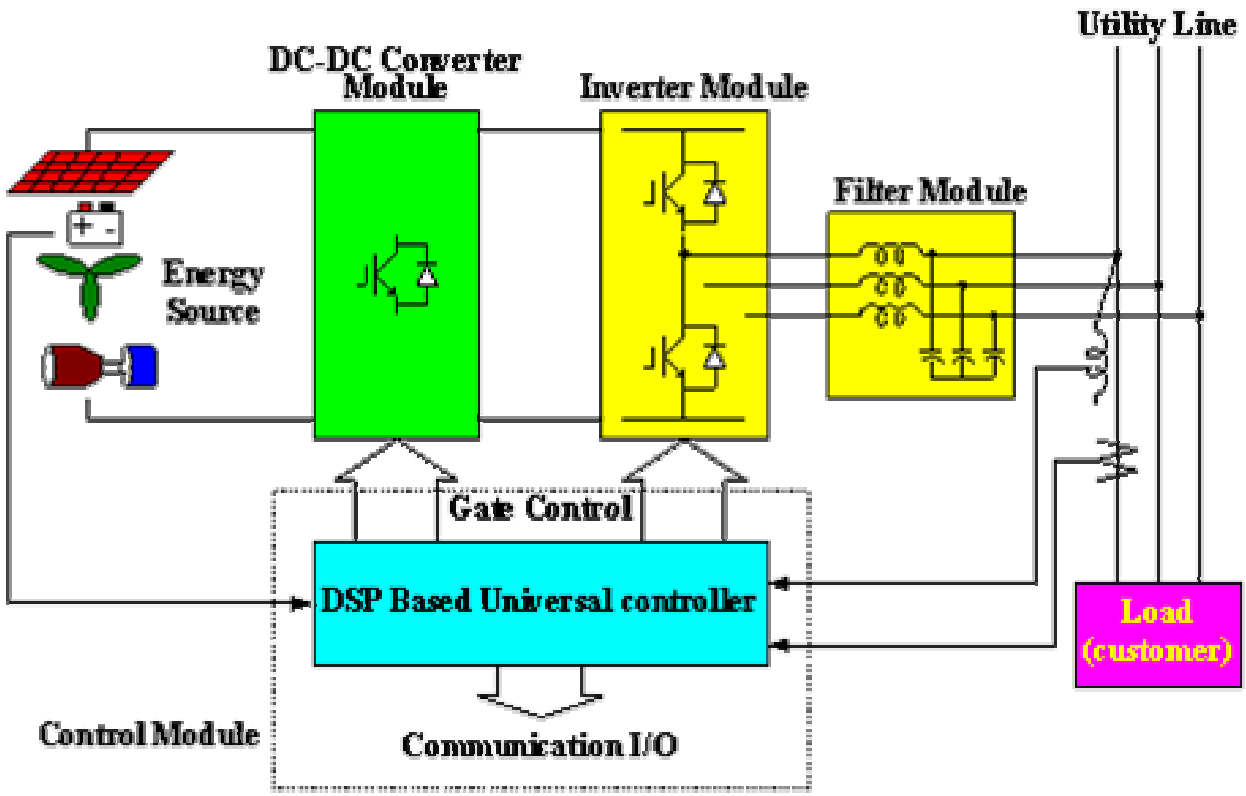
- **Feeder configuration will be monitored in real time to ensure that circuits are operated in minimize losses, and reactive power is supplied to minimize reactive current flow.**
- **Similar methods have yielded 40% loss reductions in transmission systems.**
- **Measurements of power flow will be made at many points, and a precise loss determination will be available.**
- **There will also be an opportunity to address fraud, i.e. stolen power. One estimate is that the theft of energy amounts to a loss of 4 billion dollars per year.**

Flexibility for Scheduled Maintenance, Planning and Operations

- **System operation, customer service, maintenance planning, and market functions will be integrated into an information technology infrastructure.**
- **Maintenance will be planned using analysis of current, voltage, vibration, temperature and other signals obtained by local agents.**
- **Customers will have access to their load profile, and will be able to control individual appliances in their home, plus entrance and egress, remotely. (Presently available.)**
- **Faults will be located and isolated quickly, and the system reconfigured to continue customer service and maintenance activities.**

Local Provision of Reliability Services

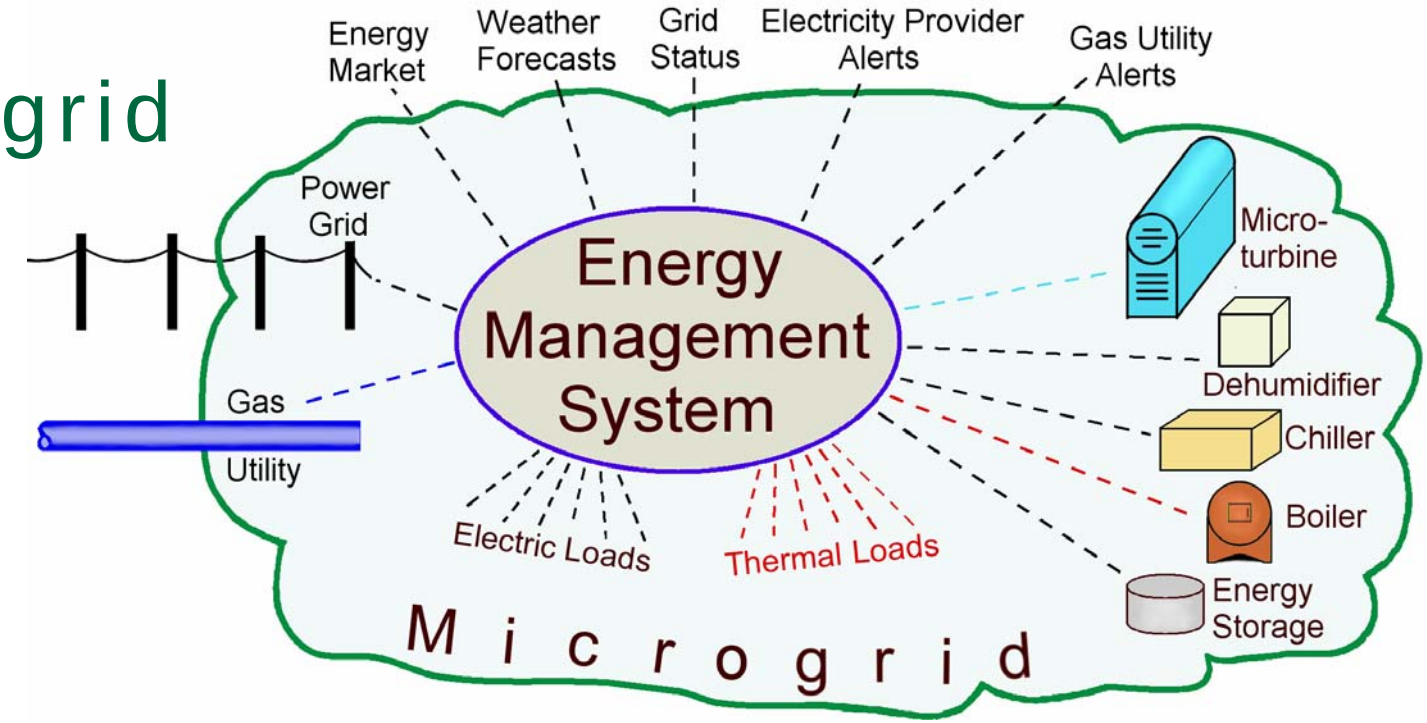
- **Local voltage regulation.**
- **Power quality.**
- **DER integration.**
- **Instead of a control and protection nightmare, DER will become an integral player in reliability.**



System Automation and Autonomy

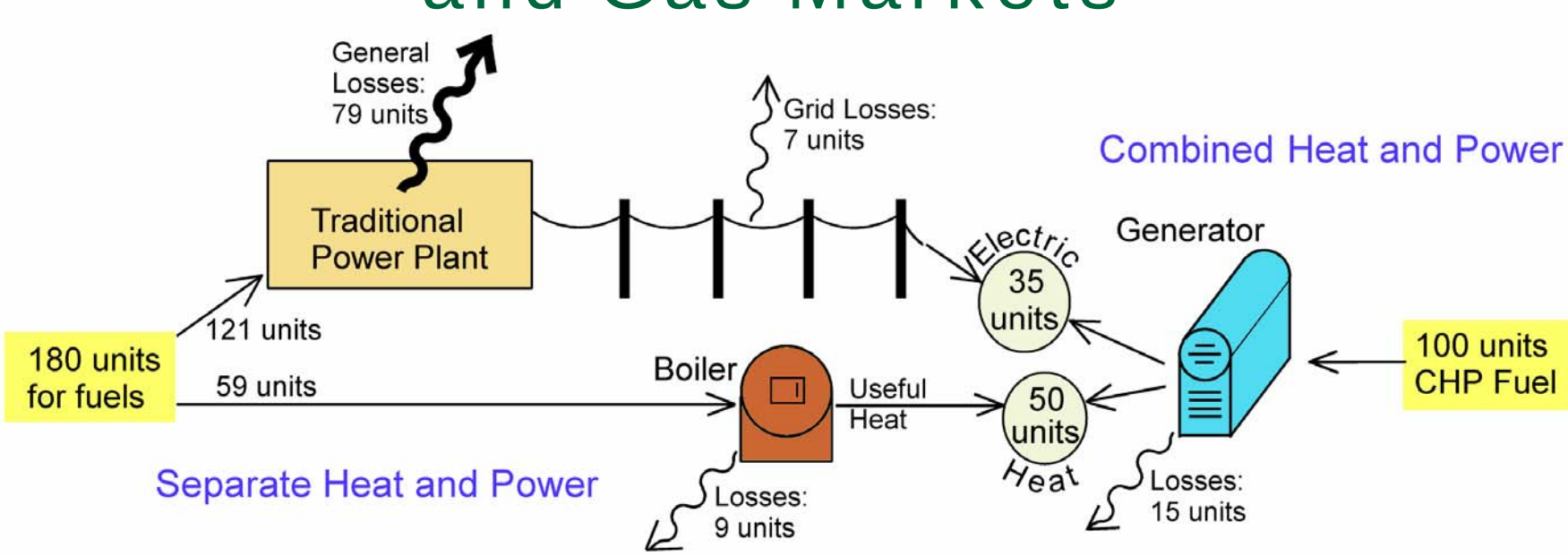
- **Intentional controlled islanding: islands that are self regulating. One type of island will be the microgrid.**
- **Islands would be developed in real time by deciding on the best configuration for any post contingency set of available circuits and generation.**
- **The local agent will help to deal with contingencies.**
- **The local agents will communicate rapidly with each other to minimize outage duration and area.**

Microgrid



- **The microgrid – industrial park or college campus, will be controlled by an Energy Management System (EMS)**
- **The EMS will assess the needs of heating, air conditioning and process energy and will make decisions to optimize fuel usage.**

Integrating with the Electricity and Gas Markets



- **Overall energy usage will be optimized by the most efficient use of CHP for gas and electric market conditions, and emissions will be minimized.**
- **The DER will act as a "good citizen", reducing net emissions and providing reliability services.**

The Good Citizen of the Distribution System is Rewarded by the Market Structure

- **He does not have a highly non linear load, an unbalanced load, or low power factor.**
- **He has an elastic load that responds to price signals.**
- **He participates in the market and sells reliability services such as reserves and dynamic reactive power.**
- **He manages his load, energy use and fuel use to optimize his overall costs and minimize emissions.**

Areas for Technology Development

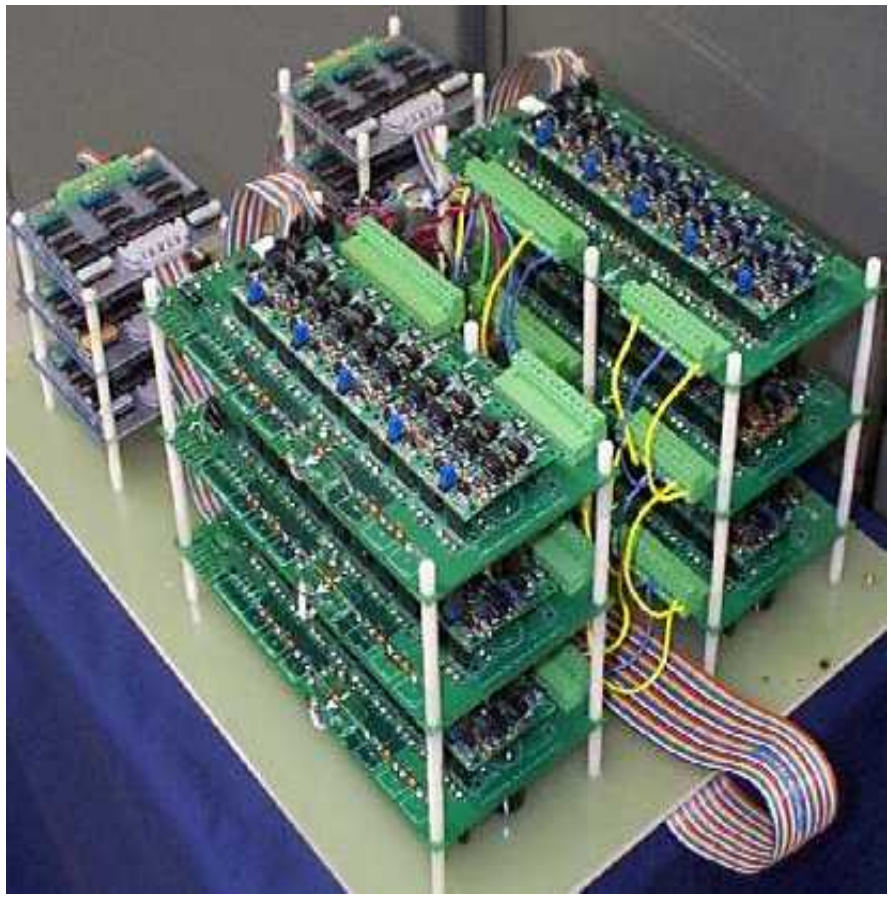
- **Probabilistic Modeling of Feeder and Substation Design**
- **Power electronics and FACTS**
- **Fault detection using current signatures**
- **Fault current control**
- **Responsive load**
- **Communication and control**
- **Real time local state estimation modeling**
- **Local independent agents**
- **System flexibility and adaptability to contingencies**
- **Microgrids and Reliability Services**
- **Equipment Cost and Reliability**

Superconductivity

- **HTS materials are now available that are super conductive at the temperature of liquid nitrogen.**
- **Transformers and underground cable are now being developed.**
- **Great improvements in efficiency and required space are promised.**
- **ORNL researchers first developed a process called rolling-assisted biaxial textured substrates, or RABiTS™. Substrates provide the underlying foundation for the super conducting wire**

Power Electronics

- **Power electronics can be used to transform voltage magnitudes, frequencies, and phase angle.**
- **They can replace transformers, and solve power quality problems.**
- **They are now used at the 200 kV, 200 MW level, and costs are being reduced.**
- **ORNL researchers have developed a multi-level inverter which can synthesize a voltage waveform from several levels of dc voltage.**



6 level, 10 kW, multilevel demo of back-to-back HVDC or grid-to-grid intertie

Partnering for the Future

This vision of a future system will not be possible without both regulatory and market changes. The vision will be realized through a partnership of utilities, industry associations, customers, manufacturers and regulators working together to frame the future, develop methods and programs, and perform pilot projects.