Agenda Day 1

September 13, 2017 – Day One
Salon E

7:30 - 8:00  Check In and Continental Breakfast

8:00 – 8:45  Welcome - NREL Deputy Lab Director

Intro to Autonomous Energy Grids

Ben Kroposki
NREL

8:45 – 9:45  Big Data Analytics – Speaker & Discussion

Georgios Giannakis
Univ. of Minnesota

9:45 – 10:00  Break

10:00 – 11:00  Big Data Analytics – Speaker & Discussion

David Culler
UC Berkeley

11:00- 12:00  Break Out Discussions – Big Data Analytics
Salons - F, G, H, & Keystone

Lunch

12:00 – 12:45  Optimization Theory – Speaker & Discussion

Steven Low
Caltech

1:45 – 2:45  Optimization Theory – Speaker & Discussion

Angelia Nedich
Arizona State Univ.

2:45 – 3:45  Break Out Discussions – Optimization Theory
Salons - F, G, H, & Keystone

3:45 – 4:00  Travel and Check In at NREL
NREL Shuttles provided

4:00 – 5:00  NREL ESIF Tour

NREL- RSF Lobby
Agenda Day 2

September 14, 2017 – Day Two
Salon E

7:30 – 8:00  Continental Breakfast

8:00 – 9:00  Control Theory – Speaker & Discussion
Sean Meyn
Univ. of Florida

9:00 – 10:00  Control Theory – Speaker & Discussion
Mihaildo Jovanovic
USC

10:00 – 10:15  Break

10:15 – 11:15  Break Out Sessions – Control Theory
Salons - F, G, H, & Keystone

11:15 – 12:00 Lunch

12:00- 1:00  Complex Systems – Speaker & Discussion
Gil Zussman
Columbia University

1:00 - 2:00  Complex Systems – Speaker & Discussion
Daniel Kirschen
Univ. of Washington

2:00- 2:15  Break

2:15- 3:15  Break Out Sessions – Complex Systems
Salons – F, G, H, & Keystone

3:15 - 4:15  Autonomous Energy Grids
Bringing everything together
Ian Hiskens
Univ. of Michigan

4:15 - 4:30  Workshop Summary – Salon E
Autonomous Energy Grids

Ben Kroposki, PhD, PE, FIEEE
Director – Power Systems Engineering Center

https://www.nrel.gov/grid/
Autonomous Energy Grids

*optimized for secure, resilient and economic operations*

- Current power systems deliver electricity in one direction from large central plants to customer loads.

- There is an increasing amount of distributed and variable generation, energy storage, and new loads being added to the grid - causing bidirectional power flows and voltage fluctuations that impact control and optimization.

- New intelligence is being added to the grid through smart devices and communications - drastically increasing the amount of information available about grid conditions.

- There is growing use of combined heat and power and natural gas generation – increasing interdependencies with the electrical grid and other domains.

- All these contribute to cybersecurity and resilience concerns and solutions.

- Our vision is to develop *Autonomous Energy Grids* that are optimized for secure, resilient, and economic operations through advanced science in controls, optimization, big-data analytics and complex systems.
Creating Autonomous Energy Grids – Needs in Foundational Science

- Equivalent to autonomous vehicles, “Autonomous Energy Grids” do not require operators, can be extremely resilient (self-healing) and can optimize themselves for reliability and economic performance while integrating energy in all forms.

- Need to advance foundational science to develop a common analytical framework for modeling, optimization, and control of complex systems at multiple spatial and temporal scales.
Workshop Focus - Technical Areas for Autonomous Energy Grids

Complex Systems Theory

Big-data Analytics

Nonlinear Control Theory

Optimization Theory
Non-Linear Control Theory

Advance core theory in:

- Stability of networked nonlinear systems
- Existence and uniqueness of ODE systems
- Nonlinear model predictive control
- Dynamic programming

Applications:

- Low-inertia energy systems
- Autonomous and fractal grids
- Autonomous electric vehicles
Optimization Theory

**Convex Optimization theory**

\[
\begin{align*}
\min_{x \in \mathcal{X}} & \quad f_0(x, y_0(x, t), t) + \sum_{n \in \mathcal{N}} f_n(x_n, y_0(x, t), t) \\
\text{subject to} & \quad h(x, y_h(x, t), t) = 0 \\
& \quad g(x, y_g(x, t), t) \leq 0
\end{align*}
\]

**Nonconvex optimization theory**

**Advance core theory in:**
- Dynamic and distributed optimization
- Optimization on manifolds
- Time-varying monotone operators
- Convex relaxation

**Applications:**
- Real-time optimization of power systems
- Transactive multi-energy systems
- Cyber-physical energy systems
- Electric (autonomous) vehicles
Big-data Analytics

Advance core theory in:

- Dynamic regret analysis
- Kernel-based data imputation and prediction
- Graphical models
- Dynamic Programming

Matrix optimization

\[ f_0 := \arg\min_{f \in \mathcal{R}\{K\}} \frac{1}{S} \mathcal{L}(y - \Phi f) + \mu \Omega((f^T \tilde{K}^T f)^{1/2}) \]

Applications:

- Forecasting at multiple time scales
- Anomaly detection and cybersecurity
- Energy data (de)compression
- Energy-customer behavioral science
- Autonomous dispatch center
Complex System Theory

Advance core theory in:

- Fixed-point methods for nonlinear equations
- Model reduction and approximation
- Uncertainty quantification
- Modeling of coupled infrastructures
- Full time spectrum modeling

Applications:

- Large-scale multi-energy systems
- Synthesis of dynamical models
- Feasibility studies
- Stochastic control and optimization
- Economical-dynamic analysis
This workshop seeks community engagement and input on the science and technical challenges that must be addressed to meet the emerging needs of Autonomous Energy Grids.

Over the two days, we will explore advances in non-linear control theory, optimization theory, big data analytics, and complex system modeling.

Identify the gaps and challenges in theory and computation related to that are need to achieve Autonomous Energy Grids.

Identify research tools and capabilities needed to meet these challenges.
Enjoy the Workshop!