

Today, nearly every person living in an industrialized country starts their day consuming energy. Energy that is largely delivered by a centralized electricity grid. The electric alarm clock rings, people switch on their lights, make themselves a cup of coffee while television and radio make for their entertainment. Electricity affects many areas of modern life. Therefore, it is not very surprising that the National Academy of Engineering (NAE) has identified electrification as the single greatest engineering achievement of the last century. Imagine not having electricity available, which means no television, no radio, no electric light. This is the reality for 1.2 billion people worldwide. The World Bank reports that this is the number of people who still do not have access to electricity and 2.8 billion are still relying on solid fuels such as wood and coal to cook and heat their homes.

The Idea: Local Energy Systems

Professor Robert S. Balog and his students from Texas A&M University started a research project to give non-industrialized regions of the world access to electricity. Together, they want to make a difference, and they are working on a concept for a hybrid power distribution grid that is based on renewable energies. A local area power and energy system (LAPES) that uses different loads, renewable energy sources, and storage technologies is at the core of this idea. The LAPES is intended to exist as a secondary feeder system alongside the central electricity grid. If required, it can be connected to the central electricity grid, but it can also be operated as a self-contained

system, for example, in developing countries that do not have a consistent electricity grid.

Why LAPES?

“The international goals set in the COP21 Paris climate agreement make it clear that societies need to drastically shift from the current paradigm, which is based heavily on fossil fuels, to environmentally friendly energy systems,” said Professor Balog. “The LAPES is envisioned as a community-scale electrical power system of the future, yet realizable in a faster time frame than a fully deployed futuristic smart grid.” In developing countries, the LAPES could be constructed and connected with less rigorous regulations. In industrialized countries, it could also create additional pockets of electrical power when outdated electrical infrastructures need to be renewed. During the maintenance works, it would not be necessary to power off the entire grid.

Hybrid Power Distribution Systems with LAPES

In contrast to a centralized electricity grid, the LAPES provides direct current (DC) instead of alternating current (AC) and is much less complex. It is considered a “microgrid” because, with its individual components, it is a self-contained and much more compact grid. According to a 2015 report by Navigant Research, a market research and consulting institute, microgrids are expected to generate 1.4 billion US dollars annually by 2024. The main reason behind this positive outlook is that microgrids not only increase the share renewables have in the overall energy supply and promote economic optimization,



Smart Grid –

An intelligent electrical grid which features a strong connection between energy generation, energy consumption control, and energy storage. The aim of smart grids is to achieve optimal balance between energy supply and energy demand.

>>



Using solar energy as the basis for innovative hybrid electrical power systems

A Bright Future Ahead

Not everybody in this world has access to electricity 24 hours a day. This is why students from Texas A&M University are developing a concept for hybrid power distribution systems that could provide developing countries with reliable power supply. dSPACE tools supported their work on this innovative solution.

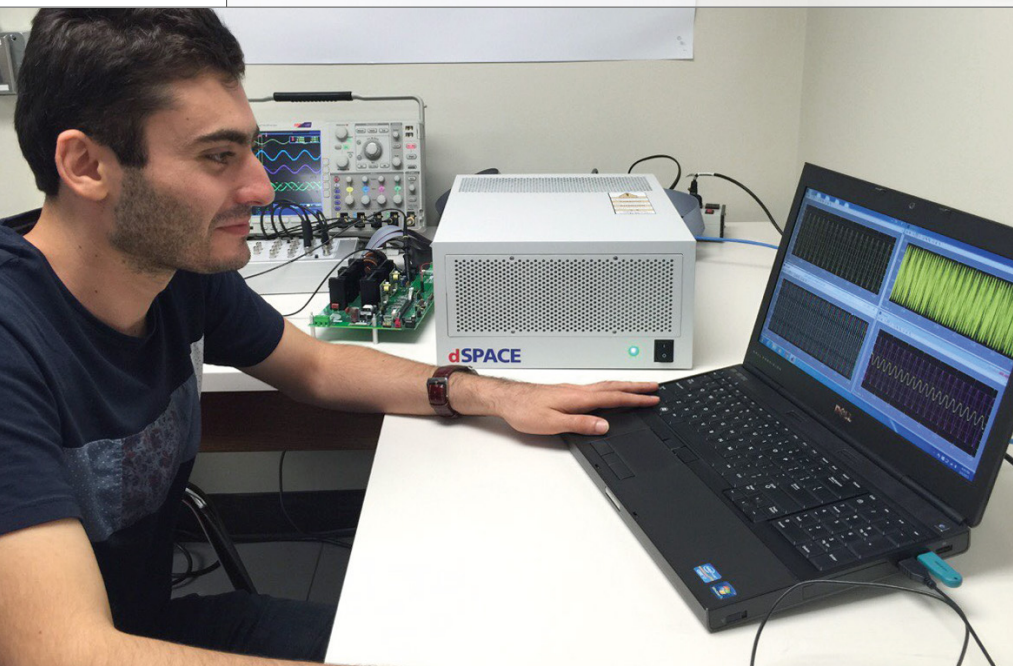


Figure 1: A student of Texas A&M University simulates hybrid power supply systems of the future.

- Cost-effective inverter systems for using alternative energy sources (including fuel cells, photovoltaics, etc.)
- Reliable power electronics with a service life of at least 40 years
- Distributed DC power systems with an emphasis on local/distributed control
- Auto-tuning coupled inductor filters
- Battery management, state-of-health management
- Non-linear control techniques such as model-predictive control
- Electrical safety such as arc fault detection

but these systems also promote grid resilience against power outages. If these DC microgrids were integrated into the existing AC grid at appropriate points, this would result in a new hybrid power supply system. However, before such microgrids can be used extensively, thorough theoretical feasibility studies are required.

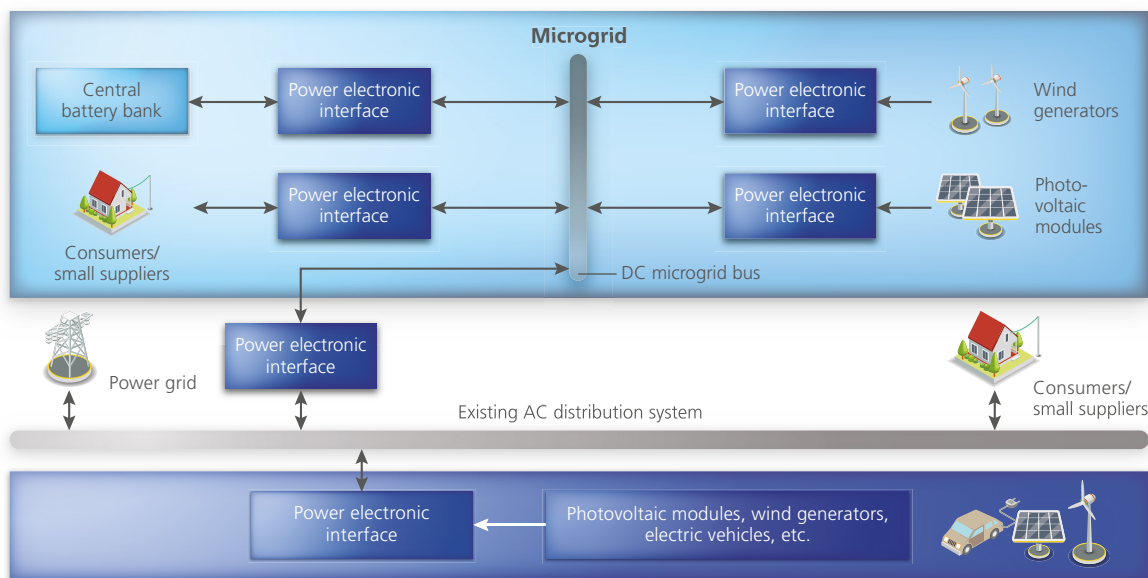
Focus on Electrical Energy Conversion

The team is currently investigating the fundamental engineering and scientific basis of electrical energy conversion. The areas they are conducting research in include:

- Converting solar energy into electrical energy (photovoltaics)

The team’s main focus is on photovoltaic systems, which convert light directly into electricity. “Ultimately, our goal is to move photovoltaic energy out of the alternative energy category and into the mainstream portfolio of energy resources in a way that is technologically and economically sustainable,” Dr. Balog said. “Our vision is to be an inter-

Figure 2: The students’ vision is to develop a hybrid power distribution system where DC microgrids exist in parallel to the central AC grid and can be connected to the AC grid when necessary.





“Our goal was not to have just another tool in the lab, but instead to find the right tool. We therefore decided on using the development systems from dSPACE.”

Professor Robert S. Balog, PhD, is Director of the Renewable Energy & Advanced Power Electronics Research Laboratory at Texas A&M University. Currently, he is teaching at Texas A&M University at Qatar.

nationally recognized center of excellence for research in this area.”

Model-Predictive Control

A fundamental aspect to the LAPES project is model-predictive control (MPC). The team uses a model that can predict the future behavior of the system based on various elemental values such as sunlight. The results are then used for the continued development of the electrical supply system. The team focuses on three main areas: photovoltaic energy conversion, DC microgrid control, and multi-sourced hybrid energy system control. The students' vision is to develop an innovative, hybrid electrical distribution system that integrates DC microgrids based on renewable energies into existing AC grids (figure 2).

Real-Time Simulation with HIL Systems

After careful evaluation, Professor Balog and his students decided on a tool chain that is based on dSPACE products to carry out the necessary tests and examinations. An integral part of this tool chain is a hardware-in-the-loop (HIL) system in a dSPACE Expansion Box with a DS1007 PPC Processor Board. Thanks to the board's high-performance processing power, the team can simulate realistic environmental conditions for the power supply system and run various scenarios in real time. The algorithms of the model-predictive control are im-

plemented on the test hardware using the dSPACE software Real-Time Interface (RTI).

The HIL system helps identify the supply system's reactions to changing basic conditions such as the weather. Moreover, the developed algorithms can be validated quickly in different applications. “With the dSPACE system, we are able to explore the full richness of the dynamic interactions of actual hardware,” explained Dr. Balog. “This enables us to more fully characterize and understand system and subsystem interactions.”

Therefore, the system is gradually developing from a first draft to a system that can be implemented under real conditions. As a result, the team will be able to set up a complete simulation of the planned hybrid power supply system in a fraction of the time it would have taken them to design and produce costly test hardware. ■

With the kind support of Texas A&M University

Conclusion

The students of Texas A&M University hope that their microgrid project will soon provide developing countries with a reliable electricity system. At the same time, they want to help renewable energies, especially photovoltaics, become a part of innovative energy supply concepts. Renewable energies are particularly suitable as the basis of hybrid power supply grids of the future. Therefore, Texas A&M University and dSPACE will continue to drive research in this area, so that hybrid power supply grids might soon play a decisive role in solving current issues in energy supply.