Smart Grids

There are many Smart Grid definitions, some functional, some technological, and some benefits-oriented. Most commonly, Smart Grids are thought of as systems that use communications technology to automatically gather and manage information, about both suppliers and consumers, in order to improve the efficiency and sustainability of the production and distribution of electricity.

Power electronic control is a core technology behind the Smart Grid, key to integrating renewable energy sources. Adding power from renewables, especially during periods of high renewable generation, can impair the functioning of transmission systems and raise safety and reliability issues. Through fundamental research and real application testing, Energy Leeds is ensuring that the next-generation transmission and distribution infrastructure will be better able to handle bi-direction energy flows and fully realise the benefits of the growing market in distributed power generation.

**ADVANCED CONVERTER TOPOLOGIES**

As part of a Smart Grid network, power converters are now essential items of hardware. Their application is diverse and rapidly increasing, ranging from connecting renewable source generators to the grid, at a few hundred volts, to transferring megawatts of power between national networks.

At Energy Leeds, our focus is on developing advanced converter topologies, and their modulation and control methods for medium to high-power applications. Our aim is to improve efficiency, reliability and power density whilst maintaining high output waveform quality.

Through in-depth investigation on multilevel converter topologies, such as flying capacitor and neutral point clamped (NPC) converters, we have developed and built a three-phase, four-leg flying capacitor multilevel inverter set which functions effectively as an active power filter in a distribution system. We have shown that this can eliminate harmonic currents under unbalanced current conditions, thereby reducing stress and heating in cabling and electromagnetic interference to communications systems.

Our research on advanced topologies includes multi-dimensional space vector modulation techniques for modular multilevel cascaded flying converters (MMFVC). In our laboratory, we have constructed a three-phase, six H-bridge MMFVC demonstrator for application in high-voltage direct-current power (HVDC) transmission.

**FLEXIBLE AC TRANSMISSION SYSTEMS DEVICES**

With the penetration of renewable-sourced power generation and network interconnection, control of flow becomes even more important. The advanced Flexible AC Transmission Systems (FACTS) devices developed by Energy Leeds are key technologies in enabling the efficient distribution of renewable energy sources on existing transmission networks.

Our research into new control methods for FACTS has led to the development of optimal control and phase locking algorithms for a Unified Power Flow Controller (UPFC). Working alongside industry standard hardware, these optimise the distribution of power flow in existing lines and enhance the controllability of transmission networks without expensive investment in new infrastructure.
We have applied this device on a simulated high power transmission system and it has shown to give simultaneous bus voltage and power flow regulation over a wide range of operating points and with high dynamic response performance.

**MODULE-INTEGRATED PHOTOVOLTAIC AND CONVERTER SYSTEMS**

Within individual power generation units, it is vital that a stable maximum power efficiency is achieved in order to minimise the adjustments required for fluctuations in supply. By using in-house wind energy simulators and solar panel arrays we are able to integrate our development of sophisticated demand control technologies with optimisation of localised power supply. Our research into Module–Integrated PV and Converter (MiPC) units has emerged as a promising technique for achieving maximum power generation for mismatched or partially shaded PV modules. Current research includes the construction and testing of a bi-directional Cuk MiPC and appropriate control methods to adjust individual units.

The topology we have designed is capable of achieving independent control of individual PV modules to generate maximum power according to their insolation. This can increase power generation by as much as 30%, compared to a conventional bypass diode structure, raising voltage and current levels enough to achieve transformerless grid connection.

**POWER SHARING CONTROL**

Adoption of the Smart Grid will increase the possibilities of distributed generation, bringing it closer to the end users. However, many of these sources will require a stand-alone micro-grid, with its own generators powered by highly variable renewable energy sources.

Lacking the ‘stiffness’ of a large scale power grid, this type of system encounters unequal power sharing between inverters and current circulation, and voltage and frequency. Connection to the external grid is often required to offset this imbalance, but in remote areas far away from grid lines the system needs to balance the power requirement itself.

In addition to developing technologies to manage the feed in from these sources to a national grid, Energy Leeds is working on advanced measurement techniques and identification algorithms to detect power shortages or surpluses in the micro-grids.

This research investigates the patterns of grid frequency and voltage variation affected by different renewable sourced generators. To identify and compensate for these power imbalances we have designed optimal power tracking schemes and are developing a Static Compensator with energy storage super-capacitors for both active and reactive power compensation.

**AN INTEGRATED APPROACH**

Adoption of the Smart Grid will enhance every facet of the electric power delivery system, including generation, transmission, distribution and consumption. But the current network infrastructure is not built to allow for the many distributed feed-in points necessitated by the growth of renewable energy sources.

To meet this fundamental challenge, the work at Energy Leeds aims to provide a flexible, integrated solution to managing new patterns of electricity usage. Our combination of advanced electronic topologies and sophisticated flow control schemes bring benefits both on a local scale and to the entire grid, giving security to consumers and supporting producers in their progress towards the decarbonisation of our electricity supply.

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